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History And Status of Introduced Fishes In California, 1871 – 1996

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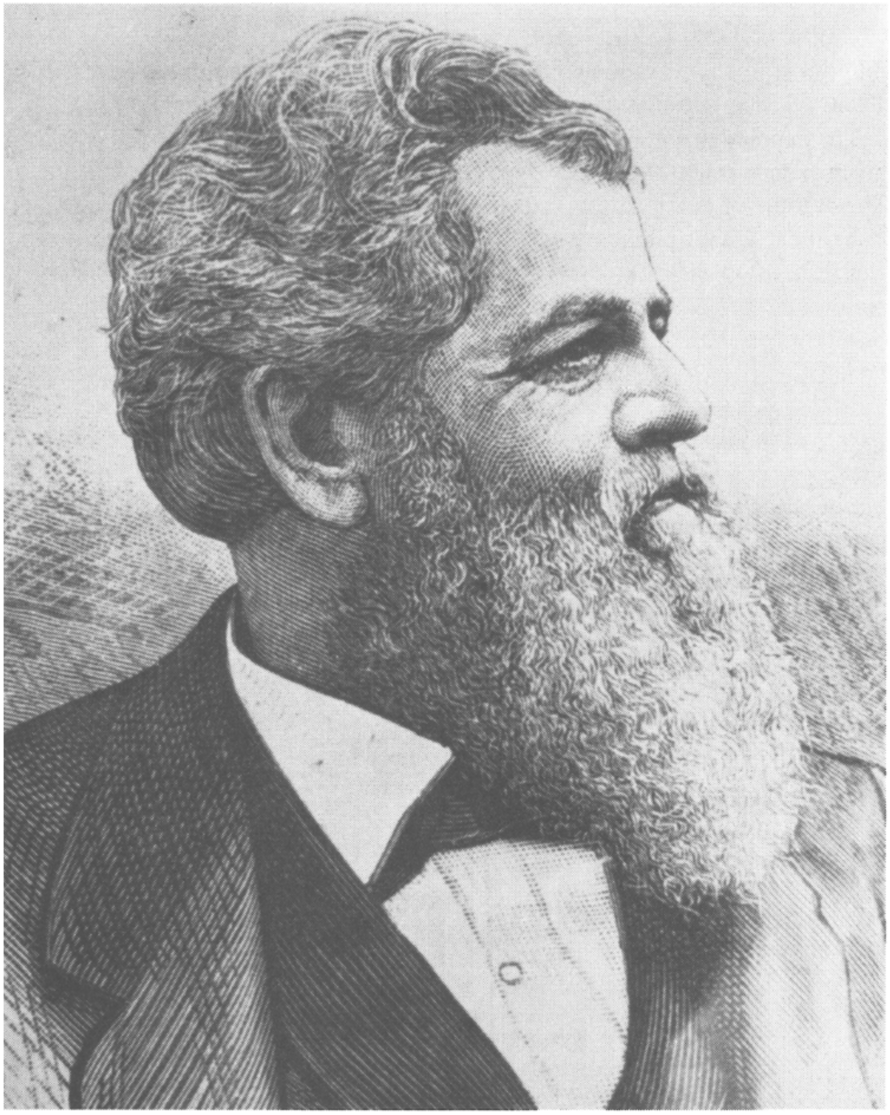
ABSTRACT

Unlike previous histories on the subject (the last being in 1976), this one is fully documented by primary references to the original publication or other sources. There are also explanations as to why some of the previous errors occurred.

The detailed history of each introduction, including the primary references, is given. The subsequent history and status of each species in California is given. The attitude of administrators, ichthyologists, fish culturists, fishery biologists, fishermen, and the public toward each introduction is given, and there is a discussion of their value. There is, with respect to California, a review of the present regulations concerning introduced fishes, and a prognostication of the future concerning them.

Approximately 111 full species of freshwater and euryhaline fishes occur in California. (Salton Sea fishes are excluded.) of these, 53 have been introduced from without the state and have been established successfully. Another five subspecies or races have become established. Twelve introduced fishes have uncertain status. Thirty-nine, including one marine fish which was deliberately introduced, have achieved no lasting success. Eight introduced fishes are listed as "hypothetical." Five were scheduled for introduction, but the introductions were never completed. Three species have been listed erroneously in scientific papers as having been introduced. About 26 other species have been formally suggested as introductions. Three species are likely candidates for introduction.



"... the historian gropes his way, trying to recapture the truth of past events, and find out 'what really happened.' He discovers that truth is subjective and separate, made up of little bits seen, experienced, and recorded by different people."

—B.W. Tuchman (1962)

"I have not ventured to speak from any chance information, nor according to any notion of my own; I have described nothing but what I either saw myself, or learned from others of whom I made the most careful and particular enquiry. The task was a laborious one, because eye-witnesses of the same occurrences gave different accounts of them, as they remembered or were interested in the actions of one side or the other. And very likely the strictly historical character of my narrative may be disappointing to the ear. But if he who desires to have before his eyes a true picture of the events which have happened, and of the like events which may be expected to happen thereafter in the order of human things, shall pronounce what I have written to be useful, then I shall be satisfied."

—Thucydides (ca. 460–400 B.C.)

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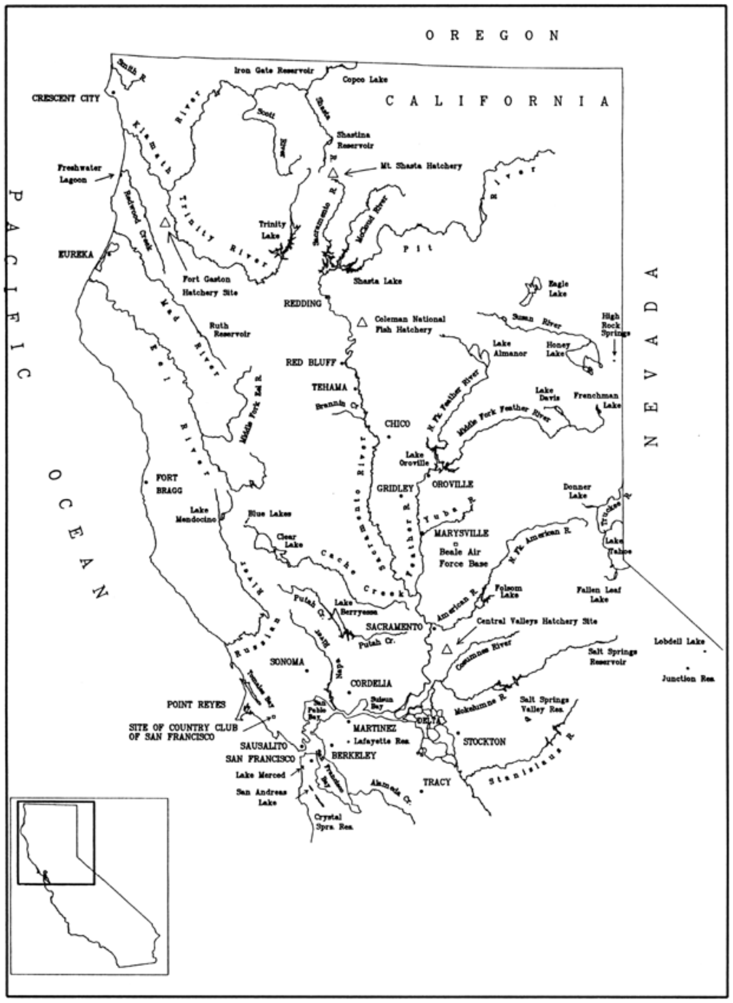
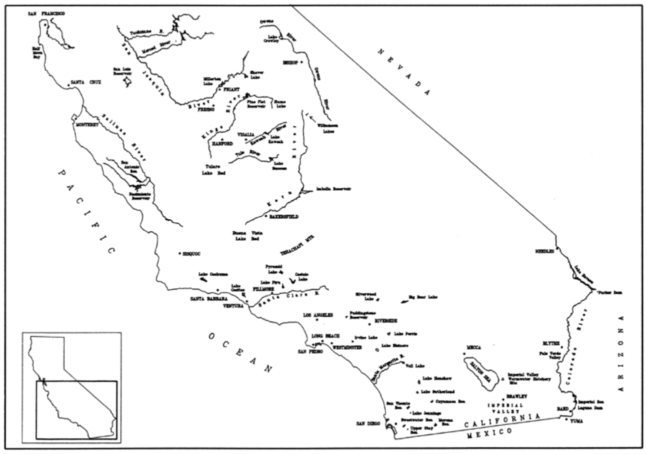


Northern portion of California showing major localities mentioned in the text.



Southern portion of California showing major localities mentioned in the text.

1. FOREWORD[1]

On 19 June 1871, Seth Green of the New York Fish Commission, known to many as the "Father of Fish Culture in America" but employed temporarily by the California Fish Commission, left the Hudson River in New York en route by train to California. With him were 12,000 newly hatched American shad in milk cans. Never before had such a trip been attempted, and on his way across the continent he tended the fish with care, coupled with anxiety.

In Green's own words: "... at Chicago ... I first tried the water from the city water-works, but found there was too much oil in it.... The fish were still in good order when we arrived at Omaha, but there I could not find any water in which they would live five minutes.... The only way I kept my charges alive was by drawing the water out of the cans into pails, and pouring it from one pail to another until purified.... June 22nd. [somewhere between Omaha and Ogden] Bad water all day, with the thermometer 100° in the shade from 9 a.m. to 4 p.m. I used ice-water the entire day, a very little at a time, and had hard work to keep the temperature of the water below 82°. I began to feel blue and doubtful of the result. The fish suffered considerably...."

But on 26 June 1871, his tribulations ended. He arrived at Sacramento, and accompanied by B.B. Redding, one of the first California Fish Commissioners, took the shad by rail about 125 miles up the river to the town of Tehama. At 10 p.m. he deposited them in the Sacramento River: "... there were about 10,000, in good order." This was the first formal introduction into California of a fish alien to the state.

Upon reaching Tehama, Green "... examined the water ... and found plenty of food for the young fry." He "... then went down to the Pacific Ocean, and ascertained that there were plenty of sand-fleas, which are the principal food that the old shad live on in the Atlantic. And now, in conclusion, I can only say, that if they do not have shad in the Pacific Ocean there will be but one cause—the roily water, caused by washing the mountains down for gold. However, I think the fish will get through all right...."

They did "get through all right." Less than two years afterwards, on 10 May 1873, the California Fish Commission paid $50 as a reward for the first adult shad taken in California.

A wave of successive introductions of fish had been started, a wave somewhat feeble 126 years afterwards, but still not terminated.

Today, many of our introduced fishes (shad, striped bass, the black basses, and others) are so commonplace that many people believe them to be native to California.

[1] A portion of this paper is based on one presented by W.A.D. at the 13th annual meeting of the Western Division of the American Society of Ichthyologists and Herpetologists, Pasadena, California, June 1941 (see Croker 1941).

Like the European wild oat of the hillsides, the eucalyptus from Australia, the pheasant from Asia, or the bullfrog from eastern North America, they are a common part of California's inheritance from its indefatigable acclimatizers.[2]

2. INTRODUCTION

"*Although most people skip them, introductions are meant to be read.*"
—W.A.D. & A.J.C. 1996[3]

"*... so much has been written about California, with total emphasis on its golden aspect, that in the tinsel glare we are becoming blinded to what California was and what it was becoming.*"
—C. Gentry, ca. 1969

"... the Californian has too often come to love mere fullness of life, and to lack reverence for the relations of life."
—J. Royce 1894

This is a chronicle of the origin of the fishes actually introduced into the waters of the state of California, those recorded as introduced, and those proposed as likely for introduction, as well as their subsequent history. We have tried to be objective, and record this history before it is too late.

There is a second reason to write this history. In recent years there has been a spate of articles opposing fish introductions—written primarily for ichthyologists or those not intimately concerned with the active practice of fishery biology. This fact is elaborated upon in our "Discussion," but must be mentioned here because it has a definite bearing upon the reasons for preparing this history. There are two sides to the argument, and the introduction of fishes into California has not been as completely evil as some of its detractors maintain.

[2] The account of the first fish formally introduced into California was written by Green (1872) in the Report of the New York Fish Commissioners for 1871, and is also derived from Green (1874) and Baird (1874a). Another initial account appears in the California Fish Commission's Report for 1870–71. According to the latter report, Seth Green and an assistant left Rochester, New York, on 20 June 1871 with 15,000 shad fry, and the fish were planted at Tehama on 27 June. An account in the Proceedings of the California Academy of Sciences (1875, p. 6) also said that the first shad were planted in California on 27 June 1871; the time was given as 9 p.m. This account was probably based on the California Fish Commission Report, but Green's own accounts were considered to be more accurate. A total of $578.30 was paid to Green and his assistant by the California Fish Commission. Green was then considered to be America's foremost shad culturist, having carried out its hatching since 1867. The account of the first adult shad taken in California came from the California Fish Commission's Report for 1903–04.

[3] Most authors believe this is true, but we couldn't find any notable ones who actually said this; we had to write it ourselves.

As will also be pointed out in the "Discussion," many of the articles castigating introductions appear in relatively obscure or specialized journals or books which are not generally available or read by common citizens. (Some of their authors persist in providing much of the same information as though it had not been presented before—thus giving themselves a long list of supposedly quite separate scientific papers.)

Furthermore, there sometimes appears to be a designed effort to treat all introductions as bad. We definitely commend the book "Dispersal of Living Organisms into Aquatic Ecosystems" (Rosenfield and Mann 1992), but note that its preface admits that "... the original title of the volume was 'Biological Pollution by Aquatic Organisms'; it was provocatively titled to emphasize the negative aspects of human-assisted invasions of living organisms into bodies of water." Although even the word "invasions" has a negative connotation (conquest and plunder), the editors pointed out, "Such a title was restrictive in that it excluded the highly beneficial effects of many ... programs."

Opinions have also been voiced that many of the fishes successfully introduced into California have been those chosen by commercial elements (such as aquaculturists), or by those not cognizant of the effect that introductions may have upon the environment. This paper will show that, although there are fish introductions of consequence in California which can be traced to commercial breeders, until quite recently there were almost no objections to introductions (even from academicians), and of late years the question of introducing nonnative fish species has generally been considered quite carefully by the relevant authorities.

As Sport Fishing Institute (1993) said, "... examination of the benefits of introductions is needed in order to make informed decisions about difficult trade-offs between social benefits and risk reduction. In some highly altered and managed ecosystems, introduced species may offer the best (or only) opportunities to maintain productive fisheries." Although Peoples et al. (1992) may have said essentially the same thing in a more suitable style by speaking of "equitable and effective solutions," we must grant that the second sentence of the quotation from Sport Fishing Institute (1993) is correct. In other words, with specific reference to California, had it not been for fish introductions, there would be little practical use to man (the layman's measure of value) of much of its native inland fish fauna, especially in the reservoirs which now dominate the state.

As used in this paper, the term "introduced" means any species or subspecies of fish not native to the state. Thus, we have usually not considered "strains," "races," or "varieties" of indigenous species to have been introduced. This definition differs from the term "exotic," meaning a species "introduced from a foreign country," as used by most recent American authors. (See, for example, Shafland and Lewis 1984.) If we were to use their terminology, most of the introductions discussed in this paper would merely be "transplants." Nor, although we agree with Hubbs (1977) and others that an "exotic" is "any species introduced into a location outside its natural geographic range," have we used the term "NIS," meaning (in this day of unexplained acronyms) "nonindigenous species." Instead, we have used a political unit (California) rather than a natural geographic unit as the area to be covered. There are good reasons not to use a political unit since its boundary may not be natural or even contiguous (e.g. Alaska, which is well-separated from the rest of the United States by a sovereign nation), or when its name may change and invalidate to some extent its selection (e.g. the breakup of "Yugoslavia" or the "USSR" into various nations or the dismemberment of "Czechoslovakia"). On the other hand, a number of writers have chosen political units for their papers on the subject (e.g. Welcomme 1988), and we have followed their system. Furthermore, the borders of California have been relatively stable since 1850, which means that its boundaries are far more stable than those of many of the nations of the world.

There are several other reasons for preparing a history of fishes introduced into California. With the exception of Florida (where water temperatures are generally higher), no state in the Union has more introduced fishes. It is also the most populous state in the Union, having over 30 million inhabitants. The very size of California, which except for three countries is larger in area than any country in Europe, and which is politically older than a number of European countries, affords it some precedence. Furthermore, the early introductions of several species of fish into California, coupled with their reproductive success (e.g. shad and striped bass), had a wide impact on introductions and on the science of "fish culture" throughout the world.

The early introducers of fish into California often used the terms "alien" and "acclimatized." The word "alien" is synonymous with "introduced" as we have used it. An "acclimatized" fish is an introduced one which has produced a breeding population; i.e. one which has achieved continued reproductive success.

With regard to the land, "... we have become so accustomed to the benefits obtained from the introduction and domestication of introduced animals, and the cultivation of nonindigenous plants, that we take them for granted and tend to forget their origin" (Cole in ICES 1972).[4] This is now rapidly becoming the case with our waters. During the last 126 years, from 1871 through 1996, more than 90 species and subspecies of nonindigenous fish have been planted in or gained access to the waters of California.

Two basic papers dealing at length with the introductions of fishes into California already exist: Smith (1896) and Shebley (1917). Smith's history covered man's attempts to "acclimatize fish and other water animals in the Pacific States" chiefly during the period of 1871–94, is reasonably well documented, and since

[4] Dowell and Krass (1992) said that about 31% of all land in California is used to grow nonendemic species. About 1000 exotic plant species now grow naturally in California—changing the face of the landscape.

it contains many original accounts is a delight to read. Shebley (1917) was actually based on an earlier publication (Shebley 1913a) which appeared in the California Blue Book or State Roster for 1911, and recounted the "History of the California Fish and Game Commission." Since the section of his article dealing with introduced fishes was reprinted without change in 1917, and because Shebley was still alive at that time, it may be concluded that no further knowledge of the subject had been gained by him. As Shebley (1917) was printed in *California Fish and Game*, which is more accessible than the earlier paper, and since it has been generally referred to and quoted by later authors, this reference is also used in this paper. Shebley's account of the early introductions, which apparently was based to a large extent upon Smith (1896), covered the period from 1871 to about 1911. Although Shebley (1917) has been taken by many authors to be the definitive history of fishes introduced into California, it was merely a summary, was not well documented, and to a large extent was a discussion of the role of the California Commission in making fish introductions. Shapovalov (1965) provided a short and by no means complete "history" written for a popular audience followed by an almost identical but updated version in 1970. Moyle (1976a) provided a scholarly document, but depended so heavily upon secondary or tertiary sources, including the repeated misspelling of one of his principal sources (i.e. Shebley 1917), and contains so many inaccuracies that it simply cannot be depended upon as a source for introduced history—as will be shown later.

In addition to these "histories" are tables showing the number of "alien" fish and the years when they were planted or distributed in California by the State Fish Commission: California Fish Commission Report for 1893–94, p. 75; *Ibid.* 1895–96, table following p. 58; *Ibid.* 1897–98, table preceding p. 49; *Ibid.* 1899–1900, table facing p. 24; and Shebley (1922), table facing p. 96. Since fish were also introduced into California by Federal and private agencies or individuals during the periods described, these tables are not complete, but even with this qualification they cannot be depended upon. Not only did several of their figures differ from one another, but they were sometimes at variance with other records which appear to be more accurate. Furthermore, an analysis of the Shebley (1922) table indicates that not all of his "distributions" represented fish which were actually planted. Some merely indicated that the enumerated fish were transferred from hatchery troughs to hatchery ponds; others seem to have represented the fish "on hand" when a yearly inventory was taken. Some represented eggs received—not fish planted.[5] .

[5] It would require a long footnote to list all the errors in this table. One example may suffice; others will be noted later. The table lists 100,000 "Mackinaw" (i.e. lake trout, Salvelinus namaycush) "distributed" in 1894 and 65,000 in 1895. Yet his own accounts, Shebley (1917, 1929) and CFG (1923c) (the latter article was undoubtedly written by Shebley), as well as the original records for plants in these years, make it clear that only 65,000 "Mackinaw" were planted during these two years. (In 1894, 100,000 eggs were imported, and the 65,000 distributed in 1895 were the resulting fry.)

One of the last attempts to summarize the history and status of the introduced fishes in the state was made by Evermann and Clark (1931). Although their distributional list of the inland fishes of California provided additional notes on the success of some introduced species, these authors drew largely on Smith (1896) and Shebley (1917) for their information.

In addition to these basic papers, three lists covered all of the freshwater and anadromous fishes of California and the general facts concerning each new introduction: Shapovalov and Dill (1950), Shapovalov et al. (1959), and Shapovalov et al. (1981). These papers were quite accurate, but the history of introductions made prior to 1950 was not covered, and there was only bare detail concerning later ones.

Although issued prior to the last named paper, Hubbs et al. (1979) listed all the fishes known to be present in California and also had a list of 28 "Introduced Fishes Not Known to Occur at Present in California." No details of introduction were given.

Two other major papers on fishes introduced into California exist: one treating of their effect biologically on other species (Curtis 1942), and one on their economic value (Clark 1942). Both authors relied primarily on some of the sources mentioned above and cast no real light on the actual introductions. Furthermore, both papers are rather dated, having been written over 50 years ago.

Two books discussing most of the inland fishes of California contain a fair amount of detail concerning the introductions: Moyle (1976b) and McGinnis (1984). A publication edited by Calhoun (1966), composed of papers by fishery biologists of the Department of Fish and Game, discussed many of the inland game fishes of the state, their life histories, and some details of their introduction. Almost all these authors, however, have used at best secondary references to the actual introduction of the species.

Most other publications on the subject have treated only an individual species that had been introduced (e.g. Raquel 1988), or the group of introduced fishes inhabiting a particular area (e.g., Healey 1977; Swift et al. 1993). Many of the published records are to be found in: Reports of the California State Board of Fish Commissioners and its successor, the California Fish and Game Commission; Reports of the U.S. Fish Commission and Bulletins of the U.S. Bureau of Fisheries; the journal *California Fish and Game* (often buried as small and anonymous unindexed notes); and in the Administrative Reports issued by the Inland Fisheries Branch (later Division) of the Department of Fish and Game or its predecessor, the Bureau of Fish Conservation of the former Division of Fish and Game.[6]

[6] The Reports issued by the California State Board of Fish Commissioners and its successors (including the Division and Department of Fish and Game) are commonly referred to as "Biennial Reports." Not all of them bear this designation but the years covered by the Reports will identify them.

Since all of these publications are accessible, why then is there need of a new history?

"Among scientists are collectors, classifiers, and compulsive tidiers-ups; many are detectives by temperament and many are explorers...."

—P.B. Medawar 1967

We are among these, and list a few of the reasons why another history is needed:

i) No single account published later than 1976 treats all of the fishes introduced into California.

ii) Even the best of the previous accounts contains inaccuracies, inconsistencies, and partial or confusing statements. This is particularly true of the early Reports of the California Fish Commission whose detail often varied from one issue to another and sometimes even within the same issue, but other publications also share this fault.[7]

We have usually not called attention, however, to mistakes in secondary or later sources unless they were completely outrageous, provided independent or nonreferenced material such as dates, or appeared in publications which have had wide circulation among interested people. Thus, for example, Wang (1986) stated that both Shapovalov (1944) and Skinner (1962) said that tench were introduced into California in 1872. of course they didn't; they both said "1922." Or, as an example of widely circulated misinformation, Neale (1931a), whose reprint alone totaled 29,000 copies, wrote that only 1000 shad survived to be planted by Seth Green in 1871, and said nothing of other plants of this species. (In both cases, the errors may have been typographical.) Reprints sometimes differ from the original article, and transpositions and misprints are common. Furthermore, even when errors have been corrected or called to notice by the author or publisher (usually by the issue of "erratum slips"), they are rarely corrected in all issues of the publication, and are thus perpetuated. Li and Moyle's (1993) report is another example of a publication which had wide circulation. Although we do not agree with all their conclusions, we have pointed out only their inaccuracies concerning fishes introduced into California. Those who copy the original manuscript, or the editor who reads it, may assume that the author has made a mistake and may "correct" it. One can only surmise, for example, that Stone (1882) really wrote "Navesink," but that someone thought that he meant "Neversink."

iii) Some accounts tried to minimize the role of other agencies, giving more credit to their own agency than was deservable. For example, a California State

[7] Note, for example, the treatment of the American shad in Evermann and Clark (1931) which indicated that only one plant of about 10,000 fish was made. There were actually six or seven plants totaling over half a million shad.

publication, CC (1936), was incorrect in saying, "With the exception of a small number of Atlantic salmon eggs ... the Federal Government has never supplied the State with any fish eggs, officials say." If officials said this, then they were wrong. Similarly, the U.S. Fish Commission Report for 1883 (p. XIX) pointed out that a large run of shad in the Sacramento River resulted from the introduction of young by the Federal Fish Commission. As will be seen, the success of the shad was due to the California, not the Federal, Fish Commission.

iv) Few authors have depended on primary or original sources for their accounts of introductions. For example, quoting fairly recent authors such as Curtis (1949) or those in Calhoun (1966) or even Shebley (1917) to describe a plant made in the 1870s, as many people have, placed complete dependence on at best a secondary and often on a tertiary or quaternary source. This is a rather simple (we hesitate to say "lazy") thing to do, but the use of less than a primary source is often unreliable. Consequently, any reader who has been incautious enough to read more than one of these "histories" is often unable to determine, except for a sometimes laborious search for the original records, which of the varying accounts is accurate. Since most have not resorted to this time-consuming process, one finds perpetuation of many errors in the work of authors who have accepted these later accounts at face value. We do not say that all earlier sources are more accurate, but generally speaking, it is best to seek out the originals. There are exceptions. Articles by the same author are sometimes more accurate in later (corrected, considered, or better edited) accounts. See, for example, the place of deposition of American eels in Stone (1875) and his later account (1876a).

In some cases, however, we have also cited authors (such as Smith 1896) who have obviously devoted a considerable time to compilation, even though they are not primary sources.

v) Unfortunately, considerable bias is shown in some of the previously published histories—either to praise introductions or those responsible for them, or to oppose them.

vi) Unlike earlier authors who have rather blithely accepted most accounts of introductions as though they were known facts, we have attempted to apply a bit of reason in determining whether or not the "facts" are logical. Although we agree with Tuchman (1962) in decrying the "... spontaneous attribution or the 'he must have' style of historical writing ...," we feel with Claiborne (1983, p. viii) that this is occasionally useful, and when this "style" has been resorted to (as in the history of the black basses), we have clearly labelled our reasoning as conjecture.

One may also note that there is a rather fine line between actual introduction into public waters (e.g. American shad, striped bass) and importation for "experimental," aquacultural, or ornamental use. Given the propensity of fish to escape from confined areas such as private ponds or hatcheries into public waters, we have thought it best to mention some of the latter instances in this paper.

We have tried to trace the true reasons for each introduction, and the attitude of administrators, fish culturists, biologists, fishermen, and the general public towards each introduced fish and its place in California. Thus, is the fish one of the favorites of the fishermen (e.g. striped bass), a mainstay of the poor (e.g. catfish), or a "villain" beyond redemption (e.g. common carp)?

Lastly, we have tried to point out the present attitude of those concerned with fish introductions, and to describe the potential sources of what may be new fish introductions into California.

"*A stream can never rise above its source.*"

—old English proverb

In an attempt to fully document this new historical account, an elaborate citation of the sources has been necessary, and a liberal use of quotations has been made to indicate the "feeling" of the day. In fact, there has been some fear that the main text would be obscured by references and quotation marks. Still, even at the risk of being overacademic, it has been thought worthwhile to list all of the primary or original sources of information known to us, especially when we have corrected a statement appearing in one of the recognized and widely accepted histories.

Not all of the sources are listed in the section "Literature Cited." Most of the primary ones appear in reports by either State or Federal governmental agencies, and, if listed here, the author would merely appear as "Anon." Furthermore, even in the case of some named authors, the name may be omitted because it is the source that is important—not the name of the administrator who ostensibly wrote the report, or even if he did write it, merely followed some information provided for his use. Rather than wade through an even longer list of "Anons" than those already cited, or to cite authors far removed from the actual introductions, it has often been thought best to simply mention the source directly in the text or provide the name of the journal or source of the information.[8]

Despite the emphasis on the citation of sources and our great dependence on published accounts, this paper is not an attempt to list every detail concerning the introductions of alien fishes into California. Such a task would require the examination of so many published records, including those in regional histories and newspapers, and so many unpublished ones, that the task would be hopeless. Furthermore, a certain amount of information on introductions appears to have been passed on verbally, or in letters which cannot be resurrected (see the account of the "Hawaiian mullet").

The old "Biennial Reports" of the California Fish Commission/California Fish and Game Commission/California Division of Fish and Game may not have been completely accurate. However, despite their prolixity and their "dullness" to some, they at least reported fish plants in considerable detail. From about 1954 onwards,

[8] See the section "Literature Cited" for a further explanation.

however, these Reports seem to have been designed primarily for public attention and their useful role as detailed recorders was minimized.

Furthermore, certain unpublished reports seem to have been written simply to provide some information or impress the recipient (the one next above in the hierarchy). The information itself was not necessarily accurate.

Many of the original records of even relatively recent introductions were destroyed or "purged" by Department of Fish and Game employees following reorganization of the agency in 1952 and are no longer available.

We offer our opinion that it will be impossible to ferret out all the exact dates, numbers, species of fish planted, and planting localities. Actually, such an accomplishment would be of dubious value. In most cases, for example, knowing the exact number of individuals of a particular species which was first planted does not help one to understand whether or not this particular form survived. Many of the records of number of fish planted were only crude approximations, and the size and condition of the fish and the type of waters stocked were probably of far more importance.

Furthermore, emphasis on initial plants of a species, although of historical interest, may be misleading. The success of a species, meaning reproductive success, abundance, and/or wide distribution, is not necessarily the direct result of its initial stocking. The striped bass, it is true, gained a wide distribution and abundance from one locality where only a few hundred individuals were planted. However, the dissemination of many of the other alien fishes was given impetus by successive introductions or the transplantation of acclimatized individuals.

The amount of space devoted here to a specific species is not an indication of the importance of the introduction. often, it merely indicates the amount of controversy concerning the actual introduction or occurrence. For example, the account of the yellow bullhead in California requires more space than that given to the much more important white catfish. Conversely, an introduction such as that of the kokanee is clear-cut and demands little data.

"Science ... is imagination in service of verifiable truth."

—G.M. Edelman, ca. 1994

"*False facts are highly injurious to the progress of science....*"

—C. Darwin 1871

Lastly, we warn against accepting all published or unpublished information concerning introduced fishes, even if the authors are generally considered to be quite reputable. We are not convinced (as will be pointed out in some of the ensuing accounts) that all the recorded information is correct. Aside from lapsus calami (as indicated above), Federal reports of plantings by the State often differ from the State's reports, even though the Federal reports should have depended upon what the State alleged. Unfortunately, the statistics concerning introductions in both State and Federal reports sometimes differ on different pages of the same report or in subsequent and ostensibly corrected ones. Or, the same author may present different information, sometimes even in the same article. In short—despite our previous assertion—it is difficult to depend upon the literature.

Some of the reports were written from memory; we all know that this is a faulty source. Sometimes there has been an apparent disinclination to refer to accurate notes even when they existed. Sometimes, those doing the actual planting did not convey accurate information to their superiors. Sometimes their superiors did not convey accurate information to them, nor to those "above" them. "Those that are documented may be a biased sample. Journals do not often publish negative results: managers don't like to hear bad news—don't document our failures" (Hilborn 1992).

Some accounts of introductions (e.g. the statement by Dill 1944 that the yellow perch had been introduced into the Colorado River) were not intended to be of historical significance, and the records were not provided.

Some accounts may simply not be true. See, for example, the manner with which "allotments" of fish to be planted were often treated (Greene 1926), and we are aware of recent known deviations from the truth concerning fish planting records by both Federal and State employees. Is there any reason to assume that the early reports were more accurate? We have tried to be scientific, but "verifiable truth" has often been difficult to find.

It must also be considered that some species may have been misidentified. Many of the people who actually caught, conveyed, or planted the introduced fish in California were not ichthyologists, and may well have confused quite different species. (This may have occurred, for example, with the black basses.) Furthermore, even competent ichthyologists may have misidentified closely related species or disagreed on the relationships.

As the methods used in ichthyological classification and the opinions of competent systematists change, both the common and scientific names of the fishes discussed here may also change.[9] However, we have tried to identify each introduction so that most readers will understand to which species or subspecies we refer.

"He who wills the end wills the means."

—old English proverb

So, with all the qualifications that we have given, what is our final aim? Again, and simply put, we wish to chronicle the introductions of fish that have been

[9] For example, even the intuitive and classical ichthyologist, C.L. Hubbs, who felt at one time that there was a "trenchant" difference between largemouth and smallmouth bass and classed them in different genera, later included them in the same genus.

Furthermore, the use of meristic and morphological characters, as used by the older systematists, is today supplemented by genetic techniques such as electrophoresis, DNA analysis, and chromosome study.

made in California as accurately and dispassionately as we can, and to describe the status of these fish.

The introduced forms are grouped systematically under the families shown in the Table of Contents. The family, common, and scientific names follow those of the American Fisheries Society (Robins et al. 1991). Subspecific names are from several sources.

Generally speaking, the treatment for each fish includes:

i) Its original distribution and place of origin.

ii) The agency or the individuals making the introduction.

iii) The reasons given for the introduction.

iv) The date of the original introduction and such later ones that might have contributed heavily toward its establishment.

v) The place of the introductory plant. (When only a few fish were stocked, the specific waters are named; otherwise only enough examples are given to indicate the type of waters stocked.)

vi) The size (length or weight) and number of individuals in the initial introduction.[10]

vii) The primary references concerning the introduction.

viii) The later distribution in California and whether it was purposeful or accidental. After its initial establishment in a few major waters or drainages, the complete current distribution of each species is not described.

The status or success of introduced fishes in California is painted with a rather broad brush since it is often dependent upon factors well beyond the inherent qualities of the species introduced (for example, the amount or quality of water available, changes in temperature, etc.), and continued success of the original introduction may change in time. Furthermore, the "success" of a species is often a very subjective one, nor may it be recorded in available published documents. The opinions or knowledge ("personal communication") of various correspondents may vary decidedly, and—even with some reluctance—we have placed our emphasis on published material.

ix) The regard with which the introduced species is looked upon or treated is given.

When the circumstances of the introduction are unknown, reported occurrences follow somewhat the same outline.

The fish discussed must have been introduced into a "wild," "open," or "public" water; i.e. one available to the public or at least a selected few. Thus, most aquarium fish, even though resident in glass or plastic containers within the boundaries of California, are excluded. Borderline cases, however, such as "experimental" stocking in private "waters" (e.g. ricefields which drain into public

[10] We have not converted British to metric units of measurement. Instead, the units are reported as they appear in the literature, correspondence, etc. We believe this is appropriate for a historical document.

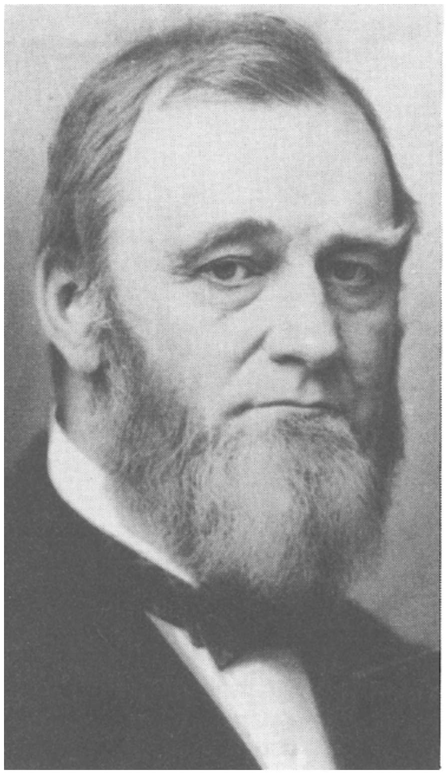
waters) have been included—especially considering the ability of fish to escape or avoid barriers to their confinement.

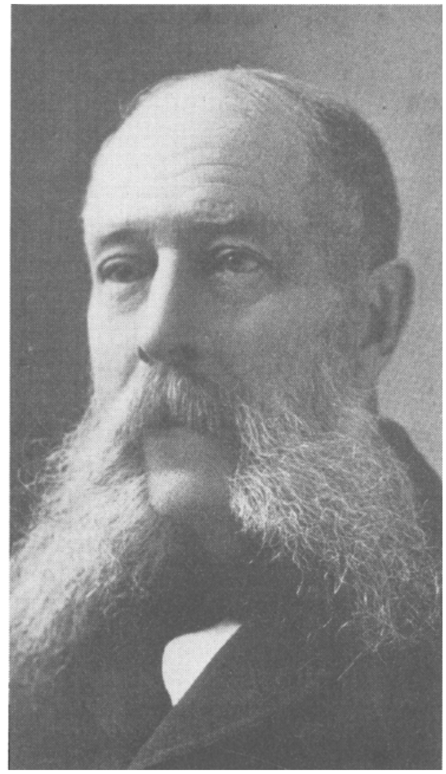
One should also note that only drainages originating in California (most of them, including the Truckee River) or passing through it (e.g. the Klamath River) or bordering it (e.g. Colorado River, Lake Tahoe) are included as "wild" or "open" waters.

Actual features of life history are best left to books such as Moyle (1976b), the authors in Calhoun (1966), or more recent publications, and are generally provided only when they have been determined in California (thereby being a part of their history) or are definitely pertinent.

This history is the result of some years of research, including examination of every: issue by the State's principal agency concerned with fisheries from its initial Report for 1870–71; the corresponding reports for the Federal Government starting in 1882; *California Fish and Game* starting in 1914; the Administrative and Technical Reports concerning inland, anadromous, and marine fisheries issued by the Division/Department of Fish and Game; Outdoor California starting with its first issue in 1940; all the files concerning the California Division and Department of Fish and Game in the State Archives collection; California Conservationist starting with its first issue in 1936; most of Copeia; and most of *The Progressive Fish-Culturist*. It is also based on original reports, whether or not they are of a "scientific" nature; e.g. newspaper and magazine accounts and regional histories. "Popular" accounts sometimes seem less accurate than the "scientific" accounts, but have often been published at an earlier time and may have had more influence on subsequent history. The history also includes references to as many unpublished letters and notes as we have been able to find. For example, we have used the fish planting notes on San Diego County by State game warden E.H. Glidden covering the period 1917–33 which we obtained from E. Henke. Finally, we have tried to contact those among the living who have been directly associated with the introductions. Thus, this history is based on the statements of those who were closer to the "action" than some of the published accounts and most of the present readers.

The State agencies charged with the management of fish and game, including decisions regarding fish introductions, have undergone several changes since 1870 when the Governor appointed three individuals to a Board of Fish Commissioners "... to provide for the restoration and preservation of fish in the state's waters." This was one of the nation's first wildlife conservation agencies, predating even the U.S. Commission of Fish and Fisheries. In 1878 this body was granted jurisdiction over game as well as fish, and in 1909 its name was changed to the Board of Fish and Game Commissioners. The title Fish and Game Commission came into use beginning with the 1910–12 Biennial Report. In 1927, "The Department of Natural Resources ... succeeded to the powers and duties of the Fish and Game Commission. A Division of Fish and Game was established





within the Department, and a new Fish and Game Commission was created to administer the Division" (Leitritz 1970, p. 9). The Fish and Game Commission was increased from three to five members in 1937, and in 1952 the Division was made a separate department, the Department of Fish and Game.

The title, duties, and responsibilities of the various units, within the foregoing agencies, which were most involved with fish introductions have likewise evolved since 1870. Apparently, no specific title was employed in the late 1800s and early 1900s when staffs were small. A Hatchery Department, later the Department of Fishculture, reported directly to the Board of Fish and Game Commissioners. In the late 1920s, a Bureau of Fish Culture was created within the Division of Fish and Game. In the 1930s, its duties and responsibilities were absorbed by the Bureau of Fish Conservation which later became the Inland Fisheries Branch and finally the Inland Fisheries Division.

As we have stated before, we have placed great dependence on published or printed accounts, especially those by well-known authors—despite their occasional lack of credibility. The latter doubt has been strengthened by the somewhat cynical remarks on the subject made by Montaigne in the 16th century (Ives 1925). Nevertheless, we have usually had nothing better to follow.

We have tried to do our best with the "facts" available, have documented these, and future historians can build on this account.

3. ACKNOWLEDGMENTS

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4. FISHES WHICH HAVE ACHIEVED LASTING SUCCESS

4.1. American shad, Alosa sapidissima (Wilson)

A portion of the history of this fish, native to the Atlantic Coast of the United States, the largest member of the herring family in North America, the first of its family to be propagated, and the first aquatic species to be formally introduced into California, has been related in the Foreword.[11] There is some question as to whether the American shad, brook trout, or the goldfish was the first species of fish to be introduced into California, but it is certain that the shad was the first formal introduction.

Seth Green's plant of 1871 was the first introduction of shad into the state, but even before that time, the American Fish Culturists' Association said, at its first meeting in 1870, that it favored an experiment to plant shad in western waters, and that if it succeeded, "... it will give cheap fish to all our western States and territories, and supply one of their greatest wants."

Following Green's plant, in a joint venture with the United States and California, pioneer fish culturist Livingston Stone of the U.S. Fish Commission started for California in June 1873 in a specially constructed "aquarium car" with a load of young American shad and various other species. However, his entire stock was lost when the train was wrecked in Nebraska. He returned to the Hudson River and brought out another shipment of about 35,000 young shad which was planted on 2 July 1873 in the presence of State officials (Stone 1874b, 1874c, 1876b; Baird 1878). Planting of shad by the Federal and State fish commissions continued through 1881 until over half a million shad fry had been stocked, all at Tehama on the Sacramento River.[12] Both the Maryland and New York fish commissions seem to have assisted in this work.

Shad plants were made in California in 1871, 1873, 1876, 1877, 1878, 1880, and 1881. Most accounts fail to list any plants after 1880, and it seems to have been generally accepted that that year marked the cessation of shad plants in the Sacramento River. Smith (1896), for example, stated, "Since 1880 no shad fry have been introduced into the State," and this advice is also to be found in the accounts of very recent authors. But apparently 220,000 more shad were recorded as being stocked in 1881, and at least one account stated that these were

[11] Jordan (1915) erroneously said that the striped bass and the shad were both planted in California about 1878 from the Potomac and Schuylkill rivers. In an otherwise excellent article on angling in California, Freeman (1974) said mistakenly that shad were imported from New Jersey waters.

[12] Accounts of the duration of planting and the number of fish stocked vary with different authors. One can find at least seven different totals recorded for the 1871–80 period ranging from 546,000 to 659,000 fry.

planted at Tehama. (See California Fish Commission Report for 1881–82, p. 8; *Ibid.* 1893–94, p. 75; *Ibid.* 1897–98, table preceding p. 49; Shebley 1922, table following p. 96.) If we accept the maximum figures given in these reports, then 879,000 shad are recorded as planted in California from 1871 through 1881. Skinner (1962, p. 86) also stated that 220,000 shad were planted in 1881, but provided a total figure of 834,000 planted. Stevens (1972) stated that about 829,000 shad fry were stocked in the Sacramento River during the 1871–80 period. The source of their data was not given by either author.

There is no way to determine which records are the most accurate; it is obvious that any of them is only an approximation. Furthermore, we know that shad from the first plant survived. For these reasons it is not considered worthwhile to provide the long list of references alluding to these plants. (The primary ones are to be found in the Reports of the U.S. Fish Commission and the California Fish Commission.)

The Foreword points out that on 10 May 1873 the California Fish Commissioners paid $50 as an award for the first adult shad taken in California. According to Anon. (1882), "The first shad ever caught in California waters was taken ... by Baltimore Harry.... [However] A. Boyd and Company have been catching the same kind of fish for some weeks past ... they attached no importance to it, and have been eating them as fast as caught." Furthermore, the California Academy of Sciences, at its meeting of 5 May 1873, received "The first shad ... caught in waters of California...." presented through S.R. Throckmorton of the California Fish Commission. It was claimed that this fish had been caught recently in a trap below Vallejo (*Proceedings of the California Academy of Sciences* 1875, p. 85). Despite such statements, one finds the President of the California Fish Commission saying "... it is thought that the first [shad] was taken in April, 1879...." (Anon. 1887). (We mention this only to show that printed records concerning fish introductions are often surprisingly inaccurate.)

Their increase in numbers and rapid dispersal from Tehama were unprecedented. Eleven years after the initial plant, shad had been recorded from as far south as Wilmington in Los Angeles County and north as far as Puget Sound (Swan 1883; Smith 1896). All of these fish are presumed to have come from Sacramento River stock as up to that time (1882) no other plants are known to have been made in any water tributary to the Pacific Ocean. The coastal range of shad on the Pacific Coast has subsequently been extended from Todos Santos Bay in Baja California to Kamchatka, Siberia; i.e. along about 3000 miles of Pacific coastline.[13]

The success of the shad went far toward convincing the California Fish Commissioners of the advisability of introducing other fishes. These men were nonetheless desirous of taking no chances of failure. A California law was passed

[13] Moyle (1976b) stated that its coastwide extension is due both to California plants and others on the Pacific Coast, but this is merely conjecture.

prohibiting the taking of shad prior to December 1877. Furthermore, despite the fact that shad were already being sold in the markets, the California Commissioners stated in their Report for 1880, p. 9, that two or three million more would be brought in a railway car made especially for fish transportation by Professor S.F. Baird, U.S. Commissioner of Fisheries.

Its success may also have been an important factor in crystallizing the dogmatic belief of many fish culturists and many scientists of the day in the efficacy of artificial propagation. Smith (1893), for example, said: "If these far-reaching ... results attend the planting [of shad] on few occasions, of small numbers of fry in waters to which the fish are not indigenous, is it not permissible to assume that much more striking consequences must follow the planting of enormous quantities of fry, year after year, in native waters? There is no reasonable doubt that the perpetuation of the extensive shad fisheries in most rivers of the Atlantic Coast has been accomplished entirely by artificial propagation." And to McDonald (1891), the wide dispersal of the shad from the Sacramento was a blow to the "... dictum of fish-culture that fish plants in a river would return to it when mature for the purpose of spawning."[14]

American shad were also planted in the Colorado River in 1884, 1885, and 1886. The U.S. Fish Commission stocked about 2,831,000 fry near Needles during this period (McDonald 1889). In 1890, C.H. Gilbert and A.B. Alexander, detailed to investigate "... the alleged occurrence of shad in the lower Colorado," ascertained that "... the reports of the capture of shad had been erroneous, the fish in question being the German carp (Cyprinus carpio) , then a stranger in the Colorado River" (Gilbert and Scofield 1898). Since later collectors in the Colorado River have failed to find American shad, it must be concluded that whatever the number planted, its spread on the Pacific Coast stems entirely from the Sacramento River plants.[15]

The economic importance of the American shad on the eastern coast is well known, and shortly after its introduction into California a commercial fishery began, centered in the San Francisco Bay and Sacramento-San Joaquin Delta. The Delta is a unique feature of the Californian landscape being a delta, a fen or marsh, and an estuary—all in one. A broad flatland fed by the Sacramento and San Joaquin rivers and traversed by many sluggish sloughs, it occupies only about 1% of the state's land area, but it is the keystone of the state's water supply.

[14] Smith's use of the word "entirely" has long been considered ridiculous. Conversely, although straying of anadromous fish from the waters in which they were first nurtured is well accepted today, there is also a widespread acceptance of the parent stream theory.

[15] American shad were also planted in the Columbia River drainage (Willamette, Snake, and Columbia rivers) in 1885 and 1886 (McDonald 1889; Smith 1896). It has been pointed out, however, that shad had already progressed north of the Columbia before these years.

Moreover, its brackish waters and many miles of channels support a variety of fish life as will be emphasized in this paper. It is well described in Dillon (1982).

The fish were taken mainly with drift gill nets and principally for their roe. Although shad were introduced as a food fish, and although there were many attempts, including a special "Shad Number" of *California Fish and Game* in 1916, to popularize it, the commercial fishery was always a minor one in California. Shad were not as popular here as in the East, and there was an absence of skilled boners in California. Erkkila et al. (1950) felt that the commercial shad fishery in California was subject to violent fluctuations from both the abundance of fish and economic conditions, but Skinner (1962) felt that shad landings were influenced strongly by economic conditions rather than abundance. Painter (1978) stated that the commercial value of shad in California peaked in 1917 when almost 6 million lb were landed. Commercial shad fishing had its ups and downs. At times it was considered that it was greatly depleted by heavy fishing, and at times it was given extra protection (by a closed season, for example). At other times, prices were so low that shad were not fished or were thrown away after capture. For a discussion of the commercial shad fishery in California, see: Fish and Game Commission Report for 1924–26, p. 62–73; Nidever (1916, 1936); Clark (1930); Skinner (1962); and Stevens (1972). As with the introduced catfishes, a great deal of shad was shipped back to eastern markets. There was even a proposal in 1916 to ship shad spawn from the San Joaquin River to the Atlantic Coast to restock the depleted Connecticut River (CFG 1916b, 1923b).

In 1957, pressure from organized sportsmen led the State Legislature to close commercial fishing in inland waters for both American shad and Pacific salmon (Oncorhynchus spp.) because of the incidental capture in gill nets of the sport fish, striped bass. It should be noted that this complete allocation to the sport fishery within inland waters was an action brought about not by commercial damage at the time to either the shad or the salmon, but because of presumed damage to a component of their ecosystem (Dill 1982). As American shad are rarely caught in the ocean, this 1957 law brought an abrupt end to the commercial shad fishery in California.[16]

Although shad had long been awarded recognition as a game fish by fly or small-lure fishermen in the eastern United States, and there was some shad angling in California in the 1930s (Nidever 1936) and 1940s (McCully 1949), California anglers did not take much advantage of the shad's recreational possibilities

[16] Fish Bulletin 170, "California Marine Fish Landings for 1976" (published 1979) stated on p. 55 that 65 lb of American shad were taken from the "Inland Waters" of Mendocino County. On p. 10 of this Bulletin, "American shad" is listed as Alosa sapidissima — indicating that the species was still a commercial one. The statement was quite erroneous, as pointed out in a personal communication of 6 June 1980 to W.A.D. by E.C. Fullerton, Director of the Department of Fish and Game.

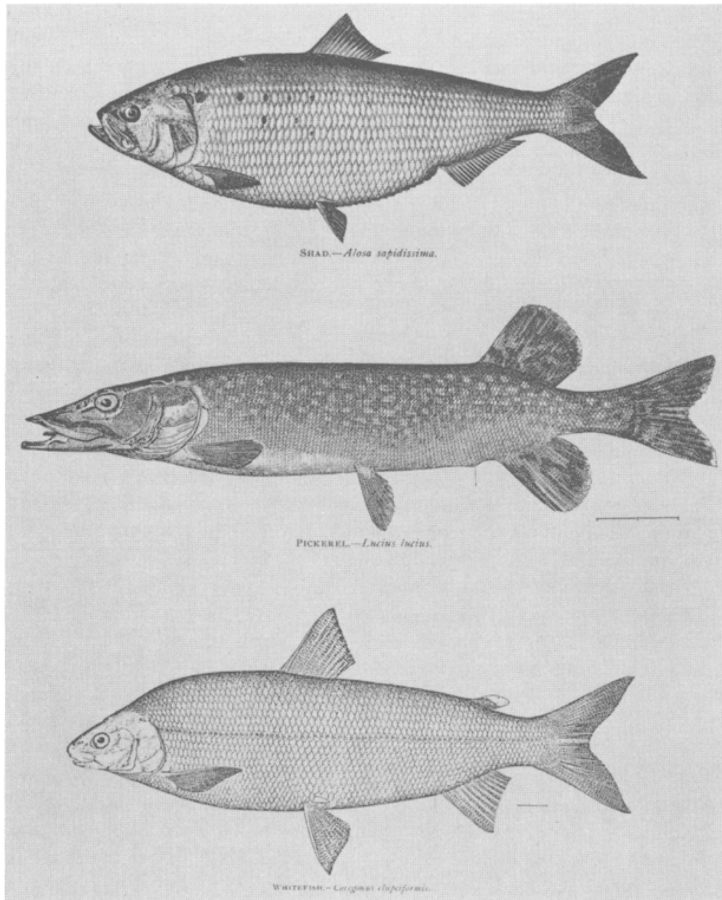
until about 1950. Among the published articles contributing to its popularization as an angler's fish was one by J. Freeman, a popular outdoor writer, and one by Warner (1956). As will be shown later, angling for shad surged and then declined.

Most of the shad taken by angling are on or near their spawning grounds, especially in the Sacramento, American, Feather, and Yuba rivers. Prior to this time, and continuing as a recreational sport, especially on the lower North Fork of the Mokelumne River and the lower Sacramento River, many fishermen practiced a form of fishing at night known as "shad bumping," using large chickenwire dip nets in the propwash of a boat powered by an outboard motor. This sport, which is essentially limited to the capture of males, is described in detail by Ruch (1963) and Meinz (1981). So abundant were shad that it was not until 1972 that a daily bag and possession limit of 25 was placed upon sport fishing for shad in California. Even at that time there seemed to be no real conservational value for the limit; it merely served to keep people happy.

It is of interest to note that the first California Fish Commissioners fully expected that natural propagation alone would not establish the shad on the Pacific Coast. On the contrary, they said, "... we require them all [i.e. all of the first expected run] for breeding ... we shall require funds to enable us to establish breeding stations on the Sacramento and San Joaquin Rivers...." (California Fish Commission Report for 1872–73, p. 12–13). As we have seen, this proved unnecessary, but in 1916 the State felt that heavy fishing had caused the shad catch to fall off and started the Yuba River Experimental Shad Hatchery for its propagation. Furthermore, it was planned to ship shad eggs back to the East, whence the California stock had originated. Some reports indicated that this was its primary purpose.[17] Only one plant was ever made from this hatchery. In 1916, 872,000 shad fry were planted in the Feather River. No shad eggs were shipped to the East. The experimental hatchery was abandoned at the close of its first season. It was considered that the efforts at artificial propagation were almost a total failure because of the inability to procure enough eggs (see California Fish and Game Commission Report for 1914–16, p. 55–79 and 80–100; *Ibid.* 1916–18, p. 23–49; CFG 1916b; Bradford 1916; Shebley 1916a, 1916b; Leitritz 1970).

Today, the shad thrives in the waters of California solely through natural propagation. Even in its native waters "The hatching and stocking of young shad, as

[17] Leitritz (1970), for example, said that the California Fish and Game Commission had been asked in 1916 by Connecticut and Massachusetts to supply them with shad eggs. Although the layman may be surprised, variations of such a procedure are not uncommon in fish culture. The State of Oregon has contributed thousands of shad eggs to aid in the restoration of runs in the Susquehanna River in Maryland (Durbin 1976). California itself has often purchased rainbow trout (Oncorhynchus mykiss) eggs from eastern states where the brood fish are descendants (fully or partially) of California trout sent to the East many years ago.



Fish illustrations from Smith (1896) and biennial repots of the State Board of Fish Commissioners of the State of California (shad, pickerel, and whitefish). The so-called "pickerel" is actually the northern pike.

practiced from 1880 until 1950, did not ... significantly increase shad abundance" (Cheek 1968).

Aside from incidental studies concerned with the commercial fishery and the Sacramento-San Joaquin Delta, there has been only one concerted attempt to study this species in California. In 1975, the Department of Fish and Game initiated a shad study to define the status of the fishery and develop a management plan (Painter 1978; Meinz 1981; Wixom 1981). Unfortunately, a lack of funds resulted in the termination of this project in 1978. However, the findings, which were summarized by Painter et al. (1978), clearly demonstrated the importance of the shad as a sport fish in California during its spawning migration in the spring and early summer. An allied attempt to popularize shad, especially to demonstrate an "easy" boning method, was a booklet by Radovich (1970). Unfortunately, the photographs in the booklet did not show the method used from the point of view of the "boner," so it probably did not greatly popularize its culinary use.

In the fresh waters of California today, shad are most numerous in the Delta, Sacramento River below Red Bluff Diversion Dam, Feather River below Oroville Project Fish Barrier Dam, Yuba River below Daguerre Point Dam, and American River below Nimbus Dam. Smaller numbers of shad are also taken from the Eel, Klamath, Mokelumne, Russian, Stanislaus, Trinity, and Tuolumne rivers. Construction of Friant Dam in 1942 virtually destroyed the San Joaquin shad run. Incidentally, the catches of American shad were first greeted with disgust by lower Klamath River Indians (Hewes 1942). Although shad were taken in the Klamath River as early as 1891 (Smith 1896, p. 411), it was not until 1949 that the Division of Fish and Game received proof that there was a definite shad run in the Klamath River, where shad were called "ten-cent fish" (letter from State fish culturist S.C. Smedley to the Bureau of Fish Conservation, 9 May 1949).

Although they are taken at sea occasionally, where they remain for most of their lives, their primary catch in California is in fresh water (W.F.T. 1919; CC 1940b; Daugherty 1946).

Reproduction of shad has also been noted at Millerton Lake, a reservoir on the San Joaquin River in Fresno and Madera counties. Von Geldern (1965a), who first reported them there, thought that they were introduced accidentally along with striped bass from the Mendota Canal and Tracy Pumping Station between 1955 and 1957. This is the only known case of American shad reproduction in a completely landlocked environment, and the Millerton Lake shad furnish a small sport fishery in the lake and river above the lake. Cooperative studies conducted as recently as 1991 at Millerton Lake by the Pacific Gas and Electric Company (PG&E), Ecological Analysts, Inc., and the Department of Fish and Game confirmed that American shad continue to reproduce successfully there (PG&E biologist T.R. Lambert, 19 September 1994 pers. comm.).[18]

[18] A relative of the American shad, Alosa fallax lacustris, is landlocked in some of the northern Italian lakes (e.g. Como) where it furnishes both food and sport, including fly fishing (Dill 1990).

All in all, the introduction of shad to California appears to have been a useful one. Although it has never fulfilled its original role as a food fish, it does occupy a place, especially in the Central Valley, as an excellent sport fish which can be captured on artificial lures. Supported entirely through natural reproduction, its fate seems to rely largely on conditions created by man, such as water diversion, water temperature, and barriers to ascent.[19]

Present shad spawning runs are almost certainly lower than those of the early 1900s. As noted previously, historical data on American shad abundance are confined to commercial catches which are not a true index of abundance. The shad has never been a very popular food fish and the lack of a better market probably prevented larger catches (Skinner 1962). Regarding the record take of nearly 6 million lb in 1917, Stevens et al. (1987) noted that this represented a catch of almost 2 million fish and concluded, "While we do not know the efficiency of the early fishery, it is reasonable to speculate that the total shad population was several times the number landed, and perhaps two to three times greater than the current runs." The most recent estimates of runs of adult shad were 3,040,000 in 1976 and 2,790,000 in 1977.

California fishery biologists tend to agree that the American shad sport fishery has declined greatly since the 1950s and 1960s (Meinz 1981; M. Meinz and L.H. Wixom, pers. comms.). Their knowledge is insufficient, however, to ascertain whether the change reflects a decline in the shad population itself or a change in the distribution of the fish and the anglers in response to stream flows and temperature conditions. A decrease in angler interest in shad fishing may also be implicated.

Meinz (1981) compared his results with information contained in the California Fish and Wildlife Plan prepared in the mid-1960s (California 1965). The Plan gave estimates of 100,000 angler-days fishing for shad compared with annual estimates ranging from 35,000 to 55,000 angler-days from Meinz's (1981) data for 1976, 1977, and 1978. Meinz (1981) also compared his data with those obtained for the American and Yuba rivers from earlier years; again a substantial decline was evident.

Severe drought conditions experienced in recent years (1976, 1977, and 1987–93 were years of drought) probably affected the distribution and survival of American shad. In dry years, shad tend to concentrate and spawn in the Sacramento River, since tributary flows during the spring and early summer are relatively low and fail to attract the adults. Angler use in the tributaries declines in response to the lower shad numbers. Shad survival is adversely affected since

[19] American shad and its relatives such as other species of Alosa and Hilsa are poor negotiators of most fishways. See Collins (1951) and Talbot (1953).

water temperatures in the Sacramento River are too low (at or below 60° F) for good egg survival.

As noted by Meinz (1981), "The present bump-net fishery in the Mokelumne and Sacramento rivers appears to be but a fraction of what it was in the 1950's and 1960's." He observed that the two commercial shad smokers operating during those decades closed down for nonfishery-related reasons. This fishery has not recovered. L.H. Wixom (pers. comm.) suspects that reduced angler interest may be partly responsible for the overall reduction in the American shad sport fishery. Shad are "bony" and difficult to process for the table. Smoked shad and shad roe are not widely accepted table fare. Many angler-caught shad are returned to the water or simply discarded.

The recent decline of American shad, however, has not been as severe as that of the striped bass (Stevens et al. 1987). The spawning and early nursery periods of both species are adversely affected by reduced river flows. However, the striped bass nursery area is centered in the Estuary, which includes the Delta as well as Suisun and San Pablo bays, whereas the shad's nursery area is partly upstream in an area less impacted by environmental degradation. Also, the shad spends most of its life in the ocean under healthier environmental conditions than in the Estuary where the striped bass spends much of its life.

4.2. Threadfin shad, Dorosoma petenense (Günther)

The first member of the herring family to be introduced into California (the American shad) was brought here after a grueling journey by railroad only two years after the first transcontinental line had been completed. It was brought to the state only because it was considered to be an excellent food fish on the Atlantic coast. Its tiny relative, the threadfin shad, was brought here in less than a day by airplane, albeit with difficulty, by fishery biologists of the Department of Fish and Game under a plan to introduce a new forage fish. This was the first time that threadfin shad had been transported by aircraft. State biologist P.A. Douglas, in charge of the plane transportation, informed us that not only temperature control but vibration made the trip of about 13 hours difficult.

The threadfin shad, a species native to the southeastern United States and along the eastern coast of Mexico and Central America, was taken from the Tennessee River, Tennessee, and placed in brood ponds in San Diego County during the period 11–16 November 1953 (Kimsey 1954).[20] The Department of Fish and Game biologists mostly concerned with the introduction do not agree on its details. Kimsey (1954) stated that 314 were planted in four brood ponds. P.A. Douglas, who actually transported the fish from Tennessee to California, said that there were 243 threadfin upon arrival. R.D. Beland, who placed them in the brood ponds, said that 129 in all were planted and that only three ponds were

[20] At the time of introduction, it was known scientifically as Signalosa petenensis atchafalayae Evermann and Kendall.

used (pers. comms.). (Again, this is of no importance, but is illustrative of the differences in reporting even within relatively recent years.)

According to Kimsey (1954), the threadfin shad was selected for experimental introduction into California because of investigations by Inland Fisheries Branch biologists designed to overcome the lack of a suitable forage species in warmwater fluctuating reservoirs. This is true. Littoral areas in most California reservoirs produce little food because of their instability due to water fluctuations, and pelagic areas did not produce a food base for most game fish species. However, Kimsey (1958) also said that selection of the threadfin shad was really the result of a suggestion by R.W. Eschmeyer, of the Tennessee Valley Authority, that it might satisfy this need.

Eschmeyer, then a special consultant on warmwater fisheries for the State's Wildlife Conservation Board (WCB), visited California several times during the period 1948–50 as a member of a group of "experts" selected by S. Gordon, then consultant to the WCB.[21] Following examination of the State's program of research and management on warmwater reservoirs, Eschmeyer felt that one of the basic lacks was the presence of a pelagic forage fish which could utilize plankton. It was stated, however, that biologists of the California Division of Fish and Game had already come to this conclusion prior to investigations made by representatives of the WCB. In the definitive printed report on the subject, it was recommended that the Bureau of Fish Conservation (California) and a university study the life history of a number of species that might be potentially desirable for such a purpose (Gordon 1950).

State biologists had previously concentrated on trying to provide forage fish which utilized benthic organisms, and it was probably the urging of Eschmeyer which finally prompted the change. A.C. Taft, then in charge of inland fisheries work for the State, was devoted primarily to work with streams and salmonoid fishes, and, in general, opposed the introduction of new species. His influence on the biologists under his direction was very strong, and prompted some rather heated discussions with the "outsider," Eschmeyer. (The senior author knew them both and respected their varying attitudes.) Eschmeyer felt almost from the beginning that a planktivorous forage fish was needed in California's warmwater reservoirs. His initial choice was the gizzard shad (Dorosoma cepedianum) , but he first mentioned this only in private conversations, believing that it would spread into the Sacramento-San Joaquin Delta where it might compete with other fishes (pers. comm. to W.A.D. and others). Kimsey (1958) explained the need for a planktivorous fish in California impoundments.

R.D. Beland recalled that A.C. Taft finally gave rather "grudging approval" to the planting of a pelagic forage fish in Lake Havasu, a major impoundment on

[21] The WCB was established in 1947 by the Legislature of the State of California to provide for a fish and wildlife recreational program and the acquisition of lands and facilities for the propagation and conservation of wildlife.

the Colorado River (pers. comm.). One judges that this was in February 1951 (monthly report to the Bureau of Fish Conservation by Supervising Fisheries Biologist, L. Shapovalov, 5 March 1951).

According to Beland (pers. comm.), who at that time was rather isolated as a Division of Fish and Game biologist in Blythe, he knew nothing of the recommendations of the WCB, but in 1952 he learned through correspondence about the threadfin shad and in 1953 recommended to Department of Fish and Game headquarters that it be introduced into the Colorado River.

In October 1954, a review of the threadfin shad's characteristics and potential as a forage fish was published by Parsons and Kimsey (1954) who did not mention any suggestion by Beland. (Neither Parsons nor Kimsey can be contacted to discuss this point.) At that time, the threadfin shad in California were still being held in the brood ponds where, according to a Department of Fish and Game press release of 19 May 1954, they had bred in the spring.

Details concerning the first planting of threadfin shad in open or public waters of California vary with the source and provide an excellent example of the variations in reports concerning numbers of fish stocked, and the initial places and dates of planting of an introduced species.

Moyle (1976a, 1976b) is incorrect in saying that the threadfin was first introduced into California in 1953. It is true that it was brought to the state in 1953, but it was not introduced into open or public waters until the next year. The first planting of the threadfin shad in open waters of California was slated to be in San Vicente Reservoir, San Diego County, in June 1954; its experimental planting as forage for black bass (Micropterus) having been authorized by the Fish and Game Commission (minutes of the Commission, 21 May 1953). The Department of Fish and Game Report for 1952–54, p. 33, stated, "The first experimental planting [of threadfin shad] from this spawning [spring of 1954] was made in San Vicente Reservoir, San Diego County, in June 1954."[22] This is corroborated by the Department of Fish and Game Report for 1954–56, p. 40, which said, "... the threadfin shad ... was introduced into San Vicente Reservoir ... in June 1954," and "Two introductions of this fish were made into Lake Havasu on the Colorado River, one in December 1954 and another in March 1955.... Puddingstone Reservoir, Los Angeles County, was stocked with shad in March 1955" (*Ibid.*, p. 41). Without providing specific dates for such plants, Beland and Kimsey (1956) said in a popular report that San Vicente Reservoir received 3200 shad in 1954, Lake Havasu 1150 in 1954, and Puddingstone Reservoir 150 in 1955. They also described the use of threadfin as a forage fish, described its transport to California, its holding in brood ponds, and reproduction in the brood ponds (12 May 1954). They also reported on the first indication of successful reproduction outside the

[22] On the other hand, this same report (p. 85) said that 877 threadfin shad were among the "Fish Rescued and Transplanted" during the period of 1 July 1953 to 30 June 1954!

brood ponds (24 May 1955) in San Vicente Reservoir, and the firm establishment of the species in San Vicente, Havasu, and Puddingstone by the late summer of 1955.

On the other hand, a report of the Inland Fisheries Branch (signed by A. Calhoun, Chief of the Branch) to the Director of the Department of Fish and Game for November 1954, p. 2, said, "... 900 threadfin shad, a forage fish for black bass, were introduced into San Vicente Reservoir, San Diego County, and 520 placed in Lake Havasu, Colorado River, San Bernardino County. These threadfin shad are offspring from the 227 adults secured from the State of Tennessee. The adults were stocked in four ponds in San Diego County." Another report from the Inland Fisheries Branch to the Director stated, "An additional plant of 2,000 threadfin shad was made in San Vicente Reservoir, San Diego County, in an attempt to establish this valuable foragefish. This makes a total of about 3,000 shad that has been stocked in this water to date" (report for the month of February 1955, dated 11 March 1955). In another report from the Inland Fisheries Branch, it is stated, "... some 2,700 shad [were] stocked there in the fall of 1954" (report for May 1955, dated 13 June 1955).

Differences in such statistics exist in various unpublished reports within the Department of Fish and Game, and Beland, one of the few living persons having anything to do with the initial stocking of this species in California, positively claimed that the first plant of threadfin shad in public waters of California was made by him in Lake Havasu, and that despite his coauthorship with Kimsey (in 1956), San Vicente Reservoir received its threadfin through migration from the Colorado River. Variation in reports are so great that they will not be further repeated here in detail.[23]

It really does not make a great deal of difference now. We do know that the planting of the threadfin shad was part of the tri-state program on the Colorado River whereby Arizona, California, and Nevada agreed in 1953 to introduce the threadfin shad in an effort to improve a poor forage situation, and that this was one of the first plants of this species in the Colorado River or in California (Kimsey et al. 1957)[24]

[23] Variations on the theme will be found in unpublished accounts of the Department of Fish and Game such as Inland Fisheries Branch monthly reports for November 1954, February 1955, and May 1955, and in published reports by Kimsey (1955), Kimsey et al. (1957), Kimsey (1958), and Miller (1967a, p. 3).

[24] These authors said that 520 threadfin shad about 2 inches in length were planted in Lake Havasu on 16 December 1954 and another 500 were planted at the same place (Havasu Boat Landing) on 3 March 1955. They also said that these were the only fish planted in the Colorado River by the California Department of Fish and Game. Kimsey (1958) appeared to agree generally by saying that 1020 fish-of-the-year varying from 1.2 to 3.4 inches fork length were planted in Lake Havasu in November 1954 and March 1955, and the monthly report by the Inland Fisheries Branch for September 1955 also indicated that over 1020 threadfin shad were released in Lake Havasu in November 1954 and March 1955.

La Rivers (1962) did report that the threadfin shad was first planted in the Colorado River drainage by Nevada in 1953, but this is an error according to W.A. Molini and J.W. Curran of the Nevada Division of Wildlife (letter of 21 October 1992 to the authors). They have furnished proof that the first Nevada plant of this species was on 10 December 1954 in Lake Mead with fish from the Tennessee River below Pickwick Dam. At later dates (26 July and 19 and 20 October 1955), Nevada made additional plants of threadfin shad in the lower Colorado drainage (Lake Mead and Lake Mojave) using stock obtained from California.

We also know that in September 1955, Arizona biologists reported threadfin shad in large numbers in settling basins and irrigation canals east of Yuma. Threadfin were also reported in other waters coming from the Colorado River and had spread as far as the Salton Sea. On 27 and 28 September 1955, a small cove in Lake Havasu was treated with rotenone by R.D. Beland, and an estimated 300,000 to 500,000 threadfin shad per acre were killed. In 1992, Beland still waxed exuberant over the amazing numbers of threadfin he saw at Havasu (pers. comm.). By the end of 1955, threadfin had appeared in every habitable part of the Colorado River from Davis Dam to the Mexican border, and their first young were collected on 14 May 1956.

Several knowledgeable writers infer or even say that the Lake Havasu planting was the first in California. Some do not say exactly where the first plant of this species in California was made. See, for example, Kimsey et al. (1957), Kimsey (1958), and von Geldern and Mitchell (1975, p. 437). Confusion as to whether San Vicente or Lake Havasu was stocked first with this species probably occurs because: some of the authors, such as Kimsey, were discussing threadfin shad planting in the Colorado River rather than its initial planting in California; of faulty memories; of generalized talk; many of the original records of introduction were never actually made; or the original planting records were destroyed or lost.[25]

We sum it up by saying that about 1000 threadfin shad, originally from Tennessee, were stocked late in 1954 by the State of California in the Colorado River (Lake Havasu), and (unless we accept Beland's statement) that they were probably first planted in San Vicente in June 1954.

Following its initial introductions and its proved success as a forage fish, the State planted the threadfin shad in many waters throughout California. A table by Burns (1966) showed that by 1964 it was present in more than 40 waters from Trinity County on the north to California's southern border. It is now present in many more waters. Not only is it well established in brackish Delta waters, but it

[25] Some of the State fishery biologists, unlike most of the fish culturists, failed to fill out planting records.

has spread to and been taken from ocean waters from Yaquina Bay, Oregon (Krygier et al. 1973), to Long Beach, California (Thomas 1962).

Although Kimsey (1958) had predicted heavy mortality during the winter months, and this was corroborated in the Delta by Turner (1966c), spawning of threadfin shad at water temperatures as low as 14.4° C has been recorded by Rawstron (1964), and survival of adults at 1.1° C (Burns 1966).[26]

In 1964, threadfin shad in El Capitan Reservoir, San Diego County, were found to be heavily infested with a digenetic trematode (Clinostomum marginatum) which also affects other fish (Miller 1967b).

In the Sacramento-San Joaquin Delta, threadfin furnish food for striped bass and other piscivorous fishes. The species has also proved to be an admirable forage fish for warmwater fish such as black bass and coldwater fish such as rainbow trout in fluctuating reservoirs. See Ruch (1964) on Shasta Lake. In fact, artificial flies and lures have been created to imitate it. There is some evidence, however, (see especially Fast et al. 1982) that in some cases threadfin shad may compete for food with young centrarchids, and von Geldern and Mitchell (1975) have shown that a combination of threadfin shad and largemouth bass is not always an outright blessing. Threadfin shad have also obliterated some attractive kokanee fishing in some lowland reservoirs according to C.E. von Geldern, Jr. (pers. comm.).

The overall advantage of the introduction still seems to outweigh its possible faults in the minds of California fishery biologists, and the advent of the threadfin shad has revolutionized fishing in many California reservoirs.

4.3. Goldfish, Carassius auratus (Linnaeus)

Just when this popular coldwater aquarium fish became a resident of open or public waters in California has not been determined.

We do know that Gill (1863) reported on two aberrant specimens of goldfish in a collection of fishes sent to the Smithsonian Institution from California in 1862. This collection was made "during the past two years" by a representative of the Pacific Mail Steamship Company which was very active in transport between the eastern coast and California before the advent of the transcontinental railroad. Unfortunately, Gill did not say whether or not these were "wild" goldfish. However, all the other fishes in the "collection" were "wild," so it may be that these goldfish were also from open waters. If so, then these are the first fish recorded as being introduced into the state.

Courtenay et al. (1986), citing Courtenay and Hensley (1980), stated that the goldfish was the first exotic fish to be introduced into North America, and that

[26] During truck transport from the Tennessee River to Nevada in 1954, great discomfort of threadfin shad occurred at 6.6 C, and complete loss at 1.6 C (Job Completion Report, 18 November 1956, State of Nevada Federal Aid to Fish Restoration Project, F-5-D-2).

DeKay (1842) recorded its first releases as being in the late 1600s. A native of Eastern Europe and Asia, it is believed by some that the goldfish was exported first to Japan, then to Europe, and finally to the United States. Opinions as to the duration of its stay in the United States vary, but it is certain that it has been here for a long time and has been collected in the wild in almost every state.

Quast (1929) said that "The goldfish industry [in the U.S.A.] may be said to have had its inception in 1878, when Rear Admiral Daniel Amen, United States Navy, presented to the United States Fish Commission ... a lot of goldfish that had been brought from Japan." During the last century, the U.S. Fish Commission distributed goldfish to private individuals within California, but it is believed that it discontinued this practice in 1893 (U.S. Fish Commission Report for 1894, p. 20). The earliest record of its Federal distribution to an applicant in California appears to have been in 1882–84 when 12 goldfish were sent here (U.S. Fish Commission Report for 1883, p. 1082). There is no proof that any of these fish were ever planted in wild waters, nor is there any certainty that they were not planted nor had not escaped into them before that time. For example, Poppe (1880) said that a pond on his Sonoma Valley ranch was devoted to raising goldfish, and Jordan and Evermann (1905, p. 528) said that as early as 1867 goldfish were being shipped to California from the Hawaiian Islands. Goldfish are still imported annually into California in large numbers. Some are used as aquarium fishes, but most are sold as "feeder fish" for other species of aquarium fishes.

Undoubtedly, the goldfish has been introduced into the waters of California many times, and continues to be introduced, either accidentally or purposefully, by private individuals. Hence, it is difficult to estimate the spread caused by its own migration and reproduction. Some have escaped from private waters. Others have been "stocked" by live-bait fishermen. Natural waters, canals, and reservoirs have formed a repository for the cast-off pets of aquarists. There have also been purposeful introductions by well-meaning but ill-informed individuals who wished to increase the food supply of game fishes.

Goldfish are now quite numerous in the Central Valley where they interbreed with common carp. They are known from many other waters throughout the state, principally in lakes and reservoirs and have been taken by anglers. Even lakes over a mile high such as Shaver (5370 ft) and Big Bear (6650 ft) have contained them.

In wild waters, the species often "reverts" back to a grey or greenish color. However, the vivid cultivated coloration is retained in some lakes. Here, large fan-tails, albinos, and pintos are sometimes abundant and impart a colorful aspect to the scene. Fish fanciers sometimes seine these waters for specimens.

Man makes use of wild goldfish in several other ways. They are used as bait but only in restricted areas of the state. In the past they have also been used as forage fish in rearing ponds at State warmwater hatcheries (Snyder 1934b). Along with carp and large native cyprinids, goldfish continue to be taken with seines by commercial fishermen. Most are sold alive to Asian-Americans, but formerly they were used as fertilizer, chicken food, or even buried. They have been cited as possible mosquito control agents (Coykendall 1980).

Overpopulation by goldfish has also been deleterious to game fish populations in California lakes, and the species has been eliminated by chemical treatment. The first instance of this was in 1940 (Vestal 1942).[27] Along with the short-fin molly and the mosquitofish, the goldfish has been implicated in the replacement of two native Nevada cyprinodontids (Schoenherr 1981).

The introduction of goldfish into California waters has not been regarded as a beneficial measure, but the species will undoubtedly continue to be reintroduced by private sources.

4.4. Red shiner, Cyprinella lutrensis (Baird & Girard)

Occurrence in California of the red shiner (formerly the plains red shiner and formerly in the genus Notropis) , native to central and southern United States, has been documented by Hubbs (1954).[28] He believed that it became a resident of the lower Colorado River through escapements from Arizona Fish Farms, Inc., at Ehrenburg, Arizona (across the river from Blythe, California), or through escaped or dumped bait. Miller (1952) reported that this minnow was raised there as forage for channel catfish and for sale as bait, and also reported that the stock at this fish farm had come from the vicinity of Lake Buchanan in Texas. (This is a reservoir on the Colorado River in the Gulf of Mexico drainage.)

First found in the main River in Baja California Norte and in Arizona 2 miles north of San Luis, Sonora, in January 1953, it was later found in one of the pools of a settling basin of the Coachella Valley Water District, Riverside County, on 3 December 1953. Reports indicated that it may have been in the River since about 1948. Hubbs (1954) provisionally identified the introduced stock as intergrades

[27] This was one of the first uses in California of a fish management technique to eliminate unwanted fish species — "chemical treatment." The first treatments (1934 in the United States and 1940 in California) involved only the use of derris, timbo, or cubé root powder — all of which contain rotenone. Rotenone is an organic compound, $C_{23}H_{22}O_6$, found in the roots of various South American legumes. Modern methods of chemical treatment often continue to use rotenone, but may include various additives or even substitute other substances, and the treatment and fish kill may be followed by detoxification.

Although useful, chemical treatment sometimes reminds one of trying to stamp out brush fires. Hume Lake in Fresno County was treated in 1940 to eliminate hitch (Lavinia exilicauda), again in 1947 to eliminate bullheads, and again in 1954 to eliminate green sunfish and golden shiners. Furthermore, the treatment of large bodies of water is, today, extremely expensive. See, for example, the section on white bass.

[28] Snyder (1934b) spoke of "red shiners," but undoubtedly meant golden shiners.

between Notropis lutrensis lutrensis and *N.l. suavis*. He felt that the red shiner might be of considerable importance as an essentially nonpredatory forage fish in the lower Colorado, particularly since the native fish fauna had become largely replaced by introduced game fish.

The red shiner was introduced into northern California as a forage fish in 1954, according to Shapovalov et al. (1959) and Leitritz (1970). The first reference stated, "A brood stock of 368 adults was brought to Central Valleys Hatchery at Elk Grove, Sacramento County, in April, 1954. Some of these reproduced successfully, and 600 were stocked in two private ponds near Lower Lake, Lake County, in 1957." Leitritz (1970) said that although they reproduced at the hatchery in small numbers, their propagation was given up after several seasons of trial. The statement by Kimsey and Fisk (1964) that the red shiner was brought north in 1953 as a bait minnow was erroneous on both counts.

Kimsey (1955) described the potential of four newly introduced forage fishes in the management of warmwater reservoirs: the red shiner, golden shiner, fathead minnow, and threadfin shad. Whereas the threadfin shad fulfilled this expectation, the cyprinids did not, but instead became major players in the bait minnow industry in California. He also said that the red shiner was brought into California from Arizona in the spring of 1954, but provided no reference, and his statement did not agree with that of Hubbs (1954).

We have no information on the fate of red shiners stocked in the Lake County ponds or any that might have been released in the open waters of the state. However, perhaps via the bait bucket, the red shiner eventually gained a strong foothold in California. It became common in drains and natural tributaries to the Salton Sea and even in some shoreline pools of the Sea (Black 1980; Lau and Boehm 1991). Swift et al. (1993) gave detailed locality records for its presence in the Los Angeles Basin. Wang (1986) reported it as resident and spawning in Millerton Lake (Fresno/Madera counties). Jennings and Saiki (1990) showed that the red shiner was well distributed in the San Joaquin Valley and also recorded its presence in waters of the Los Angeles basin. It is currently being collected at the John E. Skinner Delta Fish Protective Facility (State biologist S. Barrow, 30 January 1995 pers. comm.).

The red shiner has never enjoyed the popularity as a bait fish that the golden shiner and fathead minnow have. Its small size may be one reason. In the Department's 31 December 1995 list of registered aquaculturists, only 3 out of 222 aquaculturists (1%) were authorized to rear red shiners, compared with 39 (18%) who rear golden shiners and 37 (17%) who rear fathead minnows.

The Department initially supported the use of these three cyprinids for incorporation into the bait-fishing industry during the mid-1950s. Commission authorization occurred in 1955. As pointed out by Fisk and von Geldern (1983), these species proved acceptable to bait dealers as a substitute for native minnows such as the tui chub (Gila bicolor) and hitch. The native minnows, via the bait bucket, were finding their way into certain coldwater and warmwater lakes and reservoirs where, because they attained a relatively large size, did not provide suitable forage for game fishes. This proved to be no solution, as the establishment of golden shiners in coldwater lakes and reservoirs has seriously depressed trout production, and the red shiner and fathead minnow pose serious threats to native nongame fishes in lowland streams.

In fact, next to the mosquitofish, the red shiner has proved to be the greatest threat among fish to the welfare of the indigenous fishes of the southwestern United States. It is highly adaptable to a wide variety of environmental conditions and very aggressive in its relations with endemic fishes (Douglas et al. 1994). There is an abundant literature describing the depletion of endemic fishes by the red shiner, particularly in Arizona (see, for example, Minckley 1973; Gleason 1982; Deacon 1988; Greger and Deacon 1988; Jennings and Saiki 1990; Douglas et al. 1994; and the references therein).

Following a recommendation in 1979 by the California Citizens' Nongame Advisory Committee that the red shiner be deleted from the State's list of allowable live-bait species, the Department of Fish and Game prepared a review of the red shiner with respect to its desirability as a bait fish in central and northern California. In presenting this review, Gleason (1982) noted that it was established in the Colorado River drainage and in drains and other waterways surrounding the Salton Sea. After a literature search and a review of the information contributed by eight other western states and 18 fishery biologists familiar with this species, she recommended that the use of red shiners as live freshwater bait fish outside the Colorado River and Salton Sea area be discontinued. Among the reasons given for this recommendation were that the species was likely to become established in locations where the native fish populations were small or reduced and where habitat was degraded, and that introduced red shiners have displaced endemic fishes in habitats similar to those in low elevation foothill and coastal streams of California.

Strong opposition from the bait fish industry defeated the Department's proposal to outlaw the rearing and use of the red shiner in California north of the Tehachapi Mountains. However, in a compromise move in 1981, the Fish and Game Commission limited its use in northern California to the Central Valley north of Highway 132 and Interstate 580.

The red shiner is a permanent member of the California fish fauna, but a species that we could do without.

4.5. Common carp, Cyprinus carpio Linnaeus[29]

Today, many people wonder just why this Asiatic species was ever introduced (via Europe) into California. But to anyone who has read the early reports of

[29] Different common and scientific names have been used for common carp introduced into California. Among them have been: blue carp, Prussian carp, German carp, silver carp, leather carp, scale carp, mirror carp, king carp, French carp, Carassius vulgaris, and Cyprinus carpio communis. Colored carp, under the name "koi," are also kept in outdoor pools from which they may escape into public waters.

either the Federal or State fish commissions, the reason is obvious. During the last century, there was a great enthusiasm for carp culture throughout the United States. In California, carp were expected to "... be a very excellent substitute for the worthless and unpalatable fish of the warm waters of the great valleys in the interior of the state" (California Fish Commission Report for 1876–77, p. 24).

California has, in fact, the somewhat dubious honor of being the first state to apply to the Federal government for a shipment of carp, in September 1877, only four months after the U.S. Fish Commission had imported it from Germany. Yet, despite its haste, a private individual had already brought the first carp into the state. These fish, five in number (some accounts say eight), were imported from Holstein, Germany, in 1872 by J.A. Poppe to his ponds on Pulpili Rancho in the Sonoma Valley.[30] He sold their young to many people in California and adjacent areas who wished to propagate them for food (see especially Poppe 1880 and Cole 1905). Evidently, a great many of our carp are descendants of these first fish which Goode and Gill (1903, p. 417) claimed were "... an inferior form of scale carp."

In 1877, the State received 88 carp from Japan in exchange for trout eggs. These were held in an aquarium in Woodward's Gardens, an amusement park in San Francisco, and very possibly were never planted (California Fish Commission Report for 1876–77, p. 24; *Ibid.* 1893–94, p. 74; *Ibid.* 1903–04, p. 40), although Moyle (1976b, p. 207) said that the Commission cultured them.

California's first shipment from the U.S. Commission was received in 1879; its reception was personally supervised by Fish Commissioner B.B. Redding. Other shipments followed (U.S. Fish Commission Report for 1880, p. XLI; *Ibid.* 1882, p. XXIII, 943; California Fish Commission Report for 1880, p. 10–11). Bryant (1921a, p. 84) listed R.H. Buckingham, a market fisherman and hotel

[30] It is possible that these were the first carp to be brought into the United States; the subject is debatable. Some authors support Poppe's introduction as the first, several list the introduction by the U.S. Fish Commission (1877) as the first, and another group (notably recent authors) feel that the carp was first brought into New York State in 1831 or 1832 from France or the Netherlands. See the authors listed in this section as well as Redding (1884), McCrimmon (1968), and Courtenay et al. (1986). It is not suggested that one believe Bowen (1970, p. 73), who stated that Poppe introduced the carp into California in 1832—probably a typographical error for 1872. Similarly, the statement in Davis (1963) that carp were first introduced into California in 1812 is also probably a misprint. The statement that carp were introduced into California by S.F. Baird of the U.S. Fish Commission in 1875 is also erroneous (California Fish Commission Report for 1905–06. p, 60).

man of Broderick and a California Fish Commissioner, as one who introduced carp during his 1885–86 term in office. In view of the foregoing account, he probably merely sponsored its importation.

For several years, carp continued to be imported from the eastern United States. Some went to private applicants; others into public waters. The California Commission also purchased and planted them from private ponds within the state. As one report stated: "We do not know any fish so desirable for wide distribution throughout the State as this carp.... We can hardly do a more useful work than in the breeding of these fish, and stocking all our interior streams, lakes and sloughs with carp" (California Fish Commission Report for 1878–79, p. 15). With respect to the United States as a whole, during this period of carp acclimatization, Cole (1905) wrote: "Here seemed to be an opportunity to have a perpetual supply of fresh fish for anyone who had land with any kind of a mud hole on it that would hold a few bucketfuls of water. Accordingly, applications for Carp piled in...."

Quotations from Pasco (1882) will illustrate how unsophisticated some of the western settlers were and avid to get carp. In a letter sent to the U.S. Fish Commission from Nevada, he importuned, "Now if possible do not neglect us. We are all Uncle Sam's boys, and will appreciate the fish.... Last year I persuaded the man above me on my stream not to go to Reese River after trout, because I hoped sooner or later to get carp, and I did not want trout planted in the stream to eat the young, I repeat, stock us at once if possible."

The United States ceased distribution of carp in 1896, and such frenzy over an introduced fish did not occur again until this century when tilapia became the new "miracle fish."

It is impossible to provide any estimate of the number of carp stocked in wild waters of California during the early years. The total number planted was probably not great; the fish's natural fecundity and adaptability was. By 1884, the supply of carp was considered to be enormous. Many articles appeared condemning the fish, and blaming it for roiling the water, eating other fish and their spawn, destroying levees by burrowing, and uprooting and eating aquatic plants. It was blamed for the diminishment in numbers of the native Sacramento perch (Archoplites interruptus) and of wild ducks. It was considered unpalatable. Other articles minimized its deleterious activities, praised it as a food fish, and cited it as furnishing food for striped bass, black basses, and shad. See Smith (1896) for some spirited quotations anent this controversy. The biennial reports of the California Fish Commission published after this date also contain discussions of the value of carp.

In their early reports, the California Fish Commissioners usually awarded much credit to themselves for their acclimatization of alien fishes. It is of interest, therefore, to note that in later years they often minimized their role in the introduction of carp. For example, their Report for 1903–04, p. 40, transferred the blame of its introduction to U.S. Fish Commissioner S.F. Baird. This same report contained the erroneous statements that the first carp to enter the state was imported in 1875, and that "... the only carp we have are those which were introduced from Europe by the U.S. Fish Commissioner." In an earlier Report (1897–98, p. 34) we find the somewhat plaintive remark, "In discussing the subject of introducing foreign fish, the carp question seems to be more generally misunderstood and commented upon than the great value resulting from the introduction of the striped bass and shad."

The degree to which any of the old arguments, either for or against the carp, holds true has still not been fully evaluated in California. For example, there seems to be no direct proof that the decline of the Sacramento perch is more than coincidental with the rise of the carp (see Smith 1896). Small carp undoubtedly have some value as forage fish for game fishes, but the extent of this value is not well proved in this state. They apparently do not form a part of the striped bass diet (Hatton 1940b). Several studies have cited carp as being good forage for the black basses, but no detailed studies of the black bass-carp relationship have been made in California.

So widespread are these fish today in California, that it is useless to attempt to describe their distribution in any detail. Their absence from any warmwater stream, lake, or reservoir is unusual. They are not known, however, from many coldwater streams and lakes, especially those of the high Sierra.

Not normally classed as game fish, there are no closed seasons or limits on their take. They do, however, provide some sport fishing, and some anglers consider them a difficult, hence desirable, fish to take. In fact, the first Trophy Award Program of the California Fish and Game Commission classed carp of 15 lb or over a trophy warmwater fish (Harrell 1969). Carp have many sport fishing devotees in Europe, and as long ago as 1653 Isaak Walton called the introduced carp the "queen" of England's waters as a sport fish. In California, they are also speared and shot with bow and arrow, simply for pleasure.

From the very first, carp have been of some commercial importance, but have always comprised a minor fishery. Commercial netting and trapping have been carried on at widely separated points throughout the state. Seines, gill nets, fyke nets, and fence traps or weirs were the common gear. Only seines and traps are used today. Carp have been of limited importance as fresh fish and for fish meal, dog food, fertilizer, and oil. (See Croker 1937) and Davis 1963 on their value and commercial utilization.) Ranchers have sometimes captured them to use as chicken feed. They have also been cited as mosquito control agents (Coykendall 1980). Small carp are frequently used as bait fish, and this has led to their introduction into trout waters. Such practices are illegal in California except in the Delta and the Colorado River area.

Unlike the majority of our alien fishes, their eradication or control, rather than their promotion, has been attempted in many waters. Perhaps the first attempt to control them was in 1891 when 19 sea lions, probably Zalophus californianus, were placed in Lake Merced, San Francisco County, by the owners of the Spring Valley Water Company. Seining had failed to reduce the number of carp satisfactorily, and they had roiled the water which was used for drinking. Evidently, the sea lions killed many carp, but the Company had to employ men to pick up pieces of dead fish which littered the lake. In 1895, seines failed to catch any carp and the sea lions had grown thin (Smith 1896). This account is supplemented by a letter saying that sea gulls aided in picking up the bits of dead carp, and when carp became scarce the sea lions returned to the ocean (letter of F.S. Maskey, Secretary of the Spring Valley Company, Ltd., to the University of Washington, 18 March 1942).

Another allusion to the account of attempting to control carp by sea lions is that of a suggestion that the introduction of sea lions into Clear and Blue lakes, Lake County, might bring about the same result. It was thought, however, that the swamp and tule land surrounding these lakes would harbor the carp and furnish them with areas that the sea lions would not reach (California Fish Commission Report for 1897–98, p. 33).

There are a number of other stories that sea lions were also planted in reservoirs of the Spring Valley Water Company in San Mateo County. According to one of these stories, a sea lion left the lakes and attempted to reach the Pacific Ocean overland, being intercepted several miles away "... heading right for the Ocean." It was also claimed that harbor seals, probably Phoca vitulina, were also introduced. (The senior author heard these stories in about 1926 from several residents of San Mateo County; the accounts may be fictitious.) In 1916, this method was tried again to eliminate carp at Guadalupe Lake in Santa Barbara County. However, the sea lions soon disappeared, and the results of their stay do not seem to have been published (CFG 1916a).

In 1897 or 1898, the California Fish Commissioners endeavored to obtain a shipment of pike perch (Stizostedion) in order to control carp (California Fish Commission Report for 1897–98, p. 33).

The old State Fish Rescue Bureau considered "carp eradication of the utmost importance" and tried to eliminate them from all waters where it operated (CFG 1931b). Incidentally, it considered the native sucker (Catostomus) to be in the same class as carp. At that time, this Bureau, like most groups within the State's Division/Department of Fish and Game, considered that the use of fish for food or sport was the major thrust of the State's agency for fisheries.

In recent years, more prosaic methods such as netting, trapping, and dynamiting have been used, as well as the use of chemical agents. For example, chemical treatment of Lake Hodges, San Diego County, circa 1954, removed over 100 tons of carp. Hodges was the first public water supply lake in California to be chemically treated (Hoffman and Payette 1956).

The common carp is now found in almost every state of the Union. It hybridizes with several other cyprinids such as the goldfish, and at least three types may occur in California waters: "scale," "mirror," and "leather."

Although introduced as a food fish, it was not understood by the importers that in Europe it is primarily a cultivated fish requiring a considerable skill to rear. It is also a commercially caught fish there and has some value as a sport fish. Nevertheless, the common carp is declining in value and use even in Europe in favor of more predaceous fish and the introduced Chinese carps. There is a large amount of literature on its use in Europe, Israel, and other areas (see, for example, Dill and Ben-Tuvia 1988 and Dill 1990). However, in California, as in most of the United States, the carp has been labeled an unfortunate introduction. It is considered to be annoying in many waters, and there will probably always be a carp controversy. As Thompson (1970) has said: "There is no evidence that a carp supporter ever convinced an unbeliever."

4.6. Golden shiner, Notemigonus crysoleucas (Mitchill)

The golden shiner, native to the eastern United States, is widely distributed throughout California, but for many years after its introduction it had a very limited distribution in the state.

In 1891, the U.S. Fish Commission planted several species of game fish from Illinois in Lake Cuyamaca, San Diego County, and in the Feather River near Gridley. (These plants are discussed elsewhere in this paper.) Although the list of fishes planted in 1891, as given in the U.S. Fish Commission Report for 1892, did not include golden shiners, the Report of the California Fish Commission for 1895–96, p. 29, stated that they were planted in 1891 and implied that they were planted at both localities. Both the common and scientific names were used in the Report. Possibly they were brought out to feed the game fishes on their railway journey west, or as forage for the planted fish.[31]

In 1896, the California Fish Commission removed 253 adult golden shiners from Lake Cuyamaca and distributed them in southern California, the Central Valley, and Clear Lake. A complete list of the plants was given in the California Fish Commission Report for 1895–96 on p. 73. Aside from plants in the areas mentioned above, two shiners were planted in Stow Lake in San Francisco and six were taken to a pond at Sisson (Mount Shasta) Hatchery. Later records show that 2000 more were distributed in California in 1898 and either 200 or 750 in 1905. (See California Fish Commission Report for 1897–98, table preceding p. 49; *Ibid.* 1905–06, p. 22; Shebley 1922.) Neither the source of these fish nor the

[31] In 1873, for example, Livingston Stone's aquarium car en route from the eastern United States contained "Supplies of minnows for feed fish" (California Fish Commission Report for 1872–73, p. 7). This particular shipment never reached California as the train was wrecked at the Elkhorn River in Nebraska, but its cargo may have been typical of that used by fish acclimatizers of the day.

planting localities have been determined. However, from the 1896 distribution alone, it is apparent that the range of golden shiners in California might be fairly extensive.

Hubbs (1919) stated that golden shiners were "generally abundant" in pools of the San Diego River through Mission Valley. He (Hubbs 1921) again mentioned that they were found in the San Diego River. Cuyamaca Lake, where the golden shiner was said to have been originally stocked, is on Boulder Creek, a tributary of the San Diego River.

Plants of this species from San Diego waters, especially Lake Cuyamaca and the San Diego River, were made in San Diego County lakes during the 1930–33 period, as well as one of 200 in Lake Chatsworth in Los Angeles County in 1932 from Lake Cuyamaca (notes of State game warden E.H. Glidden).

Circa 1940, L. Shapovalov affirmed that they were present in Lake Cuyamaca, Lake Hodges, and the Santa Margarita River. He also stated that D.A. Clanton of the Division of Fish and Game said "shiner minnows" (which Clanton believed to be golden shiners) were present in Big Bear Lake, San Bernardino County, in September 1933 but appeared to be gone by about 1940 (pers. comm.). As far as we know, these were the only records of golden shiners in the state up to 1940.

In that year, State biologist J.H. Wales sent two cyprinid specimens from Castle Lake, Siskiyou County, to G.I. Murphy (1940) who identified them as the western golden shiner or Notemigonus crysoleucas auratus (Mitchill). The identification was verified by C.L. Hubbs who assigned the subspecific name. In speculating on their presence in the lake (a glacial cirque trout lake at 5200 ft elevation), Murphy stated that these fish "... were used for a time in the Elk Grove Hatchery but were abandoned in favor of native minnows." He also implied that they were still present at Elk Grove, although very scarce.

It is true that golden shiners were taken from San Diego County to the State's former Friant Bass Hatchery, Fresno County, during the early 1930s (CFG 1932d; Snyder 1934; notes of E.H. Glidden).[32] However, C.H. Freyschlag, foreman of Central Valleys Hatchery (letter of 25 May 1941 to W.A.D.), said that all of the shiners died shortly after their arrival at Friant and that none were ever taken to Elk Grove.[33] Murphy received his information about the shiners at Elk Grove from M. W. Brown, original foreman of both hatcheries, who probably inadvertently reversed the two localities (pers. comm. from G.I. Murphy).

We believe—and both Wales and Murphy agree—that the shiners in Castle Lake originated from a plant made years ago from Sisson Hatchery which is only a few miles away (see Wales 1946). The small population of golden shiners in

[32] Snyder (1934b) spoke of "red shiners," but undoubtedly meant golden shiners.

[33] Golden shiners were, however, propagated at Central Valleys Hatchery starting in 1951 (Leitritz 1970).

Castle Lake was eradicated when, in the course of experimental work, the Lake was chemically treated in October 1946.

The presence of "shiners" or "bream" (both common names for Notemigonus) at Sisson Hatchery is noted in several of the California Fish Commission's Reports: 1897–98, p. 38; *Ibid.* 1901–02, p. 19; *Ibid.* 1903–04, p. 20; *Ibid.* 1905–06, p. 21–22. The report for 1897–98 stated that "pond shiners" were being propagated for fish food. Apparently, these "shiners" were still on hand at Sisson until at least as late as 1906, and it is probable that they were Notemigonus crysoleucas.

Since about 1950, there has been a tremendous increase in the number of areas in the state where the golden shiner has been reported. We believe that most of the spread has been caused by anglers using the shiner as live bait, but it has also been introduced deliberately as a forage fish (Wohlschlag and Woodhull 1953), even by the State. For example, at Clear Lake, steps were taken to provide forage for largemouth bass (California Fish and Game Commission Report for 1948–50, p. 81, 98–99), and golden shiners were introduced there in 1950 (McCammon et al. 1964). Kimsey (1955) also indicated that the golden shiner was introduced as a forage fish into northern California from San Diego County.

Although the golden shiner may have added to the forage fish supply, it almost never establishes significant wild populations in lowland impoundments and is, therefore, of little benefit to warmwater predatory fishes (Fisk and von Geldern 1983). In other instances, some excellent fishing, especially for trout, has been harmed (Fisk 1969a; Beland 1979). In fact, a review of chemical rehabilitation programs in California during the 1968–86 period showed that the golden shiner ranked as the first or second target organism (Fisk and von Geldern 1983). In most cases, the shiner may compete for food, but at large size, say 152–203 mm, may be aggressively piscivorous (Ryan 1978).

The golden shiner is the most used bait minnow in California and is raised and imported in large numbers for this purpose. The Commission approved such commercial use in 1955. (The use of wild minnows for bait in California was prohibited in 1958.) It can survive at very low oxygen and temperature levels, and has been suggested as a suitable standardized test animal in assessing the toxicity of sewage effluent. It has also been used to monitor the purity of water supply by the San Diego County Water Authority (OC 1973). Coykendall (1980) cited it as a possible mosquito control agent.

The value of the introduction of the golden shiner into California is a debatable one. It may be confused with the rudd (Scardinius erythrophthalmus) and also hybridizes with this exotic cyprinid which is a popular bait fish (Burkhead and Williams 1991). (See the section on rudd in this report.) Its economic benefit to the bait fish industry may have been outweighed by its adverse impact on trout resources (Fisk and von Geldern 1983).

4.7. Fathead minnow, Pimephales promelas Rafinesque

The fathead minnow is widely distributed in eastern and midwestern North America.

The first record of the possibility of its introduction into California dates from the time it was found in a bait tank on the Arizona side of the Colorado River on 23 March 1950. It was found and examined by C.L. Hubbs and R.R. Miller, who identified it as the southwestern fathead minnow, Pimephales promelas confertus (Girard). Hubbs thought that it was a valuable forage fish. Although used as bait along the Colorado, no specimens were known to have been taken from California waters at that time (Evans and Douglas 1950).

In 1953, a domestic fish breeder of Turlock, F. Butler, obtained a permit from the State and imported 40,000 fathead minnows. The Department of Fish and Game purchased 1000 of these for propagation at the Central Valleys Hatchery in Elk Grove, Sacramento County. The propagation was successful and the resulting fish were distributed to a number of waters to serve as forage for game fish (Shapovalov et al. 1959). Leitritz (1970) said that the State released them to commercial fish breeders as broodstock.

Kimsey (1955) had an earlier date of introduction but provided few details. He said that it was imported from New Mexico in 1951 and 1953, and that it had been introduced into Salt Springs Valley Reservoir, Calaveras County, and other waters. However, a later publication (Kimsey and Fisk 1964) provided only the 1953 date. Fisk and von Geldern (1983) also said that it was imported in 1953 but added that it came from Arizona.

In 1975, the Department of Fish and Game purchased and planted 2000 fathead minnows in Copco Lake and 2000 in Iron Gate Reservoir on the Klamath River in an attempt to create a more desirable fish population structure like that just upstream in John Boyle Reservoir, Oregon. In addition, 5000 fathead minnows were purchased from a Clear Lake minnow farm by the Copco Lake Sportsman's Club and planted in Copco Lake. Apparently, the species did not establish itself in either water as none have been seen in recent years.

The fathead minnow is raised by commercial bait dealers in the Central Valley and elsewhere. Importations into California for this purpose and for toxicity testing are made annually. Breeding populations are now established in many waters throughout the state. Swift et al. (1993) stated that it is common and established in many of the larger low-gradient streams in southern California, as well as in some of its lakes and reservoirs. It has also been reported from the Sacramento-San Joaquin Estuary (Wang and Brown 1993). As far as is known, it has not become resident in many trout waters. It is considered relatively innocuous, although Moyle (1976b) believed that it probably should be banned to safeguard native fishes. It has also been cited as a possible mosquito control agent (Coykendall 1980).

4.8. Tench, Tinca tinca (Linnaeus)

The first published record of this Eurasian species in California appeared in Dill and Shapovalov (1939) who, with respect to its introduction, merely noted that it was "Not yet an inhabitant of our natural waters, but present in ponds near Half Moon Bay [San Mateo County]...."

The next published note on the tench in California was that of Marr (1940) who stated, "The European tench has recently been collected from one of the Mud Lakes, which are in San mateo County in the eastern foothills of the Santa Cruz Mountains, about twelve miles from Stanford University. These lakes are a series (four) of enlarged sag ponds, the one in question lying on the property of W.A. Mariani ... [who] states that the original stock in his lake was 'brought from a pool near Half Moon Bay about six years ago.'"

A complete history of the origin and distribution of the tench in the state was later provided by Shapovalov (1944). According to his information, the original specimens were brought from Italy by a Mr. Graviati in 1922 and introduced illegally into a private reservoir near Half Moon Bay. Apparently, Graviati made the trip to Italy with the express purpose of securing tench for "speculative purposes," and carried them to the United States by ship. It was probably introduced because of its use as a food fish in artificial ponds in Europe. Only one to two dozen fish survived the trip and were planted in the reservoir where they reproduced freely. On 20 March 1925, five were brought from this site to the Steinhart Aquarium in San Francisco. Since the time of its introduction into California, the species has been gradually spread by ranchers from reservoir to reservoir until by 1944 it was distributed throughout large parts of Santa Cruz and San Mateo counties. Some specific areas were mentioned. Shapovalov (1944) went on to say that the tench reproduced in most of the reservoirs and commonly reached a weight of 2 to 3 lb; uncommon specimens were reported to weigh 4 to 6 lb. The usual way to catch fish in these reservoirs was by netting. Angling, using salmon eggs or worms, was reported to be difficult.

The only other published record of tench in California, based on original data, is that of Kimsey and Fisk (1964) who repeated some of Shapovalov's (1944) data and also said that tench had spread to the Trinity and Klamath rivers. They said that it was of no importance there, but might cause problems in fish management similar to those created by the common carp and goldfish if allowed to spread into new waters. Moyle (1976b) said that State biologist M. Coots, in a personal communication, stated that there seemed to be no recent records of tench from these rivers.

Although not found in these rivers, tench may exist in their drainages. In a 27 October 1976 letter to E. Bailey, State biologist D. LaFaunce described gillnetting two tench (5 to 6 inches long) from a small farm pond in the Willow Creek area (tributary to the Trinity River) in Humboldt County. The pond owner contacted the Department of Fish and Game about removal of the tench, which he termed "pest fish." He claimed that the tench were originally from Italy and were stocked by his father. This confirmed rumors heard by D. LaFaunce about tench stocked in the area in the early 1950s. The pond was chemically treated in November or December 1976; large numbers of small tench were recovered, and the kill was believed complete (State biologist D.P. Lee, pers. comm.). No further information on tench in North Coast waters has come to us.

Tench, which are extremely tenacious of life and easy to transport, are found in other parts of the United States, and have been distributed by the U.S. Fish Commission, but have not been a dominant part of its aquatic fauna (see Courtenay et al. 1986). In Italy, tench are captured as wild fish and are also raised in rice fields and as pond fish. They are by no means as common as carp, either in California or in the rest of the United States, but may be the second-most valuable native cyprinid in Europe (Dill 1990).

In California, it appears evident that although the tench is established, it is a minor part of the aquatic fauna and has a very limited distribution.

4.9. Oriental weatherfish, Misgurnus anguillicaudatus (Cantor)

The establishment in Californian waters of the oriental weatherfish, a loach native to Asia, was first recorded by St. Amant and Hoover (1969). J.A. St. Amant discovered this species in a portion of the Westminster flood control channel, Orange County, on 12 April 1968, and during a period which extended to 20 July 1968, St. Amant and F.G. Hoover collected and noted numerous others in the channel. From the large number and the size range of those present, they concluded that the species was established in California.

St. Amant and Hoover (1969) believed that the place of origin of the oriental weatherfish was a goldfish farm in Westminster. The species had been reared in an outdoor pond during the 1930s and some had escaped into the channel. They also believed that, although the loaches were no longer reared there in ponds, a few could escape from indoor tanks into the channel. Mention was also made that loaches were reportedly being used as bait fish in other waters, and that the species could be introduced into sport fishing waters.

Shapovalov et al. (1981), on the basis of a personal communication from State biologist F.G. Hoover, stated that in 1977 a thriving population of oriental weatherfish was present upstream from the original collection site, and that another population was discovered in the adjacent Bolsa Chica Channel in 1979. Courtenay et al. (1986) stated that the oriental weatherfish was also established in several flood control channels in Huntington Beach; one assumes that their textual reference to a personal communication from M.H. Horn relates to this record.

The ability of Misgurnus to survive desiccation, its temperature tolerance, and its food habits (it swallows mud, for example) make it a likely candidate for survival in California. It has no place as either a game fish or food fish, however.

4.10. Catfishes in general

In the entire history of fish introductions into California, there have been no subjects as confused as the histories of the catfishes and black basses. Confusion of both scientific and common names has clouded the picture, and there have also been some unwarrantable errors.

The history of the white catfish (Ameiurus catus) , as well as that of the three bullheads (A. melas, A. natalis, and A. nebulosus) , in California is a good example of how the relatively clear accounts of original reports have been disregarded, and a series of somewhat cumulative errors perpetuated in the literature. Moreover, it is almost impossible to separate the history of these two groups, and the history of the bullheads may be linked together more closely than has been given recognition in most accounts. Be that as it may—the subject will be discussed later—all of the early accounts of "bullheads" or "hornpouts" in California appear to refer to the brown bullhead (Ameiurus nebulosus) , and this name will be used in describing these accounts.

In 1873, in a joint venture of the Federal Government and the California Fish Commissioners, Livingston Stone attempted to bring catfish to California, but the shipment in his ill-fated aquarium car was lost in transit (Stone 1876b). Baird (1874a, p. xxix) said that the shipment held "bullheads (Amiurus atrarius) " and "catfish (Ictelurus coerulescens) . "

In 1874, Livingston Stone brought the first catfish into California at the request of the California Fish Commission. Seventy "hornpouts" from Lake Champlain, Vermont, were placed in ponds or sloughs at Suttersville, Sacramento County, and 56 or 74 large "Schuylkill catfish" from the Raritan River, New Jersey, were placed in the San Joaquin River near Stockton on 12 June 1874. At the same time, and also in the San Joaquin River, "Mississippi catfish" from the Elkhorn River, Nebraska, were planted. Stone did not give the number; the California Fish Commission said 18. It is not known what species the latter were, but apparently the "hornpouts," now believed to be brown bullheads, and the "Schuylkill catfish," now believed to be white catfish, were the only known survivors of the 1874 plant. There is a slight question as to whether these "Mississippi" fish were catfish or black bass. (See the section on black basses in general.) The preceding account is based on Stone (1875, 1876a) and the California Fish Commission Report for 1874–75, p. 5. These are the primary sources of information on the 1874 plants and, although they differ a bit in detail, should be expected to be the most authentic in print.

Later reports of the California Fish Commission, however, gave somewhat different information. The Report for 1878–79, p. 10, stated that in 1874 the California Commission "... imported from the Raritan River, and placed in lakes near Sacramento, 74 of these valuable fish [Schuylkill catfish, Amiurus albidus]."

The Report for 1880, p. 9, also stated that "... seventy-four catfish were imported from the Raritan River, in 1874...." Again, they were called "Schuylkill catfish—Amiurus albidus, " and the Report for 1885–86, p. 5, also spoke of 74 catfish imported from the Raritan River in 1874.

One would judge from these reports that only one species was involved. However, the California Fish Commission Report for 1883–84, p. 8–9, in a section headed "Catfish and bullheads (or pouts)" stated, "... catfish proper are not as plentiful as the bullhead...." and spoke of two species: the catfish having a swallow-tail and the bullhead or pout having a square tail. According to the Report, the pout seemed to take to the lakes while the catfish proper preferred the river.[34]

The numerical lumping of the 56 fish from the Raritan and the 18 "Mississippi catfish" seems evident. The California Report for 1893–94, p. 75, then listed all the 144 catfish planted in 1874, and all those distributed by the State through 1884 as one species, "Ameiurus nebulosus. " Soon we find the entirely new statement that nebulosus and/or catus were introduced into California from the Schuylkill River of Pennsylvania. Some accounts do not mention the date; others give it as 1874. (See: Goode and Gill 1903, p. 378; California Fish Commission Report for 1903–04, p. 43; *Ibid.* 1909–10, p. 39; Neale 1915; Jordan 1925, 1928; Evermann and Clark 1931; Nidever 1937.) Neale (1915) also said that other catfish were received from the Missouri River, and seemed to imply that these were planted after 1874. Certainly, the similar statements of Evermann and Clark (1931) and Nidever (1937) lead one to this belief. Jordan (1905, p. 180; 1925, p. 399) even assigned another source for these two species by saying that they were brought in from the Potomac. Jordan (1920) stated that both Ameiurus catus and A. nebulosus were introduced into the Sacramento River in 1877.[35] There are other similar statements. The selection of these particular references is simply to

[34] This Report also spoke of a small "native catfish ... seldom over four inches in length." It is probable that the Commissioners were alluding to a sculpin (family Cottidae). California placer miners used to call cottids "catfish," and W.A.D. recalls being told as a child that cottids in Butano Creek, San Mateo County, and the marine fish, the plainfin midshipman (Porichthys notatus), were "catfish." There are, of course, no true catfish (family lctaluridae) native to California, but even scientists have awarded the name "catfish" to a cottid (then Cottus minutus of the Lahontan drainage) and also called Cottus a "bullhead" (Eigenmann 1890). Eigenmann was, of course, following the British terminology in which Cottus gobio is commonly called "bullhead" in England. The most outlandish statement concerning native catfish in California known to us is that of Brown (1850, p. 293) who said that "The lakes and inland rivers, also, teem with an abundance of Catfish...."

[35] Students of Jordan (who was a great ichthyologist) said he had such an excellent memory that he rarely looked up any references; therefore, he sometimes made bad mistakes. Certainly one can place little dependence upon his information concerning fishes introduced into California.

show how widely such statements have been circulated and how both "scientists" and "laymen" have been wrong.

There is no substantiation for any of these statements, but it is easy to see how such errors could have arisen. Ameiurus catus was introduced into California under the common name "Schuylkill catfish," and both it and A. nebulosus were frequently called by this name in early reports. The former species was also called "White Cat of the Potomac," "Channel Cat of the Potomac," or simply "Potomac Cat." The erroneous assignation of their nativity to these two rivers is obvious. The source of the statement that catfish from the Missouri were introduced is less apparent. One can find this statement in the California Fish Commission Report for 1903–04, p. 43, and for 1909–10, p. 39, as well as in the articles already mentioned. These reports said "Missouri River at Omaha." The first said that these fish were planted in 1874, the second that the first plants from the Schuylkill and the Missouri gave us two varieties of catfish, both planted in the San Joaquin River near Lathrop. One surmise appears to be that all such statements were meant to apply to Livingston Stone's "Mississippi catfish" from Nebraska. Another is that someone may have confused the Missisquoi River in Vermont with the Missouri.

The ramifications of this discussion could be prolonged. But a full analysis of the literature must convince one that there are no *primary* sources of information which indicate that: i) catfish from the Schuylkill, Potomac, or Missouri were introduced into California, or ii) there were any known importations of either nebulosus or catus after 1874.[36]

Since it is almost impossible to separate the history of the bullheads in California from that of the white catfish, the remarks that follow merely mirror the statements made before information about the two groups became distinguishable. Distribution of catfish by the State began the first year after their initial planting. In fact, two years after their introduction in California, catfish obtained

[36] It may be noted that Neale evidently discovered his error of 1915 as is shown by his later (1931a) account. (See yellow bullhead.) Unfortunately, recent authors such as Swift et al. (1993, p. 139) have perpetuated Neale's 1915 error. We do not maintain that there may not have been introductions of either the brown bullhead or white catfish after 1874. Jordan and Evermann (1896, p. 140) stated mistakenly that A. nebulosus was introduced into the Sacramento and San Joaquin rivers "about 1877." (Note the use of the word "about.") There were small shipments of catfish of unknown species to private applicants in California in 1894 or 1895, 1918, 1919, and 1924, and there may have been others by the Federal Government. (See U.S. Fish Commission Reports for 1895, p. 58; 1918, p. 17; 1919, p. 15; 1924, p. 432.) It is obvious, however, that the authors cited above were not referring to these shipments. The assignation of some of these shipments is given, but there has been no opportunity to check up on their fate. It is quite possible, however, that several of the species of catfish now known to exist in California (especially Ameiurus melas and A. natalis) may have been included.

from the San Joaquin River were sent to New Zealand (Hunter 1915). Most of the transplants seem to have been of the brown bullhead. Within five years after their introduction into the State, catfish had been planted in 10 counties. Six years after their introduction, the California Fish Commission stated that there was no county in which these fish were not found (Smith 1896, p. 386), and further asserted that catfish were "... so numerous and widely distributed that probably the time has arrived when their further distribution should be left to private enterprise, and the money of the State heretofore used for this purpose be employed in importing some other equally valuable fish...." (California Fish Commission Report for 1880, p. 10). It should be noted here that the early Fish Commissioners were in no way adamant—as they became later—that only the State should transfer fish.

There were also, however, frequent criticisms of the newcomers. Some feared that they would destroy all the native fish, and their edibility was disclaimed. For a time, the California Fish Commissioners were kept busy defending their introduction. Here is a sample of an early defense: "It is our opinion that it was a timely act ... to plant them ... as our native fish were giving out.... The prejudice that existed at the time of their introduction is fast dying out, and the majority of our people claim that they are a better food-fish than the carp. Whether such be the fact is a matter of taste. The idea that they would destroy our native fish is a fallacy, as in the last two years, statistics tend to show that such is not the fact...." (California Fish Commission Report for 1893–94, p. 9).[37]

In view of the continued apathy which "our people" evidence for carp as food, it must be admitted that such rejoinders seem a bit weak. Certainly, they failed to convince everyone, as is shown by the following quotations: "They [the State Fish Commissioners] introduced the hated and almost worthless catfish to the waters of California.... It was reported, in answer to the protests made at the time, that only a superior kind of catfish would be introduced.... But they turned out to be the same old toughs.... These catfish are voracious feeders on young trout and salmon ... most consumers turn away from these fish in disgust.... If every one of these fish and here carp were included as well could be removed from the water to the land, and there employed as fertilizers, a substantial gain would be made...." (San Francisco Evening Bulletin, 29 May 1894).

This early antipathy has been softened, and few today would term catfish "hated" or recommend their extermination. They have assumed a prominent place in our waters—albeit perhaps at the expense of other fishes—and have been accorded a considerable respect as a fishery.

[37] Might one guess from this that the Fish Commissioners were among the minority of Californians who still preferred carp? Goode and Gill (1903, p. 376) said: "The Catfish is somewhat like paté de foie gras or pickled olives. Those who do not very much like it detest it."

Catfish (both bullheads and the white catfish) formed, in fact, the basis of one of our oldest commercial fisheries. By 1892, the California catch brought a better market price in Sacramento than did shad (California Fish Commission Report for 1893–94, p. 13). Good catch records were not compiled by the State until 1916, and the commercial fishery for catfish was then well past its peak (apparently around 1900). At one time there were extensive shipments of dressed catfish to the East and Middle West. While it never became a major commercial fishery, it did remain the largest one for truly fluvial fishes. The commercial catfish catch of the Delta generally ranged from 200,000 to 700,000 lb a year with catches exceeding 1 million lb in 1908 and 1929 (Altouney et al. 1966). It was centered in the Sacramento-San Joaquin Delta area and at Clear Lake, Lake County. Fyke nets and hook-and-line fishing were employed. Prior to 1909 there were no laws regulating commercial catfishing in California. Later the fishery was regulated by restrictions such as ones on the type of gear to be used, size limits, and closed seasons. Neale (1915), Croker (1934), Nidever (1937), and Warner (1949) all described the commercial fishery for catfish in California. Their conclusions on depletion differed, but the commercial fishery closed in 1941 in Clear Lake and in 1953 in the Delta.

Catfish also became a popular sport fish. With the onset and aid of the Sport Fish Restoration Program (formerly the Dingell-Johnson Program) in California, the Department of Fish and Game began an extensive program of catfish investigation—the first in the nation—lasting from 1952 to 1956. It found that in 1951 an estimated 86,000 anglers in the Delta area caught 2,355,000 catfish while 20 commercial fishermen caught only 404,000 (202,000 lb at roughly 2 fish per lb). The average annual gross income of these commercial fishermen was less than $3000 apiece. With evidence (including diminishment in length) indicating that the Delta catfish population was being overfished, and the drain by commercial fishermen believed to be large and their return small, it was recommended that the commercial catfish fishery in California be discontinued, especially in view of the policy of the Fish and Game Commission (Pelgen 1952).[38] Following this recommendation, the State Legislature enacted a law in 1953 banning commercial fishing for catfish.

As a group, the catfishes comprise a significant element of California's inland sport fisheries. Based on postal card questionnaires, Lal (1979) summarized inland angling trends for 1971 through 1974. Catfish anglers were second in numbers to trout anglers, followed by panfish, striped bass, and black bass anglers in that order. Estimated total catch of catfish ranked third behind trout and panfish,

[38] At that time its policy was: "The combined use of fishes for both food and recreation is a more important use than for food alone. Where the supply is inadequate for both commercial and sports use in inland waters, the commercial use should be restricted or eliminated. But full and proper utilization should be provided."

and ahead of black bass and striped bass. More recently, a 1988 telephone survey found catfish in fourth place behind trout, black bass, and striped bass in terms of the most popular fish sought by California inland anglers (Fletcher and King 1988).

Clark (1942) awarded catfish the highest potential economic value of any of our introduced fishes. (He included commercial fishing, which for catfish was legal at the time, in his calculations.) By the late 1960s, another introduced fish, the striped bass, had far surpassed the economic value to the state of catfish and all other introduced fishes (Altouney et al. 1966). The current statewide economic value of catfish is unknown.

Kelley (1968) felt that the catfish resource in the Delta faced no real problem despite anticipated changes in the water pattern. He also felt that "The human demand for catfish fishing is probably now limited by the small size of the catfish and by limited access to Delta levees. A large proportion of the catfish anglers are poorer people whose other recreational opportunities are limited...."

Sport fishing for catfish varies from spinning or baitcasting gear to "catfish rigs" which are often merely bamboo poles with a line tied to the tip and a bobber. Bait for catfish varies from live or dead minnows to various "stink" baits.

There is also a sizeable aquaculture industry in California today, rearing catfish for market and for stocking of live catfish in public and private waters. Most of this industry is devoted to channel catfish (Ictalurus punctatus) , and there is only a small market for bullheads.[39]

The reputed effect of catfish on native fishes has already been mentioned. It seems unquestionable that the abundance of such acknowledged predators has brought about some change in the aquatic fauna. Their specific effects are, however, somewhat questionable. They, like several other "alien" fishes, have been blamed for the destruction of the Sacramento perch. Jordan (1928) even used this presumed effect of catfish (and carp) to illustrate one of the types of extinction or elimination of a species: "The extinction which results from competition." A number of cases have been reported where other introduced fishes such as the black basses and striped bass have choked to death attempting to swallow catfish. Curtis (1942) stated that in some high mountain waters they have "... become so numerous that they inhibit the trout populations through competition and sheer force of numbers," and among the introduced fishes he ranked catfish next to carp as having the most effect biologically on other fishes. In a number of cases, the State has eliminated catfish from lakes through chemical treatment.

As has already been related, not only has there been a considerable confusion concerning the introduction of catfish to California, but most of the general remarks

[39] In order to protect wild and cultured catfish stocks from exotic diseases and parasites, it is illegal to import live catfish (channel, blue, white, or flathead catfish, and brown, black, or yellow bullheads) into California (Section 171 of Title 14 of the California Code of Regulations).

made about them are applicable both to the bullheads and the white catfish. In an attempt to distinguish between them, the State decided upon the use of two rather artificial names: fork-tail catfish for Ameiurus catus and square-tail for A. nebulosus. This common-name nomenclature may have started with the publication of Walford (1931). His "Handbook of Common Commercial and Game Fishes of California" had as its primary purpose the establishment of "... official common names of the California fishes which are handled commercially, or which are of particular interest to fishermen and dealers. The authority for this work is derived from a State law enacted in 1919, which provides that 'the Fish and Game Commission shall have the power to decide what is the common usage name of any variety.'" The selection of "official common names" was aided by a number of men who were well aware of the names commonly used for fishes in California and those that might be appropriate. Among these were J.O. Snyder, C.L. Hubbs, W.I. Follett, and H.B. Nidever.

It was a good committee, but we consider that the erection of these two common names was decidedly unfortunate.[40] Not only have other species of catfish which have forked tails become part of our ichthyofauna, but the use of the name "square-tail" may have masked the presence of other bullheads in California. For many years, any catfish having a square or only rounded tail was assumed to be a brown bullhead, even by scientists and fish rescue workers who handled thousands of fish. It is not at all certain that many records of Ameiurus nebulosus do not represent or include one of the other "bullheads."

We do know that the California Division of Fish and Game's Reports for 1942–44, 1944–46, and 1946–48 all used the names "Forked-tail" and "Square-tail" to distinguish the catfishes, and the terms "white catfish" and "brown bullhead" seem to appear in the Division's Report for the first time in the 1948–50 issue.

"Good" or "bad" and whatever they have been called, catfish are here to stay as residents of California, and the presence of any species in almost any of our waters should occasion no surprise. The U.S. Fish Commission and its derivatives have often provided "catfish" without designation of their species to applicants in California. See, for example, Leach (1923b) who reported sending 960 catfish to applicants in California in 1922. Their viability is such that they can be transported for long distances with little or no water; there are even stories of early emigrants bringing catfish wrapped in moist burlap to California by wagon train. Furthermore, many people desirous of establishing "catfish holes" have found it easy to transplant these fish.

[40] It is true that some ichthyologists had used some of these names. For example, Jordan (1920) called Ameiurus catus the "Fork-tailed Cat." Walford (1931) even confused the issue by giving the following list of "unauthorized names": "Channel catfish, horned pout, white catfish, common catfish, Potomac catfish" for A. catus, and "Bullhead, horned pout, small catfish, black catfish, Sacramento catfish, yellow catfish" for A. nebulosus.

The specific catfishes introduced into California are discussed in the following sections.

4.11. White catfish, Ameiurus catus (Linnaeus)

The white catfish, native to the Atlantic coastal states, was introduced into California in 1874 from the Raritan River, New Jersey, by Livingston Stone at the request of the California Fish Commission. Either 56 or 74 were planted in the San Joaquin River near Stockton (Stone 1876a; California Fish Commission Report for 1874–75, p. 5).

The previous general account concerning the introduction of catfish into California discusses some of the confusion concerning the introduction of the white catfish (and that of the brown bullhead) as well as some of its later history. It has been difficult to provide specific information on these species because most accounts have not distinguished clearly between them and speak only of "catfish." It is reasonably certain, however, that most of the accounts of a catfish with a forked tail refer to Ameiurus catus.

The earliest published report in California of what is presumed to be this catfish was of a specimen classified as a "cat-fish (Ameiurus catus [L] Gill)" caught in the Sacramento River in 1875 (Anon. 1882, p. 215). The spread of white catfish was rapid, and today it is common in the Central Valley, particularly in the Sacramento-San Joaquin Delta, in Clear Lake, and in many scattered waters throughout California. It has also been stocked by the State in many waters. Swift et al. (1993, p. 139) were incorrect in citing Smith (1896) as the authority in saying that A. catus was introduced into Los Angeles and San Diego counties in 1874. Smith (1896, p. 383) clearly said that these fish were planted there at a later date.

Apparently, it has a greater preference for clear water than have the bullheads. It is a warmwater fish and can even endure salinities up to 12 ppt which allows it to live in Suisun Bay.

Early reports indicated that the white catfish was second in number to the brown bullhead and introduced into California at the same time. Walford (1931) felt that it was probably the most abundant of the catfish in the state but he depended upon the opinion of others, especially commercial fishing records. The work of several investigators has indicated that it was, by far, the most important fish in the commercial fishery and in the sport fishery which completely replaced it. Pelgen (1952) and others have indicated that about 95% of the catfish taken in the Delta were white catfish. The fish furnish an excellent fishery for the sedentary angler. Neither commercial nor angler catch records are, however, always true indicators of the actual populations. For example, at Clear Lake, Lake County, boat catch records for sport fishermen have indicated that white catfish were highly important, making up to 80% of the total catch sampled, and brown bullheads (the only other catfish present) not exceeding 9.7% of the total sport catch during the same period. However, compulsory records in the same lake maintained by a commercial seine fishery (for common carp and Sacramento blackfish, Orthodon microlepidotus) indicated consistently for many years that the brown bullhead was considerably more abundant than white catfish (McCammon and Seeley 1961). The most recent lakewide Clear Lake creel census showed that the brown bullhead was the most abundant catfish in the sport fishery followed by the white catfish and then the channel catfish (Macedo 1991).

Incidentally, Clear Lake once swarmed with countless thousands of native minnows (cyprinids), and carp have also been abundant. Not only did these fish cause Livingston Stone difficulty in fording some of its tributary streams by horse when they ran upstream to spawn, but in more recent years they died in such quantities that the stench was almost intolerable to the lakeshore residents.[41] Every year large quantities of dead fish had to be buried, but according to Capt. J.D. Dondero of the Division of Fish and Game, the establishment of white catfish in Clear Lake, which he said occurred in the 1920s, "... solved this problem."[42] The population of nongame fish diminished, and the windrows of dead fish were a thing of the past (pers. comm.).

All in all, the introduction of white catfish into California has proved highly successful for the fisherman.

4.12. Black bullhead, Ameiurus melas (Rafinesque)

There is no record known to us of the actual introduction into California of the black bullhead, a species native to much of the eastern and southern United States and Mexico. It may have been introduced in 1874 along with the brown bullhead and white catfish, although this seems doubtful in view of the lack of recorded evidence and the length of time before its presence in the state was known.

An article by Seale (1934) spoke of the "yellow catfish" and "black catfish" as being denizens of one of the tanks at the Steinhart Aquarium in San Francisco. Possibly the second named fish was Ameiurus melas, but it may equally have been A. nebulosus. Since this is a dubious record, we believe that the first published record of the occurrence of the black bullhead in California was that of Dill (1944). On 18 and 20 May 1942, two specimens of this fish were taken in the lower Colorado River by C.A. Woodhull and Dill. The identity of the fish was verified by C.L. Hubbs. Prior to this time, R.R. and R.G. Miller took two young

[41] See Stone (1876b, p. 378). There is a photograph in Jordan (1925, p. 50) and Murphy (1951, p. 479) showing thousands of Sacramento squawfish (Ptychocheilus grandis) stranded in Kelsey Creek, a tributary of Clear Lake.

[42] According to Murphy (1951, p. 450), the first introduction(s) of white catfish into Clear Lake may have been unsuccessful, and the present population may have stemmed from plants made in 1923 and 1926. Incidentally, the 1926 plant was made under the name "forked tail or channel catfish" (California Fish and Game Commission Report for 1926–28, p. 64).

black bullhead from the Kern River at Kernville, Kern County, on 11 August 1940 (pers. comm. from R.R. Miller). The next record we have is that of two from Lost River, Modoc County, taken on 7 September 1942 by W.I. Follett (pers. comm., 6 March 1946). In each case, the identity of the fish was confirmed by C.L. Hubbs.

One other definite record of the presence of the black bullhead in California during the 1940s is known to us. On 17 April 1944, an angler took a specimen from a pond in the Kings River drainage, one mile south of Malaga, Fresno County; the specimen was identified by Dill.

Almost undoubtedly, all of these black bullheads had different origins. It seems probable that those in the Colorado River were first introduced into some other state. (We know that "catfish" have been planted in the River in several states above the California line.) Miller (1946) stated that F.M. Chamberlain collected "catfish," which Miller thought might be Ameiurus melas, in the Colorado River at Yuma, Arizona, circa 1904. Hubbs informed W.A.D. that he had collections of Ameiurus melas catulus from the Colorado River in Arizona.

The species may have been in the Kern River for many years. The senior author has known of "bullheads" in the vicinity of Kernville since 1938. He was informed then by local resident J.L. Hooper that they were introduced around 1878, but other residents said that they had been brought up from the San Joaquin Valley by sportsmen only a few years previously. It is also known that "bullheads" were planted in the Kern River below Kernville by State game warden R.C. Welch and local resident L. Roux in 1931. The fish, some of which were unusually black, were taken from the overflow of the Kern River near Bakersfield (pers. comm. from R.C. Welch, 5 March 1943). If the Kern River black bullheads came from the San Joaquin Valley, as seems likely, then it is also likely that they already had a wide distribution in California, especially in the San Joaquin-Sacramento River drainage.

Pelgen (1952) stated that the black bullhead was present in the Sacramento-San Joaquin Delta, and subsequent authors have also noted its presence there and in Suisun Bay. All agreed, however, that it was not as common as the white catfish which Pelgen (1952) said comprised about 95% of the catch. At a later date, Turner (1966b) found it to be about as abundant in the Delta as the brown bullhead. Rawstron (1971) has noted its presence in Merle Collins Reservoir, Yuba County, and the species has been reported in other areas of the state.

In Arizona, where it has also been introduced, it is said to be a pest. It rarely achieves a size desired by anglers, and often forms a stunted population that competes with more desirable fishes (Minckley 1973). This is also true in some parts of Europe where it has been introduced, and where it is often known as the "American catfish." Nevertheless, it is a cultivated fish in some areas, especially in Italy (Dill 1990).

Our conclusion is that while the black bullhead may be found scattered throughout California it is not a dominant part of the fish fauna. It is also concluded that its true origin in California will never be known, and that some of the records of the brown bullhead may apply to this species. Furthermore, it is known that these two species hybridize, which complicates the problem of its origin.

4.13. Yellow bullhead, Ameiurus natalis (Lesueur)

As for the black bullhead, there is no record known to us of the actual introduction of the yellow bullhead into California. Native to the eastern and central United States, it may have been introduced in 1874 along with the brown bullhead and white catfish, but this seems unlikely. It is more likely that its introduction occurred later, and that there has been more than one introduction from stock originally from the eastern United States and sent west by the U.S. Fish Commission or one of its successors.

Aside from Seale's (1934) somewhat dubious record, we do know that the first published report of its occurrence in California is that of Dill (1944). Six specimens were seen in the lower Colorado River drainage by C.A. Woodhull and W.A.D. between 30 January and 25 May 1942, and the identification of one of these was verified by C.L. Hubbs as Ameiurus natalis natalis, the northern yellow bullhead.

Reports of fishermen (if their identifications were correct) indicated that the yellow bullhead was the commonest bullhead in the lower Colorado River at that time, and many of the old rivermen or former beaver trappers considered it to be native. These men, who called the bluegill a "sort of Johnny-come-lately," and who lived on the River long before the channel catfish was caught here, never suspected that it was an alien form. They called it the "mudcat," "yellowbelly," or sometimes the "native bullhead." Mudcats were known to be common in the lower Colorado River in 1910 (pers. comm. from Federal biologist J. Dixon and local resident D. Haughtelin). State game warden W.C. Blewett (letter of 9 April 1944) informed W.A.D. that it thrived best in the backwaters and sloughs as in the Palo Verde region, and several residents of Blythe and Needles stated that it was fairly common. In no way, however, did it approach the abundance of the channel catfish.

At the time of Dill's publication (1944), the occurrence of the yellow bullhead in California had not been definitely recorded elsewhere. Other accounts had appeared, however, which may have alluded to this species. Stephens (1914) stated that the Colorado River in California contained some carp and "catfish," and this may have been the "... smaller variety ... of catfish ... taken in this state only in the Colorado River or in irrigation canals connected directly with it" mentioned by Nidever (1937).

There are many records, extending back for more than 100 years, of the introduction of "catfish" into waters of the Colorado River by the Federal Government.

Those examined have not specifically mentioned the yellow bullhead. It is doubtful if planting records alone can ever serve to determine the first successful introduction of this fish into the River, or— for that matter— into California.

Aside from its presence in Colorado River waters, it has a limited distribution in the state. Sometime in 1944, C.H. Freyschlag rescued one in the Central Valley; the identification was by State biologist J.H. Wales. Erkkila et al. (1950) claimed that the catfishes they collected in the Delta during the 1946–49 period were the yellow bullhead and white catfish. On the other hand, State biologists D.E. Pelgen, G.I. Murphy, G.W. McCammon, D.A. LaFaunce, and others who worked extensively on catfish, primarily in the Delta, but also at Clear Lake, did not record the presence of yellow bullhead during their work, and there are few accounts of its presence here. Seymour (1969) spoke of it generally as a California resident, but probably based his remarks on casual literature search which may not have been confined to accounts of Californian fishes. Moyle (1976b) stated that it was present in small numbers in the Lost River, Modoc County. It may be established in a few reservoirs in southern California. Schoenherr (1992) recorded this species from Salt Creek, Riverside County, in 1990, and Swift et al. (1993) stated that they have records of it from Riverside County, Orange County, and the Coachella Valley. It is apparently still present in some sloughs (the inference is that these are in the Sacramento-San Joaquin Delta area) according to a personal communication from M. Caywood to Moyle (1976b). It is collected on occasion at the John E. Skinner Delta Fish Protective Facility (Bay-Delta Fishery Project 1981).

Assuming that all of the above identifications of the yellow bullhead have been correct, it is obvious that it is not found in many Californian waters. It is true that Neale (1915) might appear to state that it was planted in our waters in 1874, but the primary records do not bear out his statement. It is also true that Evermann and Clark (1931) recorded it in their list of fishes introduced into California, and said, "Two species of the common eastern catfish, Ameiurus natalis and A. nebulosus, were probably introduced together in 1874, and they are more or less confused in the records...." However, the primary records do not substantiate their first assertion and the only portion of these statements we accept are that "... they are more or less confused in the records...."

Furthermore, Neale (1915) listed only two species of catfish as having been introduced: "The bullhead or horned pout (Ameiurus nebulosus) , known here in California as the yellow or mud cat, and the blue catfish (Ameiurus natalis) . ..." Now in 1915, as well as in 1995, the two commonest species of catfish in California were Ameiurus catus and A. nebulosus. Neale was well acquainted with this, and it is inconceivable that his article would have omitted any mention of the well known species we know today as the white catfish. Obviously, he did mention it, when he spoke of the "blue catfish." This is a common name in California for catus and one would certainly never call natalis "blue." Neale's error lay in applying the wrong scientific name ("natalis") to the white catfish. It should be noted that in a later article, Neale (1931a) again listed only two species of catfish in California, but this time he used the correct terminology by calling them nebulosus and catus. A greater error lies with Evermann and Clark (1931) who listed A. natalis as an introduced species entirely separate from either nebulosus or catus. Neale (1915) was freely quoted in their article, although without specific reference to his paper, and it seems apparent that their listing of A. natalis must have been drawn from his article. As stated before, we can find no substantiation in earlier records for such a presumption. M.W. Brown, then in charge of bass propagation and fish rescue for the State and a fishery biologist, was also guilty of a complete misstatement concerning the yellow bullhead when he spoke of "Ameiurus natalis" as commonly being called the "yellow cat, blue cat, forked tail, etc." and as having been successfully introduced into the state (answer to the Editor in California Conservationist 1[8]:8). Having known Brown, we cannot understand why such a statement would be attributed to him.

The brown bullhead and yellow bullhead are close relatives. The former is highly appreciated by fishermen even though it has never attained the popularity of the white catfish, which commonly lives in the same waters in California. The yellow bullhead, however, has even more formidable competition for popularity with fishermen since its fellow resident in the Colorado River is the channel catfish. The latter grows to a large size and far outclasses the humble little bullhead as a fighter. Furthermore, it has graceful, somewhat rakish, lines which even age cannot distort into the matronly fleshiness of the yellow bullhead. Thus, the latter is granted little favor by most fishermen. Along the Colorado, the entire catch of this species is often simply tossed away to rot among the arrowweeds.

4.14. Brown bullhead, Ameiurus nebulosus (Lesueur)

The brown bullhead is native to the eastern half of the United States and its original range extends into southern Canada. It was first introduced into California in 1874 from Lake Champlain, Vermont, by Livingston Stone at the request of the California Fish Commission. Seventy "hornpouts" ("Pimelodus"), believed to be brown bullheads, were placed in waters near Suttersville, Sacramento County (California Fish Commission Report for 1874–75, p. 5; Stone 1875, 1876a).

The previous general account of catfishes refers to some of the confusion concerning the introduction of the brown bullhead, and its later history in California. It has been difficult to provide specific information on the species because most accounts speak only of "catfish" and do not distinguish between the brown bullhead (Ameiurus nebulosus) and the white catfish (A. catus) , except to say that both species are involved. Furthermore, the unfortunate selection of an artificial name, "square-tail," for the brown bullhead has further confused the issue.

There seems to be no question that the brown bullhead is the most numerous of the three species of bullheads now resident here. Furthermore, although the white catfish was the predominant fish in the old commercial fishery as it still is in the sport fishery, fish rescue records indicate that the brown bullhead was more numerous. During the 1936–41 period, for example, almost four times as many brown bullhead as white catfish were salvaged. (See the records in the Division of Fish and Game Biennial Reports and also the remarks on the abundance of white catfish in the section on that species.)

The brown bullhead also appears to have the widest distribution in the state of all the catfishes. It is abundant at lower elevations in the Sacramento-San Joaquin drainage, and is one of the few introduced fishes which has been successful in the Eel and Klamath systems. It is known from many trout streams in the Sierra Nevada, and in the warmer lakes and reservoirs throughout the state it is often plentiful and of fair size. It is also known from natural lakes in the Sierra Nevada at least as high as 7000 ft where it may reach only a small size and compete with trout. In a number of instances it has been eradicated through chemical treatment by the Department of Fish and Game.

Brown bullhead, bluegill, and largemouth bass were the usual species stocked for a time under the State's farm pond program (California Department of Fish and Game Report for 1950–52, p. 53–54).

The brown bullhead may be expected in almost any warm waters in the state, and has proved to be one of the most sought after fish in California.

4.15. Blue catfish, Ictalurus furcatus (Lesueur)

On 23 October 1969, 1758 blue catfish were released by the Department of Fish and Game into Lake Jennings, San Diego County. This was the first time this species was stocked in California waters.[43] Shapovalov et al. (1981) mistakenly (lapsus calami) said that the date was 1966.

The fish, which are native to the central and southern United States and northern Mexico, were flown from Stuttgart, Arkansas, on the same day and were part of an original shipment of 1990 blue catfish from the U.S. Bureau of Sport Fisheries and Wildlife Fish Farming Experimental Station. One fish was lost during the shipment and 231 were transported to the Department's Chino Fish and Wildlife Base to be used for future broodstock. The average length of the imported

[43] On the basis of a survey of Clear Lake, Lake County, in 1925, Coleman (1930) listed as a resident "The Great Blue, or Forked-Tail Cat—Ictalurus furcatus Cuv. and Vincen. These were planted a few years ago and seem to be flourishing...." None of the surveys of Clear Lake made prior to Coleman's (e.g. Jordan and Gilbert 1895) nor the many capable ones made since that time have ever listed this species as a resident. The authors believe that Coleman confused it with the white catfish, Ameiurus catus, which was apparently planted in Clear Lake in 1923 or 1926. The "blue catfish" listed in the 1939 fish rescue records for the Central Valley is most likely the channel catfish.

stock was 6.46 inches total length (TL) with a range of 3.39 to 8.46 inches. The average weight was 1.08 ounces.

The authors of the above report (Richardson et al. 1970) stated that the blue catfish was known to feed on the Asian clam, Corbicula fluminea, which was abundant and a nuisance in many southern California waters. They did not expect that the blue catfish would exercise any biological control over the clam, but thought that it would convert appreciable quantities of it to fish flesh for angler use. They also opined that since the blue catfish attains the largest size of any of the American catfishes, it would enhance our fisheries by providing another trophy-size fish.

Although the above account of the initial introduction is the most accurate one we possess, it was actually preceded by an account (Gillilan 1970a) which provided somewhat different figures—undoubtedly lumped for journalistic purposes. For example, Gillilan said that 2000 blue catfish were introduced. As Gopnik (1994) has said: "Historians spend decades clearing up confusions that journalists create in minutes...."

Perhaps the most noteworthy circumstance concerning the initial introduction of the blue catfish into California was the fact that it followed a recommendation by A.J. Calhoun, then Chief of the Inland Fisheries Branch, a biologist prone to favor fish introductions. The initial plant was labeled "experimental" and the fish were marked so that their growth and harvest rates might be compared with those of 2014 channel catfish (Ictalurus punctatus) of about the same size planted in the same lake on 18 November 1969. One year later, 178 blue catfish from Lake Jennings averaged 11.3 inches TL; the largest one taken was 15.6 inches with a weight of 1.25 lb (unpublished data from L.J. Bottroff, cited by Pelzman 1971a). It was also stocked in other San Diego County waters by the Department of Fish and Game and from commercial catfish hatcheries (28 May 1996 letter to W.A.D. from O.P. Ball, former City of San Diego Lake Superintendent.) Lake Mathews in Riverside County was also stocked with blue catfish for the biological control of Corbicula. This lake, on the Colorado Aqueduct of the Metropolitan Water District of southern California, has been closed to the public since its creation in about 1935 (California 1975).

The desirability of introducing blue catfish into northern California was reviewed by Pelzman (1971a) in an account which is primarily a survey of the literature on the species in areas outside California. He also stated that at that time (April 1971) it was found only in Lake Jennings and in a commercial fish breeder's ponds at Brawley, Imperial County. He felt that it: was likely that the species could be established, was not likely to have a detrimental effect on warm-water reservoir fisheries, was not likely that it would attain the great sizes reported in southern states, would probably not have a significant impact on anadromous fisheries, could be beneficial because of its habit of feeding on Corbicula, and would enhance California fisheries by providing another trophy-size fish.

For these reasons, he recommended the introduction of blue catfish to northern California.

The species has not been introduced by the State to northern California public waters, but a specimen captured in the San Joaquin River near Mossdale on 6 December 1978 was the first reported catch of a blue catfish in the public waters of northern California (Taylor 1980). Taylor thought that the most probable source of the specimen was one of the aquaculturists then authorized to raise blue catfish in the Sacramento and San Joaquin valleys. Raquel (1986) suggested that natural reproduction of the species was occurring in the Delta. He based this surmise on the collection of juvenile blue catfish at the John E. Skinner Delta Fish Protective Facility near Byron, Contra Costa County, between 24 September and 3 October 1984 and on 19 July 1985. Young and Marsh (1990) also recorded it from the Delta.

Raquel (1986) gave the blue catfish's habitat in the southern part of the state as: Lake Jennings, Lake Mathews, Sutherland Reservoir, El Capitan Reservoir, San Vicente Reservoir, and the Santee Lakes chain, all in San Diego County.

The blue catfish probably will continue to expand its range in southern California and the Central Valley, but it is unlikely to exceed that of the similar channel catfish. Its primary role is to provide an occasional trophy fish for the angler.

4.16. Channel catfish, Ictalurus punctatus (Rafinesque)

The native range of the channel catfish is the central drainages of the United States with extent into southern Canada and Mexico.

It is very probable that its presence in California stems from quite separate introductions.

The first record of its introduction was in 1891 when the U.S. Fish Commission brought out about 500 adult and yearling catfish from Illinois and distributed them equally in Lake Cuyamaca, San Diego County, and in the Feather River near Gridley (U.S. Fish Commission Report for 1892, p. LXXV; California Fish Commission Report for 1895–96, p. 29). The California Report lists "500 catfish, Ictalurus punctatus, planted in Cuyamaca and the Feather." Smith (1896, p. 383), using the term "spotted catfish" for this species and without reference, stated, "Plants of yearlings were made in Lake Cuyamaca and Feather River, California, in 1891, each water receiving 250 fish." Most subsequent authors have listed all the catfish in these plants as channel catfish, but it should be noted that the first reference above listed them as "Catfish (Ictalurus punctatus chiefly)."

The U.S. Fish Commission also planted either 10 (Smith 1896; Evermann and Clark 1931) or 18 (California Fish Commission Report for 1895–96, p. 31) fish of this species in Bolsa Chica River in Orange County in 1895. These appear to be the only recorded plants of channel catfish from the eastern United States into California which are in print.

Shebley (1917) stated that the channel catfish was introduced into California in 1874, and this statement has been accepted by a few other authors (e.g. Moyle 1976b). There is no basis for such a statement; possibly Shebley was alluding to the 18 "Mississippi catfish" planted by Livingston Stone in the San Joaquin River near Stockton that year. The identity of these fish (from the Elkhorn River, Nebraska) was unknown at the time, and even if the fish were Ictalurus punctatus there is no evidence to show that they survived. See the discussion in Smith (1896, p. 382–383).

In 1896, a representative of the California Fish Commission visited Lake Cuyamaca and reported that all of the varieties of fish planted there in 1891 were present except crappies and rock bass (California Fish Commission Report for 1895–96, p. 29). If this report can be considered affirmation of its presence, then we can assume that the channel catfish survived there until at least that date. Smith (1896, p. 386) said that catfish were reported to be abundant in Lake Cuyamaca but also indicated that only Ameiurus nebulosus and A. catus were known to have been acclimatized in California at that time (circa 1894). At any rate, the 1896 report of a successful introduction of channel catfish into California was the last for many years.

The next record we have of channel catfish in California came from the unpublished History Book of the San Diego Fish and Game Association, Volume 1. Circa 20 October 1922, there is a record of 200 channel catfish planted in Sweetwater Lake, San Diego County. There is no information in the History Book of their source; we assume that they came from San Diego County.

No subsequent accounts appear to have recorded the channel catfish in California until that of Nidever (1937).[44] He stated, "For the past fifteen years [i.e., since about 1922] ... [it] ... has been taken in the Colorado River by Southern California anglers. There seems to be no available information recorded as to how these catfish got into the Colorado, although it is reported by several sportsmen ... that they were first planted in the river by sportsmen in Utah." Following Nidever (1937), this would indicate that the channel catfish was first noted in California's part of the Colorado River in about 1922. There are authentic reports of this species being caught in the lower Colorado River as early as 1925–26 at

[44] The scientific name "lctalurus punctatus" appeared in a list of common and scientific names of fishes, crustaceans, and mollusks representing those species discussed in "The Commercial Fish Catch of California for the Year 1928" (Division of Fish and Game, Fish Bulletin 20, p. 7–8, published in 1930). Since this name was omitted from similar lists appearing in later Fish Bulletins, it may be assumed that it was decided that this species was not represented in commercial catches.

Furthermore, on the basis of extensive collections, especially in northern California, Professor H.O. Jenkins concluded in a manuscript of 20 June 1938 that the introduction of the channel catfish in California had been unsuccessful.

Laguna Dam, in 1927 "in the lower river," and in 1928 at Blythe and Yuma (letters to W.A.D. from State game warden E.H. Glidden, 16 February 1943; Arizona Director of Fisheries H.L. Reid, 21 January 1943; State game warden J.W. Harbuck, 14 February 1943). State game warden W.E. Blewett told us that private individuals were reported to have planted them at Yuma in 1912 (pers. comm.).

On a survey of the lower Colorado River in 1942, C.A. Woodhull and W.A.D. interviewed many residents in an attempt to establish the facts concerning the channel catfish's appearance there. Although the authenticity of much of the information may be questioned, there was a fair agreement among local fishermen and "rivermen" that the channel catfish was of recent origin in the California and Arizona waters of the River. All of the men questioned declared that this species first appeared in the lower River sometime between 1920 and 1930. Their conjectures as to the fish's source were varied: "from the east in a tank"; from Utah originally, then planted in a lake on the Verde (Arizona) and thence down the Gila River to the Colorado; etc.[45] One man gravely offered the startling hypothesis that it migrated down the Mississippi River into the ocean, through the Panama Canal, and eventually up the Colorado from the Gulf of California. He predicated his belief, of course, on the fact that the Panama Canal was not opened until 1914 and that it took the fish five or ten years to make the trip.[46]

We shall probably never know the origin of the channel catfish in the California portion of the Colorado River and its distributaries, other than to surmise that it resulted from plants in other states. For example, La Rivers (1962, p. 483–484) cited a report that it was brought to the river in Arizona as early as 1892, and another that it was introduced into the "lower Colorado River" in about 1906.

In California the fish became abundant throughout the lower Colorado River and its irrigation ditches in the Palo Verde and Imperial valleys. It was also found in the Alamo and New rivers and was even taken occasionally in the Salton Sea. State game warden E.H. Glidden reported that channel catfish from the Colorado River were planted in Lake Henshaw, San Diego County, in 1932, and that this was the only lake in that county where it was found (letter to W.A.D., 16 February 1943). However, Glidden's notes on fish planting made no mention of this but said that "about 2,000 catfish" were planted from Sweetwater to Wohlford on 15 April 1925, 25,000 "catfish" (source unknown) were planted in Lake Hodges in June 1925, and 70 "catfish" from 1 to 3 lb from Sweetwater Lake were planted in Henshaw on 21 March 1933. These are the only mentions of catfish in his notes.

[45] On the other hand, we have the statement made by Anon. (1944) in the Arizona Wildlife and Sportsman that the Verde was stocked with channel catfish from Colorado where they are "native."

[46] Fish have migrated through the Panama Canal. See, for example, Rubinoff and Rubinoff (1968).

Circa 1944, it was reported that its distribution had been extended to other waters in southern California. It was then expected that it would be found in waters fed by the Metropolitan Water District of Southern California which diverts water at Parker Dam (Lake Havasu) on the Colorado River.

Its success in the Colorado River was well established. McCammon (1956) estimated that the fishing in the lower River provided a catch of 750,000 catfish to 19,000 sport fishermen in 1953, representing about 10% of the state's recorded catfish catch in that year. He believed that the catch of other species of catfish was insignificant on the River. Its fighting ability made fishermen consider it second only to largemouth bass as a game fish. Specimens up to at least 22 lb have been taken in the Colorado. However, countless numbers of fish only a few inches in length have been taken by fishermen in the quiet canals and drainage ditches of Imperial and Riverside counties. The usual method of capture is by bait fishing, although channel cats are occasionally hooked on artificial lures. Ictalurus punctatus is commonly called the "spotted cat" on the Colorado, and males which assume a bluish or blue-black color are often thought to be of a different species.

For many years, fishermen have reported channel catfish in the Central Valley of California (Sacramento-San Joaquin drainages). Since the common white catfish, a long-time resident of the Central Valley, is similar in appearance (both species have a forked tail), it is often called the "channel catfish," and we accorded little credence to such reports. However, they were substantiated in May 1942 when C.H. Freyschlag, foreman of Central Valleys Hatchery, secured a small specimen taken by a fisherman in the Feather River near its mouth (near Verona). The senior author identified the specimen as a true channel catfish and C.L. Hubbs verified the identification. At the request of Capt. A.E. Burghduff, then Supervisor of Fish Hatcheries with the California Division of Fish and Game, information on this specimen was sent to B.H. Lampman who published it in Lampman (1946, p. 62). This is the first known published record of the existence of channel catfish in northern California. On 14 September 1943, C.H. Freyschlag and A. Woodard of Central Valleys Hatchery netted two more channel catfish in the Natomas district north of Sacramento in the course of fish rescue work (pers. comm. from C.H. Freyschlag, 17 September 1943). (We trust the identification.)

There seems to be no question whatsoever that true channel catfish were unknown in the Sacramento-San Joaquin drainage until about 1942. Numerous scientists and State fish rescue crews have collected in this area for many years and none of them ever recorded channel catfish as caught until the record of 1942.[47]

[47] The State records of "blue catfish" rescued in 1939 and "spotted catfish" rescued in 1940 may well be those for channel catfish. Certainly, the "blue catfish" referred to is not lctalurus furcatus.

After referring to the 1891 plant in the Central Valley, McCammon and LaFaunce (1961) stated, "An unauthorized introduction also took place sometime between 1925 and 1930.... The first authentic record of capture of the species was not made until 1942, and from that year until 1950 reports of observations of channel catfish were infrequent. During that period, the sport catfish catch of the Sacramento Valley was dominated by the white catfish (Ictalurus catus) . ..."

McCammon and LaFaunce (1961), in the statement above, were undoubtedly referring to W.A.D.'s 1942 record, and to an introduction "between 1925 and 1930" based on a 4 May 1953 letter by D.E. Pelgen to the Department of Fish and Game's Inland Fisheries Branch. For some inexplicable reason, this letter remained in the files of the Branch until lately when it was unearthed. Pelgen, who was the Department's major biologist dealing with catfish, referred to the 1942 record of capture of a channel catfish, and said that since that time, especially during the period of about 1949–53, numerous fish of this species had been captured in the lower Sacramento River. He felt that the channel catfish was most numerous in the Sutter Bypass area.

Pelgen went on to describe an introduction based on an interview with A.H. Willard (then of the Bureau of Patrol of the Division of Fish and Game). It follows: "Sometime during the period from 1925 to 1930 (probably 1926 or 1927) a group of businessmen in Roseville [Placer County] decided that channel catfish would be a desirable fish to have in nearby waters. Arrangements were made to have some of the fish shipped out from the State of Kansas Fish Hatchery at Pratt, Kansas. The shipment was to be consigned to Mr. William Rowe of Roseville. The charges were paid by donations from Roseville businessmen including, Mr. Rowe, Carl Stamm, Guy Bootelier, Dr. D.W. McKennan, and others. Five cans of channel catfish arrived ... approximately 65 of the fish were still alive. They were put into a pond near Loomis [Placer County].... After about a month the pond began to dry up, so it was decided to plant the fish in permanent waters. The fish were ... planted at Horseshoe Bar, which is about 10 miles above Folsom on the North Fork of the American River. Approximately 65 fish were planted. They were young fish, ranging in size from about 4 to 10 inches. The entire operation was carried out by the group from Roseville, assisted by A.H. Willard ... who assumed that the plant was authorized by the Division of Fish and Game." Pelgen concluded his letter by saying, "It is assumed that this plant resulted in our present population of channel catfish in the central valley."[48]

[48] California (1981) said that "The earliest records indicate that it was intorduced into the San Joaquin River ... in 1874 from the Mississippi Valley." The records do not indicate this; see the general section on catfish. California (1981) also said that "Apparently ... the Feather River plant [of 1891] was successful." In light of our discussion, this assumption is also probably incorrect.

At a later date, the channel catfish's most important areas in California were still considered to be the Colorado River, reservoirs of San Diego County, and the Sutter Bypass area of the Feather River (Rawstron 1967). It had, however, been introduced into many foothill reservoirs, Folsom Lake, Clear Lake, and elsewhere where it established populations.

The Department of Fish and Game felt, however, that rearing this species artificially to catchable size would also be of advantage (Calhoun et al. 1963). Previous to that time, the Department was rearing channel catfish experimentally at the Central Valleys Hatchery at Elk Grove using wild broodstock captured in Sutter Bypass and Honcut Creek, Sutter County, but with emphasis on developing a domestic stock with rearing only to fingerling size (OC 1958a; Murray and Warner 1965). Raising this species to catchable size was an entirely new venture. Following further experimentation, including rearing it in ponds near the Salton Sea (OC 1966a), in 1970 the State started its first hatchery for mass production of catchable-size (about ½ lb or 10 inches) channel catfish, the Imperial Valley Warmwater Hatchery near Niland, and completed it in 1971 (Gillilan 1970b; Wentzel 1972). From that time until 1990, when it closed down, the species was stocked extensively from here, and provided an alternative, especially in southern California, to the stocking of catchable trout.

Today, the Department of Fish and Game cooperates with private aquaculturists to stock catchable channel catfish in southern California as part of an urban fishing program. Fish up to 3 lb have been planted. "Kids, women, single parents, the retired, working people, seniors, first time anglers—just about every city-dweller can benefit from the urban fishing program," according to a State fishery biologist in *Fish and Game Today* 41(1):1. (It would appear that the Department of Fish and Game functions as a sociological as well as a resource agency.)

Cage culture for channel catfish has also been tried in California. In 1970 a project to raise this species in "live cars" was started at Clear Lake by a local fishing committee with aid provided by a commercial fisherman and the Department of Fish and Game. Catchable (7½-inch) channel catfish for the lake resulted (Hubbard 1970; OC 1971). However, the project is no longer active.

Commercial aquaculture of channel catfish has also been started in California. In 1966, a private hatchery in the Coachella Valley produced a substantial crop. By 1981, the industry consisted of 50 producers farming about 455 ha of ponds with most of the production going to recreational pay lakes and live delivery to Asian markets in cities. Constraints in California to producers entering the processed catfish market (common in the southeastern United States) are: insufficient production volume, inadequate processing facilities, competition from low-priced Mississippi products, and high production costs.

In the southern United States, a herpes virus called channel catfish virus disease (CCVD) is prevalent and inhibits aquacultural yields of this species. Although it had an outbreak of CCVD in 1973, California was believed to be free of the virus, and the State invoked restrictive legislation to prevent further introduction. However, there are many indications to show that it is indeed present (Amend and McDowell 1984).

In summary, we believe that: i) the 1891 plants were failures; ii) the Colorado River populations resulted from plants in states other than California; iii) there were populations in some of the San Diego County lakes but their origin is dubious; and iv) the Sacramento River area populations resulted from the plant, circa 1926–27, described by Pelgen. Other populations have resulted either from transplants of wild stock, hatchery stocking, or separate importations from Texas as stated by the Region 5 office of the Department of Fish and Game in Swift et al. (1993).

It is in the role of a game fish, rather than as a food fish, that the channel catfish now occupies a secure—although rather recent—place in California. It has spread or been introduced into many waters of the state.

4.17. Flathead catfish, Pylodictis olivaris (Rafinesque)

Native to the central and southern United States and streams in northeastern Mexico, the flathead catfish is held in high regard by many fishermen for its fighting ability, large size, and edibility.

The first known published report of the flathead catfish in California was that in OC (1967b) which recorded catches made in the lower Colorado River near Yuma in 1966. There was also a report of the first of this species to inhabit waters in California: the East Highline Canal and lateral ditches in the Imperial Valley in early 1968 (OC 1968b).

A collection of four young-of-the-year from the Highline Canal and its tributaries near Niland, Imperial County, during January and February 1968, marked the first completely verified record of its occurrence and reproduction in California (Bottroff et al. 1969). It was believed that these fish stemmed from the original plant made in the Colorado River in March 1962 by the Arizona Game and Fish Department when about 600 fish averaging 10 inches in length were released in the River above Imperial Dam (Anon. 1980).[49] It was believed that the route of the catfish was downstream to Imperial Dam and thence into the All American Canal system to the Imperial Valley.

The flathead catfish has spawned successfully in the Colorado River since fair numbers have been caught in both Arizona and California. It is known to range in the River from Imperial Dam upstream to Headgate Rock Dam and is common in

[49] Minckley (1973) stated that the flathead catfish was also introduced prior to 1950 into the Gila River system (tributary to the Colorado). However, as far as is known, the species was not taken in the lower Colorado River system until after 1962, lending credence to the theory of Bottroff et al. (1969) as to its origin in California.

the Imperial Valley. It has been taken in the Coachella Canal by Minckley (1981). Fish over 40 lb have been taken in Colorado River waters of California.

Because of their piscivorous habits, large flathead catfish can be expected to affect populations of native fishes adversely. For example, Marsh and Brooks (1989) described efforts to reestablish the endangered razorback sucker Xyrauchen texanus in Arizona's Gila River. They found that intensive predation by flathead catfish and channel catfish on juvenile suckers "... may be high enough to preclude local re-establishment of the species by juvenile stocking...."

It has become a new trophy-type fish in California, especially for users of live bait, although it is rather difficult to catch.

4.18. Northern pike, Esox lucius Linnaeus

This is one of the few freshwater fish which has a circumpolar or holarctic distribution from northwestern Europe across northern Asia to northern North America, although not in California. It is a common fish in Europe where it is usually simply called "pike" and is a common fish in the eastern United States. It is known as a sporting fish, a vicious predator, and a good food fish.

Over a span of 100 years, the northern pike has experienced a complete reversal of acceptance in California. In 1891, there was an unsuccessful effort to establish it in California (see the section on grass pickerel). In 1991–92, the State spent many thousands of dollars to eradicate the pike from Frenchman Lake and adjacent waters—an operation clearly reflecting the Department's current policy regarding introductions. Although that effort was apparently successful, reproducing pike have since been discovered in Davis Lake, and the State must decide whether or not to apply another expensive chemical treatment. This is but one example of illegal stocking, apparently by anglers, which is severely damaging the Department's fisheries management efforts.

Supposedly, the northern pike was first brought to California by the U.S. Fish Commission in December 1891 with a shipment of other fishes from Illinois. However, one of the so-called "pike" was identified as a grass pickerel and for many years the northern pike was unknown in California. Hubbs et al. (1979, p. 30) listed Esox lucius as having been introduced into California (although no longer present). They undoubtedly referred to the 1891 introduction.

In 1943, E. V. Hart of Almanor Inn said that the Grasteit brothers, who were then seining carp in Lake Almanor, Plumas County, took a "northern pike" from the Lake. No more is known of the matter (pers. comm. from State biologist J.H. Wales to W.A.D., 1943). Whether or not this was a northern pike is open to question, but we do know that the Grasteit brothers were well acquainted with the usual California lake fauna and their find must have been an unusual one.

As far as is known, however, this was the last report of the species until 1988 when an angler landed a 7-lb northern pike from Frenchman Lake, a 1580-acre reservoir at 5607 ft in Plumas County (Department of Fish and Game, Region 2 monthly report for September 1988, p. 16). It should be noted that this lake (a reservoir) was chemically treated in 1975 to eradicate golden shiners. As no northern pike were found at the time, this indicates that it was introduced after that date.

Additional details regarding the status of northern pike in Frenchman Lake and its downstream waters were summarized in a 1 April 1993 letter from State biologist R.J. Decoto to A.J.C. In June 1989, a second northern pike (about 10 inches long) was reportedly taken by an angler from the Lake. By September 1990, pike from 9 to 23 inches in length were showing up in creel censuses. Also in September 1990, the first northern pike from downstream waters was electrofished from Smithneck Creek in Sierra County. It was an 11.8-inch specimen and another pike about 18 inches long escaped the sampling.

In June 1991, the Department of Fish and Game applied rotenone to the reservoir and achieved what appeared to be a complete "kill" of northern pike. Literally thousands of pike of various sizes were eradicated. No pike have been recorded from Frenchman Lake since that time.

In September 1991, however, an angler caught a 20-inch, 2¼-lb, northern pike from the Middle Fork Feather River below the Lake, near the town of Beckwourth, Plumas County. A stretch of the Middle Fork about 1 mile downstream and 1 mile upstream of the A23-road bridge was chemically treated in September and October of 1991, and three pike (10, 12.5, and 18 inches long) were killed.

On 2 July 1992, field personnel of Region 2 of the Department of Fish and Game collected 23 northern pike from 5.5 to 9.0 inches TL using a gill net in the Middle Fork Feather River just below the Beckwourth Bridge. These were probably young-of-the-year pike. Region 2 staff pinpointed where the pike were and rotenoned a stretch of the river and Sierra Valley waterways to remove them. An estimated 3370 northern pike from 10 to 27 inches long, were killed. The operation was apparently successful.

More recently, the capture in August 1994 of three northern pike from Davis Lake in Plumas County was confirmed by the Department of Fish and Game. Two pike, 14 and 18 inches in length, were caught by anglers, and an 18-inch pike was taken in a gill net by Department personnel. Occasional catches of adult pike (18 to 24 inches) in the spring of 1995 were confirmed by the Department. Electrofishing in the summer of 1995 and autumn of 1996 yielded numerous young-of-the-year pike, proof that reproduction in Davis Lake had occurred. The initial plant probably took place before 1994.

Like its neighbor Frenchman Lake, Davis Lake is owned and operated by the California Department of Water Resources. However, at 4026 surface acres, it is much larger and also supplies domestic water for the town of Portola. The complexities involved make chemical treatment expensive and difficult. Because of high water and other problems, chemical treatment in the autumn of 1995 and 1996 was ruled out, but will be reconsidered for the autumn of 1997. Now that reproduction is confirmed, it appears that the northern pike is a permanent, albeit unwelcome, member of California's fish fauna.

This was, we assume, a classic example of the problems created by a few anglers who, through ignorance or selfishness, moved fish illegally from one water to another. The pike may have been transported to California from waters as close as Nevada or Oregon, or they may have been purchased from eastern aquaculturists and moved to California. Such undertakings are relatively simple and will always pose a threat to California's fishery resources.

It is the highly predacious and piscivorous nature of the northern pike that concerns the Department, should it escape and find its way into the Central Valley. In jeopardy are already depressed populations of important fishes such as the chinook salmon, steelhead rainbow trout, striped bass, delta smelt (Hypomesus transpacificus) , and splittail (Pogonichthys macrolepidotus) .

4.19. Wakasagi, Hypomesus nipponensis McAllister

The taxonomy of this species has been confused. At present we follow Kljukanov (1970) in using this scientific name, and in California the wakasagi has usually been called the "freshwater smelt." Moyle (1976b), on the other hand, considered this introduction to be a subspecies (Hypomesus transpacificus nipponensis) of the native delta smelt.

Whatever the name (scientific or common), the same fish, then thought to be the pond smelt, Hypomesus olidus, was introduced "experimentally" from Japan to six waters in California in 1959 by the Department of Fish and Game.

At the time, this fish was considered to be native in California, resident primarily in the Sacramento-San Joaquin Delta, but difficult to secure. Reliance on a Japanese source was therefore made, and on 10 and 31 March 1959, air shipments of its eyed eggs on palm-fiber mats were received in San Francisco. The eggs were sent from Tokyo but had been taken at Suwa Reservoir about 70 miles to its east where they had been spawned artificially. Upon arrival, many of the eggs were dead, but enough were alive to furnish sizeable plants. Approximately 3,600,000 eggs had been shipped, but the number actually going into each of the six test waters was unknown: tributaries of Dodge Reservior, Lassen County; Shastina (Dwinnell) Reservoir, Siskiyou County; Freshwater Lagoon, Humboldt County; Spaulding Reservoir, Nevada County; Jenkinson (Sly Park) Reservoir, El Dorado County; and Big Bear Lake, San Bernardino County.

By August 1961, Freshwater Lagoon was found to have a self-propagating population of wakasagi. Chemical treatment of Big Bear Lake in 1960 resulted in the killing of some of its smelt, but none have been recorded since according to Swift et al. (1993). In April 1961, one was recorded from Shastina Reservoir.

The preceding account of introduction and initial survival published by Wales (1962) also indicated that: i) the introduction of the wakasagi was made to provide a planktivorous forage fish for trout lakes; ii) any of the planted waters, situated in different parts of the state, could be used as a source for later transplants; and iii) any of the waters could be chemically treated if it were found that the wakasagi were undesirable.

There are several reports on the progress of the wakasagi in California, but we shall merely recapitulate the summary given by Fisk and von Geldern (1983). They reported that the initial introductions were based on a report by Kawamura (1956) that indicated that smelt form an important link between zooplankton and trout in Japan. They also reported that in 1972 an introduction of the smelt was made into the 28,000-acre impoundment, Lake Almanor, Plumas County, resulting in: i) virtual elimination of a prolific kokanee fishery; ii) extensive use of the smelt by other salmonids (rainbow trout, coho salmon [Oncorhynchus kisutch], and brown trout); iii) a doubling of the growth rate of coho salmon; and iv) improvements in the growth and size of smallmouth bass. Wakasagi eventually migrated down the North Fork of the Feather River to the "two-story" Lake Oroville where there were: i) further declines in a kokanee fishery already adversely affected by threadfin shad; ii) a significant reduction in the threadfin shad population; and iii) extensive use of smelt for forage by brown trout, coho salmon, and chinook salmon (Oncorhynchus tshawytscha) . Fisk and von Geldern (1983) concluded by saying that wakasagi introductions have had positive impacts on trout and salmon fisheries which are sustained by stocking yearlings. They hypothesized, however, that young wakasagi and young black bass might be competitors and planned to discourage wakasagi introductions into waters supporting black bass fisheries.

Unlike the native delta smelt, now known as Hypomesus transpacificus, and Hypomesus olidus, which is not found in California, the introduced form is generally considered a freshwater species. However, the wakasagi may prove to be more tolerant of brackish water than anticipated. It has recently been observed from "... the lower American River (below Nimbus Dam), Cache Slough off of the Sacramento River and the Mokelumne River system and at the CVP [Central Valley Project] and SWP [State Water Project] fish salvage facilities in the south delta" (6 March 1995 letter from State biologist D. Sweetnam to fish researchers in the Sacramento-San Joaquin Estuary). This does not bode well for survival of the threatened delta smelt, particularly with the recent discovery of hybridization between it and the wakasagi.

The wakasagi is now established in other areas throughout the state, in most cases as a result of transplants (purposeful or accidental) from California waters.

4.20. Kokanee salmon, freshwater form of the sockeye salmon, Oncorhynchus nerka (Walbaum)

The kokanee, as it is usually called in California, has been classed as a subspecies, Oncorhynchus nerka kennerlyi (Suckley), or a full species, O. kennerlyi (Suckley), but it is now generally considered to be a freshwater form of the sockeye salmon. It is true that the sea-run form is not alien to California from the Sacramento River north, but it occurs only rarely in our waters, and the planting of the landlocked form constituted a definite introduction since no similar native stock was present.

Sometimes called the little redfish or blueback and commonly miscalled the "silver trout," it is a small landlocked form native to lakes of the northwestern states (Pend Oreille in Idaho, for example), Alaska, British Columbia, and Hokkaido (Japan). Although it does not attain a large size, it is a good game fish with excellent eating qualities, and in 1941 was introduced into this state for a specific purpose: to provide a game fish suitable for artificial lakes with heavy fluctuations of water level. Such lakes have a paucity of bottom foods, and at that time California reservoirs lacked planktivorous fish such as the threadfin shad. Furthermore, in some California reservoirs, the tributary streams which are major spawning grounds for salmonids are not uncovered until the water drops in autumn. Since the kokanee is a plankton feeder as well as a fall-spawner, it was thought that it might be more successful than other coldwater fishes. As it can be taken by trolling or jigging, on bait, or at times by fly, its popularity as a game fish was the basis for its introduction.[50]

Its 1941 introduction was not signalled by formal publication until seven years later when Curtis and Fraser (1948) described the original and some subsequent plantings. There was, however, a prior, although much less detailed, account by Taft (1945) which merely said: "An experiment started in 1941 bore fruit in 1943. The 'kokanee' ... was introduced into Salt Springs Reservoir on the Mokelumne River [it is actually on the North Fork of the Mokelumne River in Amador County] in July, 1941. These fish throve and reached maturity in the autumn of 1943 when eggs were taken for transplanting. To the eggs thus obtained were added others purchased outside the State and the experiment is now being extended by planting these fish in several other lakes in different parts of the State."

This delay in reporting, and certainly the delay of the detailed report by Curtis and Fraser (1948), was in marked contrast to the rapidity with which most earlier and some later introductions of fish to California were heralded. The circumstances, however, were different with respect to the introduction of the kokanee. Both A.C. Taft (then Chief of the Bureau of Fish Conservation of the California Division of Fish and Game) and Brian Curtis (its Supervising Fisheries Biologist) were conservative men who wished to proceed cautiously. In fact, Curtis wrote, "We are not making any of the kokanee information public until we can be sure of having fish to supply the expected demand" (letter of 2 December 1943 to W.A.D.). In another letter (5 December 1946 to the Bureau of Fish Conservation), Curtis reported that kokanee had been found "... during the last week ..." in and around the mouth of a small stream which flowed through the Tahoe State

[50] Kokanee were not introduced into California as a forage fish as Moyle (1976a; 1976b, p. 122) stated.

Hatchery into Lake Tahoe. He thought that they must be survivors of some which escaped while they were being raised in the Hatchery. They were in their third year and their numbers indicated high survival. Another mitigating circumstance was the onset of the American World War II years (1941–45). Salt Springs Reservoir, site of the original plant, was closed shortly after the first plant was made.

Curtis and Fraser (1948) said that the eggs first introduced were obtained from Idaho through the U.S. Fish and Wildlife Service and hatched at Basin Creek State Fish Hatchery near Sonora, and that the fish were planted 12–16 July 1941 at a length of a little under 2 inches. Tests in the spring of 1943 showed the kokanee to be abundant and easily caught at a length of about 10 inches. In November 1943, at a length of 11 to 12 inches and at the end of their third year, they were ready to spawn and some 300,000 eggs were taken from 626 females. A total of over 3000 fish were caught in seines at this time.

Kokanee were then planted in other lakes, especially in the Donner-Tahoe area, but in 1945 new introductions ceased for several years although maintenance stocking continued in some of the previously planted waters, primarily Donner Lake where an important kokanee fishery had developed.

In 1951, kokanee from eggs taken from a tributary of Kootenay Lake in British Columbia were planted by the State in Shasta Lake in an effort to establish a forage fish for Kamloops rainbow trout. A large self-sustaining population of kokanee developed rapidly and renewed interest in its possibilities for large cool lakes. From 1951 on, kokanee salmon were planted in other lakes by the State: in reservoirs (e.g. Millerton and Folsom), in natural lakes controlled by dams (e.g. Donner), and in completely natural lakes. Some of these were coldwater lakes or reservoirs; some were "two story" reservoirs with bottom waters cold enough for salmonids and top waters warm enough to grow warmwater species successfully.

As a sport fish, kokanee have been considered to be a success in many California waters. Their populations have been maintained through natural propagation, as they are able to spawn both in streams and on gravelly shores, sometimes even under poor conditions (Kimsey 1951), and by stocking, using either California stock or that derived from other areas such as Colorado, Idaho, Montana, and British Columbia. Owing to their relatively small size (varying from water to water from about 8 to over 14 inches in length), they do not typically provide a "trophy" fishery but are nevertheless popular and augment the catch in many waters. A few reservoirs, notably Stampede and Shaver, provide anglers with kokanee in excess of 18 inches. The Department of Fish and Game, while feeling that one of its primary duties is to maintain fish stocks for angling, has also helped anglers to adopt methods which will catch kokanee (see, for example, Beland 1965).

The observation of kokanee spawning has also become a use of this resource in California. During this fish's spawning period in the Tahoe basin, usually centered in the October–November period, some people simply watch kokanee salmon spawning. Taylor Creek, which flows into the southern end of Lake Tahoe from Fallen Leaf Lake, is a favored area for kokanee watchers, and information on kokanee spawning activity can even be obtained by calling Lake Tahoe authorities.

The overall status of kokanee in California has been well summarized by Seeley and McCammon (1963, 1966). Among their findings influencing the use of this fish in California are that: kokanee must have a cool, well oxygenated layer of water available; different strains exist; their spawning time varies; they provide a relatively cheap return to the angler; and they feed primarily on pelagic zooplankton. They also pointed out that kokanee may compete with trout, have not been proved to have value as forage for large trout in California, and sometimes produce large populations that are relatively unaffected by angling. In general, Seeley and McCammon felt that unless kokanee were known not to be detrimental, and would actually add to the total catch, their plants should be restricted.

At a later date, Cordone et al. (1971) discussed kokanee fishing at Lake Tahoe, concluding that the fishery should be enlarged in both space and time. Even later, Morgan et al. (1978) felt that the impact of kokanee on Lake Tahoe had not been of lasting benefit to basin fishermen, but their discussion also revolved upon the introduction of the opossum shrimp (Mysis relicta) and that kokanee alone could not be blamed for the disappearance of three cladoceran species.

It seems apparent to Department fishery biologists that kokanee do not compete well with other planktivorous fishes and invertebrates. For example, kokanee salmon populations have been depleted or even extirpated through competition with threadfin shad at Shasta Lake (Shasta County) and Millerton Lake (Madera/Fresno counties), with wakasagi at Lake Almanor (Plumas County), and with opossum shrimp at Lake Tahoe (Placer/El Dorado counties) and Trinity Lake (Trinity County).

The Department's kokanee management program was advanced with the establishment in 1992 of a cooperative program with the California Inland Fisheries Foundation. Called "Project Kokanee," monies from the private sector help the Department fund equipment used in egg procurement, hatching, and rearing of kokanee for stocking in California lakes and reservoirs. Ten to 15 waters, most of them located in the central Sierra Nevada, are stocked annually with kokanee fingerlings. The eggs originate from kokanee runs in California or from other states, usually Colorado.

Generally speaking, especially since the establishment of kokanee has been a comparatively careful one, the introduction of this species seems to have been beneficial to California.

4.21. Kamloops rainbow trout, Oncorhynchus mykiss kamloops (Jordan)[51]

Like the kokanee salmon, the species to which the Kamloops rainbow trout belongs is native to California. However, this subspecies was introduced into California as a new form.

This variety of trout, North America's largest, is native to certain large lakes in central British Columbia. According to Smith (1991), two distinct strains of Kamloops trout exist in Kootenay Lake: the "standard" Kamloops that feeds on invertebrates, matures at an early age, and attains a mean size of 3 to 4 lb; and the Gerrard strain of the Lardeau River that matures at a late age, lives on kokanee, and attains a maximum weight of about 50 lb. A 52-lb specimen from Jewel Lake in British Columbia holds the record. However, it was trapped during egg-taking operations, and the official angling record is a 37-lb specimen from Lake Pend Orielle in Idaho. The Idaho Kamloops originated from the Gerrard strain, which is apparently the one that has been distributed all over the world (Mottley 1947). Supplied with an abundance of small kokanee, as in Lake Pend Oreille, this strain has the genetic potential to attain extreme size.

According to Wales (1950): "The first known introduction of Kamloops rainbow trout ... into California waters was made on June 17, 1950. At that time, 1,000 fish were liberated in certain tributaries to Shasta Lake, Shasta County...." A list provided by Wales showed that Shasta Lake itself received 200 of these fish and that its immediate tributaries (e.g. the McCloud and Sacramento rivers) received 800 more. The eggs were imported in 1949, and at the time of planting the fish were 11 months old and averaged 12 to the pound. All of the planted fish were marked to see if returns indicated that the introduced fish would grow fast and be a better game fish than the native rainbow as the sportsmen believed, but the results are unknown.

The introduction of the Kamloops rainbow trout marked the culmination of a long campaign to bring this game fish to California. In 1946, a group of northern California sportsmen under the leadership of H. Clineschmidt of Redding started the plan to plant Kamloops in Shasta Lake.

The Department of Fisheries of British Columbia began to stock this variety of rainbow in barren lakes in 1910, established a hatchery near Kamloops, and distributed it all over the world. It gained a reputation as a fine game fish and in 1941 was planted in Lake Pend Oreille, Idaho, to develop some spectacular fishing, especially for large fish. It was the fishing at Pend Oreille that gave Cline-schmidt

[51] Introduced as Salmo gairdnerii kamloops. Differences between the Kamloops and the California stocks of Oncorhynchus mykiss are outlined by authors such as Behnke (1992) who called the Kamloops the "Columbia River redband trout" (O. m. gairdneri) and said that its lacustrine populations are commonly called Kamloops trout.

and his group the idea of stocking these fish in Shasta Lake. The then Division of Fish and Game was not particularly favorable to planting them, feeling that the stock of rainbow then present in the reservoir was quite adequate, and having received information from fishery biologists in the Pacific Northwest indicating that Shasta Lake was not especially suited for Kamloops. As a consequence, the fish were reared at the Coleman Hatchery of the U.S. Fish and Wildlife Service. The State did, however, accede to Clineschmidt's request and assisted in the venture.

Clineschmidt's organization, known as California Kamloops, Inc., offered life memberships to support it, had a club camp at Dekkas Creek on the McCloud River arm of Shasta Lake, and planned an annual planting of the year's production of Kamloops (Matthews 1952). The organization was also instrumental in planting kokanee salmon in Shasta Lake as forage for the Kamloops but did not initiate this practice in California.

As with many fish stockings, both the source of the introduced stock and the number of fish planted varies with the informational reference. Wales (1950) identified Idaho as the source of the original plant of Kamloops in California in 1950, but L. Shapovalov (table attached to 3 June 1955 letter to C.F. Pautzke, Chief of the Division of Fishery Management of the Washington Department of Game) gave Nelson, British Columbia, as the source. The table summarizes the first five years of Shasta Lake plants by California Kamloops, Inc., as follows: 934 from Nelson in 1950; 25,232 from Nelson in 1951; 71,654 from Nelson in 1952; 28,493 from Greenaugh, Montana, in 1952; 51,778 from Nelson in 1953; and 83,936 from Missoula, Montana, in 1954.

The exact number of fish planted is usually not important, but it may be of some interest to note that both Wales (1950) and an undated brochure issued by California Kamloops gave the number of Kamloops stocked in 1950 as 1000, Shapovalov's letter of 1955 to Pautzke said 934, and Matthews (1952) said that 1319 Kamloops were planted.

The Department has maintained a broodstock of Kamloops rainbow trout at Junction Reservoir in Mono County (Busack and Gall 1980). The stock originated from eggs obtained in 1964 from the Oregon Department of Fish and Wildlife's egg-taking stations at Diamond Lake. Eggs acquired from Pennask Lake, British Columbia, established the Diamond Lake population. The Junction population is a true "wild" broodstock since no continuing hatchery broodstock is maintained and all fish returned to the Reservoir are from eggs taken at the Reservoir. The eggs are reared at Department hatcheries and stocked mostly as fingerlings by airplane in backcountry lakes in the southern Sierra Nevada, with lesser numbers of yearlings released into Crowley Lake, Mono County.

Recent egg take from Junction Reservoir Kamloops totaled about 1 million eggs annually (State fish culturist D. Redfern, 8 March 1994 pers. comm.). State Kamloops production goals for 1997 call for fingerlings for backcountry lakes and subcatchables for Crowley Lake. Remote lakes in the central and northern Sierra Nevada and the Cascade Mountains managed with rainbow trout are stocked with fingerling domesticated Mt. Shasta or Mt. Whitney rainbow strains or with the wild strain of Eagle Lake rainbow trout, Oncorhynchus mykiss aquilarum. If more Junction fingerlings were available, it might be the strain of choice for some of these waters also.

The reliance on Junction Kamloops for backcountry lake management is based on a study by Partridge (1978) who compared plants of fingerling Kamloops with fingerling Mt. Whitney rainbow, a domesticated strain commonly used for this purpose. Gillnetting once each summer over a 5-year period, he found that "More than twice as many Kamloops as Whitneys were collected. The greatest differences were in lakes containing eastern brook trout, where the Kamloops exceeded the Whitneys by a ratio of five to one."

Trials in Beardsley Reservoir, Tuolumne County, using wild strains of Kamloops rainbow from British Columbia and Diamond Lake, found the Kamloops to be superior to two other domesticated strains of rainbow trout in terms of harvest, although they had a greater tendency to leave the reservoir during periods of spillway discharge and were less available to shore anglers (Cordone and Nicola 1970).[52] Kamloops also performed well in comparison with other rainbow strains in tests conducted at Jackson Meadows Reservoir, Sierra and Nevada counties (Rogers 1980).

From 1960 through 1964, numerous groups of marked or tagged rainbow and cutthroat trout were stocked in Lake Tahoe (Cordone and Frantz 1968; Nicola and Cordone 1974). Fingerlings, subcatchables, catchables, and 2-year-old fish were studied. None of the plants was deemed successful. The larger domesticated rainbow trout gave the highest immediate returns to the angler. The Kamloops, however, gave the best long-range returns, apparently because they dispersed more rapidly from the stocking site where heavy angler pressure was applied. Kamloops were also the most abundant stocked trout in both the pelagic zone and in the tributaries to the Lake.

Unpublished studies at Crowley Lake in Mono County showed that plants of yearling Kamloops grew rapidly and returned well to the angler. They were more surface- and shoreline-oriented than other strains of rainbow trout (State biologist C. Milliron, 17 March 1994 pers. comm.).

The most recent importation of Kamloops rainbow trout occurred on 19 February 1986 when 200,000 eggs were received from the Federal Fish Hatchery at Ennis, Montana. The resulting fish were marked and planted as fingerlings in: Upper Sardine Lake, Sierra County; Frenchman Lake, Plumas County; and Lower Echo Lake, El Dorado County. The purpose was to compare this strain of

[52] Fry (1973) said that some marked Kamloops passed through the turbines of Shasta Dam, migrated to the sea, and returned to the upper Sacramento River as "steelhead."

Kamloops with the Junction Kamloops and other strains of rainbow trout in fingerling management programs, but the study was terminated before definitive results could be obtained.

Kamloops appear to be more responsive to fly fishing than domestic strains of rainbow trout reared and stocked by the Department. In a comparison of fingerling plants, Wales and Borgeson (1961) found that 14.8% of the Kamloops catch at Castle Lake in Siskiyou County was taken on artificial flies, compared with only 8.4% for domesticated trout. They also referred to unpublished Departmental data in which 50% of the catchable-size Kamloops stocked in lakes in the Lakes Basin Recreation Area in Sierra County were taken on artificial flies, while only 15% of the catch from a comparable lot of catchable-size domesticated rainbow was taken by fly anglers. They go on to say, "Judging from unsolicited comments from anglers and from personal experience, the Kamloops also exhibit a fighting ability superior to that of domestic strains." In addition, Partridge (1978) observed, "The Kamloops appeared to be a more active surface feeder than the Whitney [a domesticated strain] and were readily caught by fly fishing in all the lakes."

Using "Coleman Kamloops," a domesticated strain held at the Coleman National Fish Hatchery for (at the time) 19 years and perhaps crossed with other rainbow from the Sacramento River, it was found that this strain showed more promise for trout lakes with threadfin shad populations than another (Mt. Whitney) strain of domestic rainbow (Rawstron 1972). Other experiments by Rawstron (1977a) showed that the "Coleman strain" (which he then considered to be domestic) showed a clear superiority over both "Shasta" and "Whitney" strains in two California reservoirs. Another experiment (Rawstron 1977b) in one of the same lakes (Berryessa) showed Eagle Lake rainbow to outperform Coleman rainbow.

The introduction into California of Kamloops rainbow trout can be considered a benefit for trout anglers, especially those who fish high-mountain lakes in the state's many wilderness areas. That the Kamloops in California waters has not attained the large size of specimens from British Columbia and Lake Pend Orielle is likely a function of the limited food base in California trout waters.

4.22. Colorado River cutthroat trout, Oncorhynchus clarki pleuriticus (Cope)

The Colorado River cutthroat trout has been recorded (as Salmo clarki pleuriticus) in the lower Colorado River drainage, especially the Salton Sea, since 1916, and the last published record of its occurrence there was in 1930. Nevertheless, Dill (1944) felt that records of its presence in the lower river or its lower drainage were rather old and that some might be dubious. Professor R.R. Miller (pers. comm.) also cast doubt on its occurrence here, and it was dropped from the main list of freshwater and anadromous fishes of California by Shapovalov et al. (1959).

The original distribution of the true Colorado River cutthroat trout apparently included the upper Colorado River drainage, including the Green and San Juan River systems of Wyoming, Colorado, Utah, New Mexico, and Arizona (Behnke 1992).

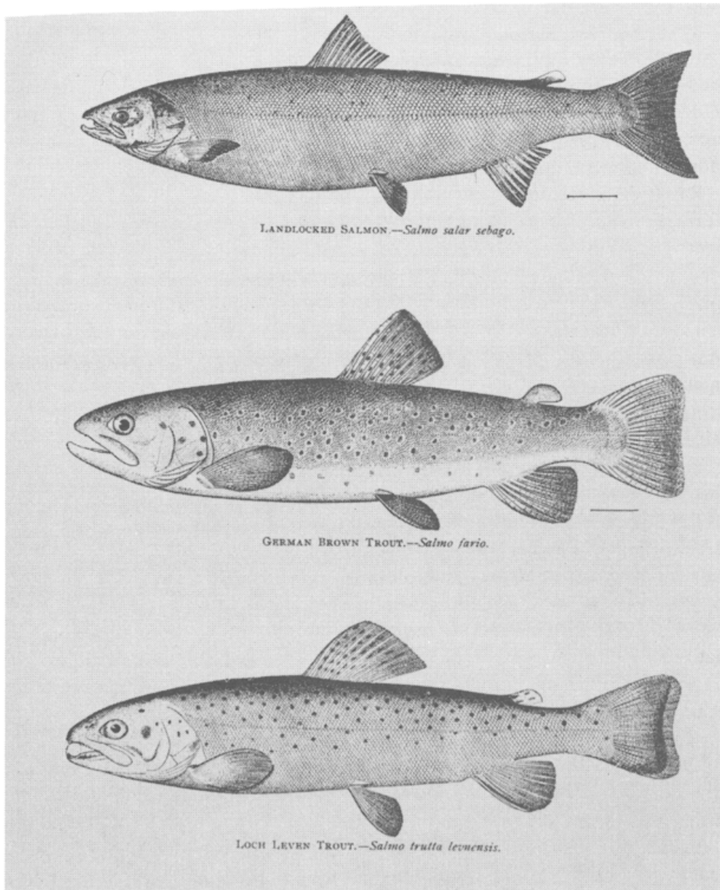
In 1931, 30,000 black-spotted trout eggs, said in the Mt. Whitney Hatchery, California, log to be "Native trout of Colorado" were received by the State from the Colorado Game and Fish Commission in exchange for 25,000 golden trout (Oncorhynchus mykiss aguabonita) . [53] It was felt that these were Colorado River cutthroat, then known as Salmo clarki pleuriticus, from Trapper's Lake, Colorado, which was the main source of Colorado's cutthroat trout eggs.

Recognizing the unique character of these fish, J.O. Snyder, Chief of the California Bureau of Fish Culture, directed the Mt. Whitney Hatchery Superintendent to rear them in a remote section of the hatchery and plant them in an isolated location to preclude mixing or later hybridization. The instructions were followed to the letter, and the resulting fry were stocked in three of the seven barren Williamson Lakes, Inyo County, all above 11,000 ft in altitude and very difficult of access. A field check made in September 1974 revealed a thriving population in all of the lakes planted in 1931. It was felt at the time that despite any change in the status of this subspecies in its native range, the Williamson Lakes contained a reservoir of an essentially pure strain.

The above account, from Pister (1975), was the first notice of the presence of this subspecies in California, and in a personal communication he has informed us that he was reluctant to disclose the whereabouts of this stock to the public lest it be exploited. He did, however, repeat some of the information and amplify some of his remarks in later publications (Pister 1983, 1988, 1990). For example, he gave the date of stocking the Williamson Lakes with this subspecies as 9 October 1931 (Pister 1983). Because the Colorado River cutthroat trout in its native range has declined to the point where its existence is threatened, the Williamson Lakes population has special significance (Gold et al. 1978; Martinez 1988; Behnke 1992).

Gold et al. (1978) studied the meristics and morphometrics of 21 Colorado River cutthroat trout from the Williamson Lakes, comparing them with Colorado River cutthroat trout reported in the literature. They found that "No apparent differences in meristic characters exist between S. c. pleuriticus from Williamson Lakes and S. c. pleuriticus from Wyoming, Colorado, and Utah ..., we conclude that the Williamson Lakes trout are a phenotypically pure population of S. c. pleuriticus. " Gold et al. (1978), who repeated some of the information given by Pister (1975), erred in saying that the trout fry were stocked in five Williamson

[53] It was not until 1948 that the California Legislature prohibited the transportation of golden trout eggs or fry out of the state. This law was repealed by the Legislature in 1993.



Fish illustrations from Smith (1896) and biennial reports of the State Board of Fish Commissioners of the State of California (landlocked salmon, German brown trout, and Loch Leven trout).

Lakes. They were stocked only in three lakes and are currently found only in Lakes 1, 2, and 3 (E.P. Pister, pers. comm.).

The establishment in the Williamson Lakes of a pure population of the Colorado River cutthroat trout was a fortuitous event for the preservation of the subspecies which had been depleted in its native range. To assist in its restoration in Colorado, almost 300 adults were collected from the Williamson Lakes in August 1987 and transported to Colorado where they were stocked in Bench Lake and Ptarmigan Creek in Rocky Mountain National Park (Pister 1988, 1990). Although some questions remain concerning the purity of these fish, Martinez (1988) maintains that "... their progeny could be the purest existing Colorado River cutthroat trout available for reintroductions."

4.23. Brown trout, Salmo trutta Linnaeus

The "German Brown" or "Von Behr Trout" and the "Loch Leven Trout" were introduced from Europe into the eastern United States and from there into California as separate species. Their subsequent history has been somewhat confused. According to Mather (1889), the first brown trout in America were hatched in New York state in 1883. The eggs came by ship from Germany as a personal gift from Baron L. von Behr, President of the Deutscher Fischerei-Verein, to Fred Mather, angler and pioneer fish culturist.[54] According to Heacock (1974), part of this hatch was retained at the New York State Hatchery at Cold Spring Harbor where Mather was in charge, part sent to the New York State Hatchery at Caledonia, and the remainder to the U.S. Fish Commission's hatchery at Northville, Michigan.

The first "Loch Leven" arrived by ship in the United States in 1885, being sent as eggs from Scotland's Howietoun Hatchery to the U.S. Fish Commission and taken to the Cold Spring Harbor Hatchery (Smiley 1889). Heacock (1974) said they arrived in 1884, but according to Smiley (1889) this was the year the eggs were taken in Scotland.

It is not considered that there is any major distinction between the two trouts; they are treated here, as is now general elsewhere, as one species. The brown trout, or Salmo trutta, is the "trout" of Europe, being known as the Bachforelle of Germany, or the trout or brown trout of Great Britain. (See Blanc et al. 1971 for

[54] R.J. Behnke of Colorado State University (pers. comm.) agrees that this is the "official line," but believes that brown trout were hatched in 1864 or 1865 in New York City where all the young died (New York Tribune, 7 October 1865).

The open jealousies of the fish culturists of the day are illustrated by some of Fred Mather's remarks concerning Seth Green, who first brought shad to California: "... Mr. Green ... never could admit that there was more than one fishculturist on earth.... The unfortunate prominence which the newspapers gave him retarded fishculture some years, through his antagonism to Prof. Baird and all other fishculturists...." (Mather 1909).

a list of common names in Europe.) It extends naturally throughout the continent and its island adjuncts, North Africa, and parts of Asia. It has many forms, some termed subspecies, and when originally introduced into the United States and later to California, the usual scientific name applied to the German stock was S. fario, and S. levenensis or S. trutta levenensis to the Scottish stock.

At an early date, and reemphasized throughout the years, most authors writing in California publications considered them as one species, saying that even if there were any decided differences between the two originally, the imported stock had hybridized to such an extent that no distinction could be made between them. Despite an attempt to establish "official common names" (Walford 1931) by calling Salmo trutta "brown trout," the State of California used only the term "Loch Leven" in its planting reports starting in 1933. Nevertheless, the two terms "brown" and "Loch Leven" were used in various State publications for many years.[55] Sometimes only one of the names was used; sometimes both were used. In some cases, the term "full blooded brown trout" was emphasized (Shebley 1925). Although many sportsmen continued to distinguish between "German browns" and "Lochs," the State finally changed to the one term "brown trout" in its official documents. (The term "German" was generally dropped throughout the United States during and following World War I.)

Persistence of the name "Loch Leven" in State records is due in part to A.C. Taft, former Chief of the Bureau of Fish Conservation for the Division of Fish and Game, who expressed his belief that it was more "romantic" than the term "brown trout" (personal conversation with W.A.D. circa 1951). Change to the more universal name "brown trout" may have also been slowed by the reluctance of some Division employees to incur the expected criticism by some sportsmen that by a name change the State was "trying to put something over on us."

Regardless of the name or date of arrival in the United States, eggs of the brown trout were sent from New York to the Northville, Michigan, station of the U.S. Fish Commission. From here, 25,000 eggs of the Von Behr or European brown trout (Salmo fario) were sent to the U.S. Fish Commission's Fort Gaston Hatchery near Willow Creek, Humboldt County.[56] The U.S. Fish Commission Report for 1893 (p. 119, 132) stated that "Von Behr Trout" were liberated from its Fort Gaston Hatchery in May 1893 into several streams in Humboldt County, and later Reports of the U.S. Commission list more plants from here of this variety in northern California, including the Country Club of San Francisco and

[55] The statement of California (1969, p. 52) that "In the 1930's the decision was made to have the official name agree with the official or common name used for these fish in Europe...." was erroneous.

[56] The Fort Gaston Hatchery (1889–98) was erected by the Federal Government on the grounds of a former military reservation on the Trinity River about 14 miles from its mouth on the Hoopa Indian Reservation, Humboldt County (Leitritz 1970; Roberts 1988).

streams in Marin County. They also wrote of eggs of Von Behr and Loch Leven going to the California Fish Commission or to Sisson (Mt. Shasta) Hatchery in Siskiyou County (U.S. Fish Commission Reports for 1895 and 1896). Smith (1896) also listed the plants in detail. The Report of the U.S. Fish Commission for 1893, p. 15, also stated that 20,000 Loch Leven eggs were sent to the California Fish Commission in 1893. However, the California Fish Commission's Report for 1893–94 said that it first received Loch Leven eggs in 1894, as did Shebley (1917).

Further confusion as to the introduction into California was caused by Shebley (1922) who listed 14,478 "German brown" trout as having been distributed by the State in 1891, although no other authors nor even Shebley in his other articles mention this. Furthermore, Shapovalov (1965, 1970) cited 1895 as having been the year of successful introduction of this species. To compound the confusion, we find Moyle (1976a) citing "Shelby, 1917" (obviously Shebley) as specifying the year 1872 as the first introduction of Salmo trutta to California. The species had not even entered the United States at that time nor did Shebley make this remark. The Report of the California Fish Commission for 1893–94, p. 25, said that Salmo trutta was brought to the United States in 1872–another clear case of the danger of using a reference well removed from the original source. It also said (evidently erroneously) that the California Commission received 30,000 Loch Leven eggs from the U.S. Commission in 1894. But enough of this comedy of errors. We wish only to note that a number of California authors have listed the introduction of Salmo trutta to California as 1894. It is believed that their statement was based primarily on Shebley's (1917) account that in February 1894, 20,000 Loch Leven eggs were sent to the California Fish Commission from the U.S. Commission at Northville, hatched at Sisson, and later distributed to public waters. Shebley (1917) also said that in 1895, 135,000 "Von Behr or German brown" eggs were hatched at Sisson, some of the fry being retained as brood-stock and others being distributed to a number of lakes in the "high Sierra." (This might explain Shapovalov's 1965 remark concerning the first successful introduction of brown trout in California in 1895.) However, Shebley clearly followed his statements as to the 1894 and 1895 plants by saying, "Previous to this the federal government had made several plants in the state."

We hold to the opinion that 1893 was the year of the initial plant of Salmo trutta in California under the name "Von Behr Trout." The year of first planting was corroborated by Wales (1957) who gave particular attention to this species. The date of this original introduction to California means little, however. Since 1894 there has been but one year (1903) when S. trutta has not been hatched and planted by the State. In fact, at one time more brown trout fingerlings were planted annually in California than any other species. For example, in 1936, when fingerlings were still being planted in large numbers, 18,050,630 "Loch Leven" were planted; the next most abundant among those fish planted were 12,681,256 rainbow and steelhead trout (CC 1937c). However, by 1997 production goals had declined to about 230,000 brown trout fingerlings and 235,000 catchables and subcatchables.

California began to take its own eggs of this species in 1897 and built up a large broodstock (California Fish Commission Report for 1897–98, p. 38). Eggs have also been taken from wild brown trout in California. The State has also obtained brown trout eggs from the federal Government and from several states, including Massachusetts, Minnesota, and New Jersey. California (1969) stated that the Massachusetts strain (a highly domesticated one imported in 1954) "... is much easier for the average angler to catch." This strain has since been discarded because it lacked disease resistance. The Department continues its efforts to improve its brown trout broodstock, and in recent years has imported eggs of domesticated brown trout from hatcheries in New York, Utah, and Wyoming to meet this goal.

Two of the primary purposes for the continued propagation of brown trout in California were: i) an endeavor to furnish a nonmigratory trout to waters where the native rainbow evidenced traveling tendencies (in the lower reaches of coastal streams, for example),[57] and ii) to establish a trout in the lower, warmer waters of large streams. For example, Greene (1926), then the Executive officer of the California Division of Fish and Game, noted that brown trout were to be planted below the 3500-ft contour or where they could not pass into rainbow streams. Their reputation as denizens of "warmer" waters may have come from their well-earned reputation as inhabitants of waters warmer than those tolerated by the native brook trout (Salvelinus fontinalis) of the eastern United States. Brown trout have, however, been stocked as fingerlings and in large numbers in almost every type of trout water and drainage in the state.

Another basic reason for the continued propagation of brown trout in California hatcheries was the feeling by some fish culturists that it was easier to raise than rainbow. Brown trout actually grow more slowly than rainbow and are rarely raised at commercial hatcheries, where the well-domesticated rainbow is the predominant trout throughout the world.

Poor survival of planted brown trout fingerlings has been observed in some streams, but it has not been proved that this is the fault of the species. Other trout species planted as fingerlings may also have had poor survival in some of these waters; their presumed survival may actually have been better explained by the presence of naturally spawned individuals. In some waters, however, brown trout seem to persist in spite of little stocking and in the face of heavy fishing, and often attain a larger size than strictly resident native trout.

[57] The native Lahontan cutthroat trout (Oncorhynchus clarki henshawi) used to be selected for this purpose. Literally tons of them have been planted as fingerlings in coastal streams with little or no return.

The advent of the brown trout in the United States was received with mixed feelings and many opposed its introduction. See, for example, the sentiments quoted in Leach (1923a). Many of the same sentiments were expressed in California where those opposed to the species complained of: its predacity or "cannibalism," the difficulty of catching it, its failure to rise to a fly, its lack of fight, its failure to jump, its lack of beauty, its unpalatability. A portion of this criticism was continually refueled by certain newspaper outdoor writers such as Tod Powell who seemed to take delight in constantly demeaning the brown trout as an "exotic pig-fish" (San Francisco Chronicle, 20 May 1949, p. 41). (The senior author, one of the early inland fishery biologists in the state, used to feel at times that if "Lochs" were eliminated he would have few problems with sportsmen. He could only take solace in knowing that some of these sportsmen could not even identify the species correctly.)

Our popular rainbow trout has been accused of many of these same characteristics in England where the brown trout is native. See, for example, the discussions in old copies of the *Salmon and Trout Magazine*. It is quite true that some specific criticism of the brown trout is justifiable. Nevertheless, condemnation of the species as a whole on any one or all of the above points is unwarranted. In some waters of our state, the brown trout has had an admirable success based on its angling quality, and each author can attest to many cases where brown trout have fought just as well or better than rainbows from the same waters, where they have jumped just as much, and where they have been very good eating.

Furthermore, the brown trout has many other friends in the angling community. Westman (1961), for example, stated, "The brown trout is one of the most perfectly suited water animals ever introduced to the North American continent." Heacock (1974) said, "The brown trout is a delight to the eye, exciting to the mind, stimulating to the spirit, and delectable to the palate," and "To the dry fly fisherman the brown trout is the wariest, wiliest, most fascinating, challenging, respected and best-loved trout of all." One can find many California anglers who will share these paeans and request that browns be stocked.

There has long been controversy, however, as to the advisability of this introduction both in the eastern states and in California. As early as 1900, the Commission decided to discontinue the propagation of brown trout, feeling that the fish was too predacious (California Fish Commission Report for 1901–02, p. 19). The stock of brood fish was, therefore, reduced by planting it. (The dictum of most hatcherymen at that time was never to destroy anything despite the consequences.) However, despite the claim of some "that they are so destructive that all other forms of trout life must disappear," the stock of brown trout was soon restored (1906) and the Commission stated, "... this hardy and gamy fish is a decided acquisition to our trout supply. It is easy to raise and apparently less liable to disease than any other trout we handle ... we expect to continue the propagation and planting of this fish with special reference to stocking the smaller lakes...." (California Fish Commission Report for 1905–06, p. 44). Furthermore, the success of "Loch Leven" in the Twin Lakes in Sequoia National Park prompted the planting of many barren lakes in the southern Sierra Nevada circa 1911, according to Ellis (1915).

Less inclusive today, either in praise or scorn, the State has a more rational policy concerning the species. The comparative number of brown trout planted has greatly diminished and attempts have been made to confine the species to a more limited area (see, for example, *Outdoor California* 3 [29], published in 1943).

Taft (1939), referring officially to the State of California, stated, "... definite steps have been taken ... to reduce the number of Loch Leven." Von Geldern (1959) placed the date of curtailment of brown trout planting in California as 1940, and added that the State "... gave up widespread stocking of brown trout fingerlings in streams for just one reason—it didn't pay." Staley (1966) agreed with the date of 1940 but stated, "... drastic reduction occurred because of a growing consensus that they were too difficult to catch...." He also said, "... fish culturists consider them difficult to rear." We agree generally with von Geldern but again wish to point out that trout fingerling stocking in streams generally produces few results despite the species used. Furthermore, in 1953, a leaflet issued by the Department of Fish and Game to review its progress (California 1953a) claimed, "Studies have shown that brown trout are providing good fishing in a certain class of California streams and lakes." Specific studies of the role of brown trout in California started at about the same time. The then Director (S. Gordon) of the Department of Fish and Game issued a memo on 13 May 1954 to all the Regional Managers pointing out that it had become evident in 1952 that the Department had gone too far in cutting down on brown trout, and advised some cautious resumption of their planting.

There have also been attempts to reduce or eliminate brown trout from certain habitats. Not only did Hubbs and Wallis (1948) recommend that stocking of brown trout, a species which they said was "regarded as generally objectionable," be discontinued in the waters of Yosemite National Park, but they recommended the lessening or removal of fishing restrictions on it "... or its depletion in the Valley by other means." Seven years later, Wallis (1953) stated that as part of the Trout Fishery Management Program of the Park, brown trout should not be stocked in any Park waters "at present," but that current studies might "... justify supplementing reintroduction of the species in the Merced River in Yosemite Valley." (In passing, it may be noted that the Merced River in the Valley is famous for its large brown trout.)

"Cannibal" browns were deliberately destroyed by the State in Convict Lake, Mono County, by netting in 1953 (von Geldern 1959). There have been suggestions that the brown trout population in the upper Trinity River be reduced by seining or electroshock to eliminate predation on anadromous steelhead rainbow

(Wertz 1979). In the South Fork Kern River drainage, "invasion" of native golden trout territory by "voracious" browns was followed by chemical treatment and electrofishing, as well as creation of barriers, to prevent the browns from destroying the native trout (Gerstung 1982).[58] According to State biologist E.P. Pister, the results, as measured in 1994, have been largely successful (pers. comm.).

Conversely, it has been suggested that browns might be considered as reducers of "rough fish" and stunted brook trout populations (Wales 1955).

In general, it is now recognized that brown trout can offer excellent fishing, especially to skilled anglers, but in many circumstances become increasingly piscivorous as they grow larger.[59]

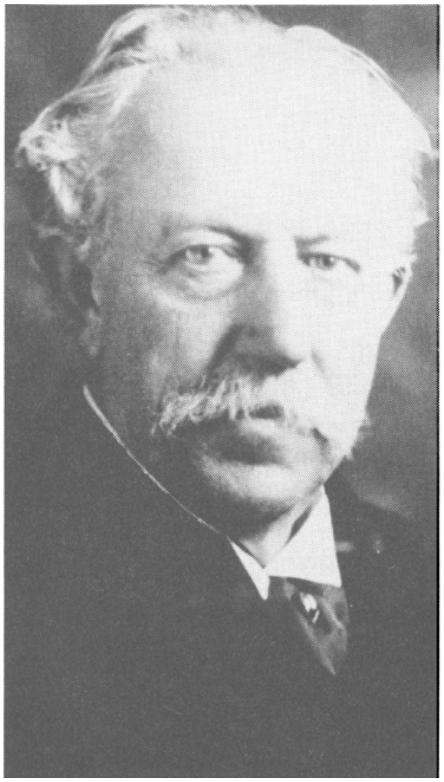
Today, brown trout thrive in sections of most of the major west slope Sierran streams and many of their tributaries. Their distribution, even in small streams here, is often quite discontinuous. Pools and the quieter waters, not necessarily low or warm waters, seem to be to their liking. (In fact, rainbow trout are somewhat more tolerant of warm water.) There are, however, some surprising exceptions, and sometimes browns are abundant in waters which, at first sight by either experienced anglers or fishery biologists, would appear to be better suited for rainbow or golden trout. In the Sierra Nevada, they often attain large size in big waters such as the Merced or San Joaquin rivers as well as in reservoirs. Their degree of success is much less in high Sierra lakes where their condition may be poorer than that of other species. In eastern California, they are well established in the Truckee, Owens, and other rivers and are abundant in some of the lakes such as Crowley in Mono County.

A number of southern California waters have resident brown trout populations. Their success in north coastal streams (where they were first planted, incidentally) is not great, although they sustain themselves in some of them by natural propagation. They are not numerous in either the Eel or in streams or lakes of the Klamath drainage where they appear to have difficulty in reproducing. A notable exception is part of the Trinity River. Although stocking of resident browns in the upper Trinity and its tributaries had ceased by 1932, a large population of naturally propagated and predacious browns is well established there (Wertz 1979).

Sea-run or anadromous brown trout have been reported occasionally in California, but are of little importance to the angler, unlike the situation in Europe where "sea trout" furnish an exciting fishery. They have been recorded, or at least their presence has been suspected, in the Sacramento, Klamath, and Trinity rivers, and possibly from the coastal Scott Creek and San Lorenzo River. See, for

[58] Courtenay, as reported in U.S. Congress, office of Technology Assessment (1993, p. 64), is in error in stating that the Little Kern River contained brown trout from which attempts were made to eradicate them.

[59] It is of interest to note that rainbow trout have been stocked in some famed European streams because they are easier to catch than the resident browns (e.g. the Test of England and the Gacka of Croatia).



example, Moffett and Smith (1950) and Fry (1973). It has been suggested for some of those from the Trinity River (where they were classed as anadromous by their appearance and by scale study) that their ocean-type growth might have been acquired in the Klamath River rather than in the sea (Murray 1965). The rare "tiger trout," a cross between the brown and the brook trout, has also been found a few times in California.

In general, the present State policy calls for the brown trout to be a dominant species in wild trout fisheries. Von Geldern (1959) said, "...it is doubtful if ever an exotic game species has been viewed with such skepticism and controversy," but as Curtis (1942) said, in somewhat abridged form, "There is a feeling among some fishermen that this trout is more cannibalistic than the other members of the genus ... this species is more difficult to catch than the others, especially in lakes; ... individuals survive to a greater size and age;... large trout, regardless of species, are more apt to be fish eaters than small ones.... As biological credit for this trout must be placed the fact that it lives ... in the slower, weedier portions of trout streams not favored by rainbow and thus brings about a more complete realization of the biological potentialities of the habitat."

Controversial or not, the brown trout has a secure place in California.

4.24. Brook trout, Salvelinus fontinalis (Mitchill)

Even before the State of California planted its first fish, eggs of the brook trout (actually a char, although commonly called the Eastern brook trout, and native to the eastern United States and Canada) had been imported and hatched by the California Acclimatization Society. The Society operated small fish hatcheries near the City Hall of San Francisco and on the grounds of the University of California at Berkeley (California Fish Commission Report for 1870–71, p. 47).

Alta California (a popular newspaper at the time) for 13 February 1871 said that 5000 brook trout eggs were received in January 1871 from the fish ponds of Seth Green and Collins in Caledonia, New York, and hatched at the Society's hatchery in San Francisco. Leitritz (1970) said that the Society, "... under the supervision of J.G. Woodbury, first began experimenting and had made several successful hatches of eastern brook trout eggs shipped from the eastern states." He also said, "After the fish hatched, they were placed in Lake Merced, ponds near San Francisco, and small streams in different parts of the state. Trout native to the Lake Tahoe area [Oncorhynchus clarki henshawi], as well as eastern brook trout, were hatched and distributed. Some fish and eggs were sold to help pay expenses. Others were retained as brood stock." Somewhat similarly, Skinner (1962, p. 207) said that the Society is reported to have raised brook trout eggs imported from the East as early as 1869 or 1870. The Society does not appear, however, to have been established until 1870, according to Alta California for 13 February 1871.

Neither the source of information from Leitritz (1970) nor Skinner (1962) is known to us, although Leitritz (1970) does seem to have borrowed heavily from Bryant (1922) and Shebley (1917), and some of his other information seems to have stemmed from Alta California. If their accounts are authentic, then plants of brook trout by the Acclimatization Society possibly preceded that of American shad, which is generally felt to be the first fish formally introduced into the state. Shebley (1927b) said, "... owing to impurities in the water, high temperature and lack of knowledge of how eggs should be handled, the efforts to raise fish were a failure." This may be true, but we respect the accounts in Alta California just as much as those of Shebley who was prone to minimize the activities of agencies other than the State of California. Moreover, his statement of 1927 concerning the Acclimatization Society did not agree with his earlier statement that the Society "... had made several successful hatches of eggs [trout] introduced from the Eastern States previous to the establishment of a state fish commission...." (Shebley 1922).

Stone (1874a), referring to the year of 1872 and the "California Acclimating Society," said, "This society has successfully introduced from the East ... the brook trout (Salmo fontinalis) , " and also that a specimen of the Lake Tahoe trout was hatched in the ponds (at San Pedro Point in San Mateo County) in April or May of 1871. Whether the Society's brook trout were actually planted in open or public waters is unknown to us, but the inference is that they were. We do know that according to Alta California for 14 February 1871, "In three months the trout [we assume brook trout] will be distributed in brooks in different parts of the state." We also know that it was determined on 19 April 1871 to put the young trout at the foot of Lake Merced. It was also proposed to bring trout from Lake Tahoe to the pond into Lake Merced, and it was expected that there would be good fishing there within a year.

Lake Merced in San Francisco County was and is well known. It was considered a true lake by Davis (1934, p. 234), and its history has been discussed by R.C. Miller (1958) who explained that this body of water, about 350 acres in extent, was formerly connected with the Pacific Ocean by a channel closed sometime between 1869 and 1894 to become essentially, as it is now, a freshwater lake. It is well known historically because of its proximity to the site of the famed duel in 1859 between Senator David C. Broderick and Judge David S. Torrey "... in the lower or westerly end of the first small ravine, which connects with the easterly shore of Lake Merced, just south of the county line between San Francisco and San Mateo" (Freeman 1938). One may view the site from the 7th tee of the old San Francisco Golf Course.

Because of recorded planting in Lake Merced of rainbow trout from Crystal Springs in July 1865 (Powell 1944), other reports that planted Pacific salmon once thrived here, and its modern record of catches of planted rainbow trout and brook trout, it is our conjecture that brook trout may well have been planted here in 1871, and thrived to be caught. Such a conjecture is based not only on the present evidence, but on the early remarks (1871) of the California Acclimatization Society and those of R.C. Miller (1958) that Lake Merced circa 1871 was brackish but very low in salinity, and might well have supported salmonids.

Whether or not brook trout were first planted in Lake Merced is, however, only of academic or historical importance. It is highly doubtful if any reproduction of the species occurred there, and Lake Merced was certainly not the area from which the brook trout spread throughout much of California.

In 1872, the California Fish Commission purchased 6000 brook trout from the Acclimatization Society, evidently paying about five cents apiece for them, and made the first well-known plants of this species in the state (California Fish Commission Report for 1872–73, p. 12, 15). Whether or not the Society planted any of its trout is unknown to us, but both Smith (1896, p. 437) and Shebley (1917) agreed that the first introduction of brook trout into California was by the California Fish Commission in 1872 which purchased 6000 fish and planted them in the North Fork of the American River, the headwaters of Alameda Creek, and San Andreas Reservoir in San Mateo County.

Occasional stocking of brook trout in other areas of the state followed. Shebley (1917) said that the first shipment of eggs (60,000) that produced results was purchased by the California Fish Commission in 1895 from New Hampshire and hatched at Berkeley. The fry from this lot were distributed principally in lakes and streams in Mendocino, Sonoma, Napa, Yolo, Alameda, and Santa Clara counties, in Prosser Creek, Nevada County, and the North Fork of the American River in Placer County. Leitritz (1970) indicated that the year was 1874, saying that this was the first official record of State hatching and planting.

In the 1890s, the State commenced its systematic distribution of this species and the Report of the California Fish Commissioners for 1888–90 was highly enthusiastic about stocking it saying (p. 39), "... it is but reasonable to suppose that as they become acclimated they will gradually descend the rivers and spread themselves over the whole State." But within only a few years, circa 1895, it was stated by J.F. Babcock, Chief Deputy for the California Fish Commission, that the brook trout had "... added but little to the attractions of the sportsmen.... The commission will make no further efforts to propagate these fish" (quotation from Smith 1896, p. 436). Although no brook trout were distributed in 1896, a change of heart was evident, since—with but one exception—brook trout have been planted annually since that time by the State. As with its fellow alien species, the brown trout, it has been planted so frequently that the date and place of the original introduction is not of much importance.

The ability of this char to spawn in lakes which lack permanent inlets (a characteristic of many high mountain California lakes) has made it a desirable addition to many waters where native trout could be maintained only by stocking. Furthermore, its fall-spawning habits, with a consequent early recovery of condition in the spring, make the brook trout a good fish for anglers at high altitudes. Hundreds of alpine lakes, usually of low pH and formerly barren of fish, now contain this species.

Its establishment in streams has not been as noteworthy. It has been a failure, for example, in southern California and in the short coastal streams where it is no longer planted. This latter fact appears to have been recognized at an early date. Early reports and several subsequent ones stressed this point. (See, for example, California Fish Commission Report for 1878–79, p. 13; *Ibid.* 1888–90, p. 24; *Ibid.* 1903–04, p. 35; *Ibid.* 1905–06, p. 32; *Ibid.* 1909–10, p. 34.) Despite this recognition, thousands of brook trout fingerlings continued to be poured into the coastal streams for many years. (Failure to be guided by the lessons of history is, of course, a universal characteristic; it is not peculiar to fish culturists.) Similarly, "big waters," streams with steep gradients, and those with marked fluctuation in volume are poor habitats for brook trout, even in the Sierra. The most suitable type of Sierra Nevadan stream seems to be one that meanders through flat mountain meadows.

The brook trout is popular with California anglers, although its fighting ability is rated below that of the native rainbow. Unlike the brown trout, it rarely attains a large size in heavily fished waters, and its freely biting habits allow many to be taken before they can grow larger. Nevertheless, the species does not grow as large as either the brown or the rainbow. We know of no good reason to accept the remarks of *Sunset* (1986) (apparently based on Cutter 1984) that the generally small size of this species is due in part to the stocking in the San Bernardino Mountains in the 1870s of a specific strain developed by Seth Green. (See paragraph two of this section.)

of more importance is page 30 of Cutter (1991) which also refers to stunted populations of brook trout in California but presents the opposing viewpoints of W. Flick (formerly of Cornell University) and those of W. Youngs (Cornell) and T. Jenkins (Sierra Nevada Aquatic Research Laboratory) concerning the growth of brook trout in California. Flick believed that typical hatchery brook trout in the United States had their origins in an artificially manipulated stock of Seth Green.[60] Conversely, Youngs and Jenkins felt that habitat (short growing season and unproductivity) was of more importance in influencing the growth rate of brook trout. From our own experience, we generally agree with them.

In a popular article, Vachini (1993) cited a handful of California lakes in which he said "... they [brook trout] have met with optimum growing conditions and

[60] It is also of interest to note that Flick (1991, p. 200–201) apparently discounted some of his earlier statements by saying that even when the progeny of slow-growing populations of brook trout are stocked in productive environments, their growth has been similar to that of resident fish. Greene (1955) had previously pointed out that observations in Wyoming showed that brook trout would grow in a fertile environment.

achieve leviathan status." However, the largest brook trout he mentioned do not really "... rival [as he said] their Canadian cousins."

In areas which are lightly fished and poor in food, one often finds large populations of small or stunted brook trout. In such waters, they have been known to attain an advanced age. For example, brook trout in the 10,900-ft Bunny Lake, Mono County, California, which was overpopulated, grew very slowly, 5-year-old fish being only 6.4 inches in total length (Reimers 1958). A single 24-year-old specimen (the last known survivor in this small Sierra lake) measured only 9.4 inches total length (Reimers 1979).

Stunted populations of brook trout have even been eliminated through chemical treatment by the California Department of Fish and Game (OC 1958b). An entire population of brook trout was eliminated by the Department of Fish and Game from a 13.5-acre backcountry lake and replanted with rainbow trout to "... allow some variety in the fish species available to anglers in the area" (OC 1959b).

A shipment of 40,000 eggs of "splake," fertile hybrids from a cross between the brook trout and the lake trout, was imported from Quebec and raised at Mt. Shasta Hatchery for test purposes (OC 1955).[61] A total of 17,500 fingerlings from this shipment was stocked in Lower Salmon and Deer lakes in Sierra County in August and September 1955. The first splake reported taken in California were caught in Lower Salmon Lake in June 1956 (OC 1956b). It was later decided that the introduction was not worthwhile (Boles and Meyer 1964).

In California, brook trout have been known to hybridize with native Dolly Varden (Salvelinus malma) at Mt. Shasta Hatchery and, in an intergeneric cross in the wild state, with brown trout to form the so-called "tiger trout."

According to McAfee (1966), anadromous brook trout (which are known from Canada and the New England states) had not yet been recorded from California (he quotes a personal communication from L. Shapovalov). Fry (1973) also said that the brook trout is never anadromous in California. Frederiksen et al. (1980), however, stated that Needham (1940) said that anadromous brook trout have been found in northwest California. We have been unable to find this latter reference and believe the statement of Shapovalov or Fry rather than the one attributed to Needham.[62]

Broodstock of the brook trout was obtained by California at an early date, and on occasion it still imports some eggs from without the state; for example, it has obtained brook trout eggs from Colorado, Massachusetts, Nevada, New Jersey,

[61] The name "splake" is derived from the "sp" of "speckled," the name usually used in Canada for brook trout, plus "lake" from the other parent.

[62] Incidentally, a syllabus prepared by Needham (1950) pointed out that the brook trout may be anadromous in the northeastern corner of the United States and adjacent Canadian coast, but he did not refer to this characteristic for the species in California.

Pennsylvania, and Rhode Island. In some cases the eggs were purchased; in many cases "California" eggs (including those of brown trout) were traded for brook trout ova.

As part of a study to evaluate the ability of various strains of brook and rainbow trout to coexist with nongame fishes and brown bullhead, the Department of Fish and Game imported about 100,000 eggs of the Nipigon brook trout strain from Ontario, Canada. They were received in January 1983, courtesy of the Ontario Ministry of Natural Resources and via the Dorion Fish Culture Station. Hatched at the Department's Silverado Field Operations Base in Napa County, 32,250 fingerlings from this Base were stocked in 14 lakes and reservoirs in the central Sierra Nevada in August 1983. Additional fingerlings were transferred to Mt. Shasta Hatchery to be reared to the yearling stage for stocking in the summer of 1984. About 30,200 yearling Nipigons were released in 12 central Sierra Nevada lakes and reservoirs. Fin marks and tags were employed to facilitate the investigation, and the Nipigons, from wild stock, were compared with the Department's Mt. Whitney brook trout, a domesticated stock. There was no difference in survival or growth of Nipigon brook trout compared with the Mt. Whitney brookies. As yearlings, however, the former were caught sooner and in higher numbers than the latter. Neither strain contributed significantly to the catch rate in the second year after release. Although the program was abandoned, some Nipigon brook trout may be established in the test waters.[63]

The Department's fingerling brook trout stocking program underwent a major change in recent years. Compared with about 1,700,000 in the earlier years, fingerling plants in the 1980s and 1990s approximated 850,000 fish annually, and the 1997 allotment was only about 750,000 fingerlings. Apparently this change was in response to growing concerns about numerous stunted brook trout populations plus a desire to provide more diversified backcountry fishing opportunities by planting more rainbow, golden, and cutthroat trout. For many years, the Department has provided anglers with a small but popular catchable brook trout program by stocking from about 50,000 to 200,000 catchable-size fish each year.

Brook trout were also distributed by the U.S. Fish Commission in past years.

Brook trout were also used in one of the first tests using sodium amytal to quiet trout transported in tank trucks (OC 1953).[64]

All in all, brook trout provide big catches in the less accessible and higher areas of California, especially in cold and placid waters. The species is considered

[63] The world record brook trout, weighing 14.5 lb, was caught in the Nipigon River.

[64] Sodium amytal, a hypnotic barbiturate, was first used by Al Reese of the California Department of Fish and Game to quiet trout during air or land transfer, and California was the first state to use drugs in fish planting.

to be an admirable success especially in the natural lakes or tarns of the Sierra Nevada, and the upper Sacramento, Feather, and Klamath watersheds.[65]

4.25. Lake trout, Salvelinus namaycush (Walbaum)

The lake trout, commonly known as the "Mackinaw," is native throughout much of Alaska, Canada, the Great Lakes drainage, and the northeastern United States. It has a limited distribution in California, being well established only in Donner, Fallen Leaf, and Stony Ridge lakes, and Lake Tahoe, although it is found in smaller numbers in a few other California waters.

Attempts at acclimatization of this char in California, the largest North American freshwater salmonid, and a resident of deep cold lakes, have been pursued at two periods in our history. The lake trout was an important food fish in the 19th century. In 1897, the lake trout commercial fishery in the Great Lakes was second only to that of the whitefish. The first plant by the State was in 1895 when 65,000 fry were placed in Lake Tahoe. These had been hatched at Sisson (Mt. Shasta) Hatchery from eggs received from the Northville, Michigan, station of the U.S. Fish Commission in 1894 (California Fish Commission Report for 1895–96, p. 30–31, 67; U.S. Fish Commission Report for 1895, p. 67). It has been pointed out in the Introduction that Shebley's (1922) record for a distribution of lake trout ("Mackinaw") in 1894 applied to eggs received—not to fish planted. His record (Shebley 1917) for a plant in 1865 is a misprint.

Most introductions of fish into California were made by the State, but the first plants of lake trout in Californian waters (Lake Tahoe) were made by the Nevada Fish Commission.[66] Possibly they were made as early as 1885; possibly not until 1889 or later. Miller and Alcorn (1946) stated that the date was 1889. However, Smith (1896, p. 433), who at least in point of time was closer to the year the initial plant was made, said: "In 1885 the United States Fish Commission sent 100,000 eggs [of lake trout] to the Nevada fish commission. One lot of 25,000 eggs was lost in transit, but the other arrived in good condition. In December, 1889, the Nevada commissioner received another consignment of 30,000 eggs, which were hatched with little loss. The State reports do not show where these fry were planted, and no data are at hand giving the results of the early plants, but Mr. George T. Mills, fish commissioner of Nevada, states that the lake-trout fry planted

[65] Brook trout are absent from southern California south of the Tehachapi Mountains and, with two minor exceptions, from the Coast Range south of the Klamath-Trinity drainage. The exceptions are Keller Lake (Glenn County), tributary to Black Butte River and then the Middle Fork Eel River; and Cow Creek (Mendocino County), tributary to Sulphur Creek and then the Eel River (State biologist W.E. Jones, 11 May 1994 pers. comm.).

[66] The Colorado River is another exception to the rule that most formal introductions of fish into California were made by the California agency concerned with fisheries.

in 1889 have done well and are multiplying. They were planted mostly in Lake Tahoe and are now occasionally taken by fishermen...." We believe that whether the first plant by Nevada was as early as 1885 or as late as 1889 is a moot point.[67] We do know that lake trout were planted in Lake Tahoe in 1889 by Nevada and by California in 1895 and that the species has been resident there for many years.

Following the 1895 plant, stocking of lake trout continued by California for four more years, and during the entire period of 1895–99, a total of 217,800 were planted by the State. Evidently, most of these were planted as fry, some as year-lings, in Tahoe and other lakes of the Truckee River basin. (See California Fish Commission Report for 1895–96, p. 67; *Ibid.* 1897–98, table preceding p. 49; *Ibid.* 1899–1900, p. 23; Shebley 1917; CFG 1920). The U.S. Fish Commission Report for 1897, p. LXXXVI, also listed 25,000 lake trout eggs as distributed to Col. S.B.M. Young, of the U.S. Army, Wawona, California.[68] The disposition of these eggs is unknown; possibly the fish resulting from them (if any) are included in the foregoing summaries of "distribution."

At a later date, condemnation of the State for planting this fish (accused of predacity and thereby decreasing the supply of other game fish) led Shebley (1929) to explain that lake trout "... were introduced into Lake Tahoe at the request of the resort keepers and market fishermen and recommended by the United States Bureau of Fisheries." Conversely, there were also residents of the Tahoe area who opposed the introduction from the start (pers. comm. from State biologist B. Curtis). Adult lake trout were kept on exhibition at Sisson (Mt. Shasta) Hatchery for some years (California Fish Commission Report for 1901–02, p. 19). It is believed, however, that no further plants were made in California until 1923 and 1924 when the State again obtained eggs from the Federal Government.

The U.S. Bureau of Fisheries Report for 1907, p. 32, also listed 50,000 lake trout eggs as assigned to the Brookdale Hatchery (Santa Cruz County) in 1907.

[67] As W.A.D. wrote R.R. Miller on 14 January 1944, "There is at least a chance that some [of the 1885 shipment] were planted — whether or not with success. (Fish culturists — at least the old ones — were usually desirous of planting fish no matter what their condition might be or whether or not waters seemed suited for them.) If any of those 1885 Cristivomer [the generic name used at that time] hatched out there is a good chance that they were planted — even if only in the stream on which the hatchery was located. This is all conjecture, of course." A somewhat similar conjecture has been voiced by La Rivers (1962, p. 258). Following Smith (1896), he pointed out that there was an 1885 shipment of lake trout eggs to Nevada, saying that the subsequent fate of these eggs is unknown. La Rivers (1962, p. 263) did say that a specific planting of lake trout in Tahoe was known for 1887, but the source of this latter information is unknown to us. Sigler and Sigler (1987, p. 26) and Moyle (1976b, p. 153) stated that the lake trout was introduced into Lake Tahoe in 1885. This, also, is probably conjecture.

[68] At that time, the U.S. Army governed Yosemite National Park and the shipment to Col. Young was probably destined for its waters.

The fate of these eggs is unknown. We know of no records of lake trout taken in the counties served by this hatchery, or of any of their waters suitable for them.[69]

Although published accounts differ somewhat both as to the number of eggs received and the number of lake trout planted circa 1923, the most dependable records (unpublished distribution lists of the Division of Fish and Game) show that 20,000 were planted in Eagle Lake, Lassen County, in 1923, and a total of 135,000 in Clear Lake and its tributaries, Lake County, in 1923 and 1924. (Both waters have been favorite "proving grounds" for alien fishes. It is our opinion that both plants were doomed to failure.)

Some of these lake trout were retained in ponds at the Mt. Shasta Hatchery where they grew to adult size.[70] In 1926, some of the adults were sent to Steinhart Aquarium and some planted in lakes in Golden Gate Park, San Francisco (California Division of Fish and Game Report for 1926–28, p. 146; unpublished records of the Division of Fish and Game). Others were killed and used as fish food. Perhaps a few of them were planted. It is probable that the lake trout once found in Castle Lake, Siskiyou County, near the Hatchery, were remnants of some planted at that time. These fish reproduced and some were caught at large size. There was every expectation that the lake would retain its population until it was treated chemically on 6 October 1946 with presumed destruction of all its inhabitants (Wales 1947).

W. Curtis (1981) wrote that the original lake trout in Tahoe were shipped from the Great Lakes in 1890 and moved by pack train to Tahoe. However, local opposition was so vigorous that the trout ended up in the Tallant Lakes chain from which they may have eventually populated Tahoe. A communication from W. Curtis to W.A.D. (1 May 1981) stated that this information stemmed from S. Rubin, then a fishing guide at Lake Tahoe, and that Rubin's account was undoubtedly "hearsay." A request for further information from Rubins was unacknowledged.

A more detailed discussion was put forward by Scott (1957, p. 448). He reported that Lake Tahoe resort owners, headed by H.L. Comstock, contested the plan to plant "65,000 Great Lakes mackinaw fingerlings" in Tahoe. Instead, in 1895 these fish were transported in 5-gallon metal containers on horseback for release in the Tallant Lakes above Meeks Bay. (The Tallant Lakes are a chain of

[69] The Brookdale Hatchery (1905–53), built on the San Lorenzo River for the County of Santa Cruz, served primarily to raise salmonids from eggs taken at Scott Creek. This egg-collecting station was operated by the California Fish Commission and Santa Cruz County and the fry distributed in waters of Santa Cruz, San Mateo, Santa Clara, and Monterey counties. In 1912, both the hatchery and egg-collecting station were taken over by the State of California (Leitritz 1970).

[70] The last of these, "Old Granny," died at the age of 28 years in 1951. She was part of a shipment of eggs originating in Minnesota and brought to the Hatchery in 1923 (OC 1951a).

small lakes draining into Meeks Creek.) The largest is Stony Ridge Lake (55 surface acres), and it was here that the first lake trout was reported captured in 1920 by B. Callendar of Homewood. Scott (1957, p. 448) also contended that lake trout made their way from the Tallant Lakes down Meeks Creek and into Lake Tahoe. To us, this appears to be an unlikely event.

Roush (1976, p. 125) had a somewhat similar story, saying that following the Nevada plant of 1889, lake trout were planted in the "Tallant Lakes basin above Meeks Bay" from Sisson (Mt. Shasta) Hatchery in 1895 from which "some say" the fish worked their way down into Tahoe. He also claimed that the lake trout in Tahoe came from Lake Superior. However, from other remarks made by Roush (1976), his information lacks accuracy.

Regardless of the date of the actual introduction into California, the lake trout has become a part of its fauna.

Efforts to improve the fish food supply in Lake Tahoe, especially for lake trout, have been made by California and Nevada. About 333,000 opossum shrimp (Mysis relicta) from Alberta, Canada, were introduced by the California Department of Fish and Game and the Nevada Fish and Game Commission in September of 1963, 1964, and 1965 (Linn and Frantz 1965; Hanson 1966). The Bonneville cisco (Prosopium gemmifer) was also introduced into Tahoe in 1964, 1965, and 1966, again by the State groups dealing with fish and game. (See the description of the Bonneville cisco.)

The lake trout is, of course, predacious, and has been implicated by some in the extirpation of the original Lahontan cutthroat trout population of Lake Tahoe. Defended by some and maligned by many others, it remains a controversial fish. Scott (1957, p. 448) and Moyle (1976b, p. 140 and 154) referred specifically to lake trout, and Gerstung (1988, p. 95) and Trotter (1991, p. 261) referred to nonnative salmonids in general as contributing to the loss of the native Tahoe cutthroat. These authors listed additional factors involved in the loss such as unrestricted commercial fishing, inadequate replanting methods, tributary egg-taking operations, and habitat damage to spawning tributaries caused by pollution, logging, and water diversions.[71] Sigler and Sigler (1987, p. 25) maintained that the demise of the native Tahoe cutthroat was "undoubtedly" influenced by commercial fishing and habitat destruction. The introduction of nonnative trout was not mentioned in regards to Lake Tahoe. La Rivers (1962, p. 263) said the lake trout was unjustifiably condemned, and Cutter (1991, p. 25) said, "The lake trout was mistakenly held responsible for the extinction of Lake Tahoe's cutthroat fishery," and that the decline was actually due to overharvest, habitat destruction, and the introduction of foreign pathogens into the watershed. James (1921, p. 273) stated that by 1920 lake trout had largely displaced Lahontan cutthroat in Fallen LeafLake, where habitat destruction and overfishing were not major changes.[72]

[71] Circa 1895, 28, 750 lb of cutthroat trout from Lake Tahoe were shipped from Truckee (Report of the California Fish Commission for 1895–96).

[72] James's opinion was probably based on that of local residents. He was not a student of fisheries but a writer who was employed by the Southern Pacific Railroad Company for many years to promote California as a place to live. Nevertheless, he may have been correct.

Conversely, La Rivers and Trelease (1952) felt that "Probably mismanagement of spawning streams tributary to ... [Tahoe] ... has been a much more important factor in reducing the cutthroat than have been the presence and habits of the lake trout." It is obvious that all of these conclusions are conjecture. On the basis of A.J.C.'s extensive studies (about six years) and residency on the Lake, we suspect that the lake trout was a major factor in extirpating the cutthroat population.

Self-sustaining lake trout populations in lakes Tahoe, Fallen Leaf, Donner, and Stony Ridge are the product of the very earliest plants made in the late 1800s and early 1900s. Over the past 15 years, occasional releases were made in Donner and Tahoe in an attempt to augment existing lake trout stocks. They have appeared to benefit the former water but not the latter.

Beginning in 1965 and continuing to the present time, the Department has stocked lake trout into about 20 additional high-elevation lakes and reservoirs in the central Sierra Nevada. Self-sustaining populations have been established at Gold Lake (Sierra County), Caples Lake (Alpine County), and Jenkinson (Sly Park) Reservoir (El Dorado County). They constitute an important trophy element in the catch from these waters. Other waters where lake trout are caught but where reproduction has not been confirmed include Bucks Lake (Plumas County), Hell Hole Reservoir (Placer County), Stampede Reservoir (Sierra County), and Union Valley Reservoir (El Dorado County).

The eyed lake trout eggs imported for the foregoing programs originate from sources in Colorado, New York, Utah, and Wyoming. They are reared to fry or fingerling size in Department hatcheries and usually stocked by air. The program is inexpensive and popular and will be continued. Size alone accounts for the popularity of lake trout among anglers. They add a trophy element to the trout catch which would otherwise be absent or rare in these waters. Anglers use specialized gear (special lures, downriggers, and fish locators) to fish for the deep-dwelling lake trout in these waters.

Although the lake trout never became an important commercial fish as it was in Canada and the northeastern United States, it remains a relatively popular sport fish in certain areas of California.

4.26. Arctic grayling, Thymallus arcticus (Pallas)

Despite repeated attempts by the State to acclimatize this beautiful salmonid from North America and northern Asia, and despite survival in a number of instances, there is no evidence to show that it ever established a self-reproducing population in California except in one instance (Rieber 1983). This being the case, the history of its introduction will be abridged with emphasis on the later introductions which resulted in a self-sustaining population.

At one time it was believed that several species of grayling existed in the United States, and it was under the name of Montana grayling or Thymallus montanus that it was first brought to California from Montana, the only state other than Alaska in which it is still native.

At intervals from 1904 until 1916, grayling (hatched from eggs from the U.S. Fish Commission in Montana) were held at the ponds of the Sisson (Mt. Shasta) Hatchery. With respect to a stock of some 7000 fry (originally from Bozeman, Montana) held there in 1904, "This marks the first effort of the California Fish Commission to introduce this beautiful fish into our waters.... It is believed that suitable waters ... can be found in the vicinity of Mt. Shasta, perhaps in the upper reaches of the McCloud River...." (California Fish Commission Report for 1903–04, p. 47–48). They appear to have been destined for the "... wilder and more remote parts of the country...." (California Fish Commission Report for 1905–06, p. 23). As nearly as we can determine, the first grayling were not liberated into the natural waters of California until 1906. Some of the first of these fish escaped from a pond into the upper Sacramento River. Others were planted in both lakes and streams of northern California, some of which were barren of fish. The most specific planting localities mentioned in published reports were only "... in the Tahoe region, in the high Sierras ... waters in Siskiyou County...." (California Fish Commission Report for 1905–06, p. 43). Most of them were probably released as fry or fingerlings, although some grayling up to at least two years of age were reared in the ponds.

It is impossible to determine the number of grayling planted during the period of 1904–16. It might be inferred from Bryant (1929), Shebley (1917), and others of this period that only a small number were planted. But Shebley (1922) listed a distribution of 230,000 between 1904 and 1913, inclusive, and from this one might assume that they had been given a fairly good trial in state waters. As for other species in his table, however, the perusal of other records (most of them his own) clearly shows that most of these fish were never actually planted. Probably only a few thousand grayling were ever liberated, and no reports of their success were recorded.[73]

Besides these State plants, there is a record of 50,000 grayling eggs sent by the U.S. Bureau of Fisheries to "San Gregoria Creek" in 1917 (U.S. Bureau of Fisheries Report for 1917, p. 59 in Appendix I). The disposition of this shipment is unknown. If the record pertained to San Gregorio Creek, San Mateo County, one would not expect survival.

[73] As has been pointed out in the Introduction, most of Shebley's (1922) record simply applied to transfer of fish from troughs to ponds, eggs received, or fish "on hand." It is not considered worthwhile to present a complete record of the grayling "plants" recorded during the 1904–16 period.

In January 1917, State game warden W. Toms secured several species of fish from an exhibit of the U.S. Bureau of Fisheries at the termination of the San Diego Exposition of 1916. The original sources of these fish are unknown. Fifteen of these, said to be "grayling," were planted in a pond on upper Cottonwood Creek near Lake Morena, San Diego County. There is no record of their survival. This account, as well as those of other introduced fishes planted by Toms in 1917, was furnished by State game warden E.H. Glidden in a letter of 16 February 1943 to W.A.D. and was supplemented by a copy of Glidden's notes, which added the exact date of planting as 6 January 1917 and noted that the plant was originally intended for Lake Morena itself.

The next attempts to rear grayling began in 1924 at the Steinhart Aquarium in San Francisco. Apparently, this introduction was for the primary purpose of research regarding food for young grayling (Seale 1930b), which were considered difficult to feed in hatcheries. Its planting in California appears to have been an afterthought, and it was not until five years later that any were stocked. During the period of 1929–33, about 182,300 were planted. Some of these were raised at the Steinhart Aquarium; others at State hatcheries. Most of the fish, with the exception of plants in Echo Lake, El Dorado County, and Star Lake, Mariposa County, were planted in Mirror and Grayling lakes in Yosemite National Park.[74]

There is a record of 5000 grayling eggs sent by the U.S. Bureau of Fisheries to the California Fish and Game Commission in 1935 (U.S. Bureau of Fisheries Report for 1935, p. 408), but none of the records of the then California Division of Fish and Game shows that they were received.

Several reports of the survival of the last plants in Yosemite were recorded. Presnall (1932) reported that a visit to "one of the high lakes of Yosemite National Park" by P. Topp, State hatchery foreman, and U.S. National Park Service ranger S. King on 11 August 1932 found grayling planted 19 June 1930 attaining a length of 13½ inches and a weight of ¾ lb plus many young grayling hatched in the spring of 1932. S. King also caught a few grayling 8 to 10 inches in length from Grayling Lake in 1934 (letter of State fish culturist A. Thompson to W.A.D., 9 June 1941). Emig (1969) gave a much later date, stating that the last reported grayling was taken in 1942 several miles downstream from this Lake. Successive plantings in this Lake cast doubt upon previous reports of CFG (1932c, 1933) that the presence of young fish indicated natural reproduction, those of Snyder (1933, 1940) that the grayling appeared to be established in the Yosemite region, and that of Needham (1950) that it was established in the Park. Investigations in

[74] The complete planting records are to be found only in the unpublished files of the California Division of Fish and Game. Published summaries of the distribution of grayling during this period are listed as follows: California Division of Fish and Game Report for 1928–30, p. 167; Ibid. 1930–32, p. 109, 113; Ibid. 1932–34, p. 82–83-A and G. Although Seale (1930b) wrote of a lot being sent to Mt. Shasta Hatchery (apparently in 1929), no record can be found of its planting.

1947 and 1948 by Park ranger M.B. Evans failed to reveal the existence of any grayling in Yosemite Park (Evans and Wallis 1944; Wallis 1952).[75]

Emig (1969) presented a review of Arctic grayling, including a rather detailed history of its introduction into California waters during the period of 1904–35. He concluded by saying that the species was not present in California after about 1942. He suggested, however, that the grayling might survive in California's high-elevation lakes which develop low oxygen levels in winter, that periodic restocking would be necessary because such lakes lack suitable spawning areas, that reproducing populations could perhaps be established in other waters if competing species were eliminated, that the grayling posed no problem or threat to other game fish in California, and that fishable populations would add desirable elements of diversity and trophy fishing in California.

Accordingly, "In 1969 Arctic grayling were reintroduced in California in an attempt to diversify cold water angling opportunities and to find a game fish which would thrive in shallow high mountain lakes subject to annual 'winter kill'" Gerstung (1973). The new program, as he described it, was as follows. In 1969, grayling eggs obtained from Arizona (obviously introduced and probably from Montana) were hatched and raised to fingerlings at the State's Hot Creek Hatchery. Despite substantial egg and fry loss, six small California lakes were planted that year with grayling fingerlings: Bullpen Lake, Nevada County; Papoose Lake, Sierra County; Devil Lake, Amador County; Upper Virginia Lake, Alpine County; Fawn Lake, El Dorado County; and Jim Lake, Placer County. One thousand fish were planted in Bullpen Lake; 500 in each of the others. During the summer of 1970, overwinter survival of Arctic grayling was observed in four of the six lakes, and in the fall of 1971, 12 additional small high-elevation lakes, most of them in Siskiyou County, were planted. During the summer of 1972, most of these lakes were again planted with grayling. Stocking density of fingerlings ranged from 60 to 200 per acre in 1969, and up to 300 per acre in 1971. In 1972, when grayling fry were used, the planting density ranged from 500 to 1000 per acre. The results were varied, but indicated that grayling could survive well in some lakes even in the presence of trout, and that both their growth and catch rate could be excellent. Their ability to survive low dissolved oxygen levels and severe winter conditions was considered to be equal to or perhaps slightly above that of brook trout and above that of rainbow trout, but the species was not considered to be a panacea for shallow "winter-kill" lakes. They were definitely considered to provide novelty and diversity for California cold-water anglers (Gerstung 1973).

[75] There have been several issues in Yosemite Nature Notes, including revisions of Evans and Wallis (1944) and of W.A. Evans's "Fishes of Yosemite National Park," and their citations are somewhat difficult. Nevertheless, there is no doubt that the grayling did not survive in the Park.

Planting of grayling by the State continued until 1975 by which time 58 high mountain lakes and one stream had been planted. There was no evidence, however, of natural spawning until studies in 1980 indicated that Lobdell Lake, a 19-ha reservoir at 2800 m in Mono County, and its outlet, Desert Creek, contained a self-reproducing population of Arctic grayling (Rieber 1983). Grayling continue to survive not only in Lobdell Lake, but also in the 14 to 16 km of Desert Creek from the Lake to the Nevada border, and they appear to have at least partially displaced brook trout from this stream (State fishery biologist D.M. Wong, 22 September 1994 pers. comm.). It is of some interest to note that the Lake was stocked in 1970 with 500 catchable-size grayling from Arizona. Emig (1969) indicated that it is difficult to establish a self-sustaining population of this species anywhere, but that it is possible.

Apart from its novelty, attempts at grayling introduction into California appear a bit frivolous.

4.27. Giant rivulus, Rivulus harti (Boulenger)

The giant rivulus, sometimes known as the Trinidad rivulus, is a South American cyprinodont used as an aquarium fish. It was collected by J.A. St. Amant on 13 January 1967 in a small ditch below the Hot Mineral Spa adjacent to Del Rancho El Sargent, a tropical fish farm in Imperial County on the eastern side of the Salton Sea. Other specimens were collected on 13 November 1968 and in 1969. The specimens were identified by C.L. Hubbs. St. Amant believed that the tropical fish farm was the source of the introduction (St. Amant 1970).

The farm is now closed, and the lack of further observations led Shapovalov et al. (1981) to conclude that the population had disappeared. However, as noted by Courtenay et al. (1991) and Swift et al. (1993), further collections by J.A. St. Amant in 1990 demonstrated that the giant rivulus remained established there.

This species of Rivulus is very common in the islands of Trinidad and Tobago and also is found in Venezuela and the Amazon Basin. It has a habit of traveling across country through wet grass and can stay out of water for several hours. It is said to be quite voracious and, as the largest member of its genus, is sometimes eaten.

As the species can withstand rather low temperatures, it could probably exist in additional waters of southern California but would have only a limited distribution.

4.28. Rainwater killifish, Lucania parva (Baird & Girard)

The euryhaline rainwater killifish is native to the coast of the United States from Cape Cod to southwest Texas with interior populations in Florida and New Mexico. Hubbs and Miller (1965) said that it made a "... sudden appearance, for no immediately apparent reason ... in five places in the western United States....": about San Francisco Bay and Irvine Lake in California, Yaquina Bay in Oregon, and two isolated spring-fed waters in Utah. They enumerated the early collections and provided a detailed account of the species.

The first California specimens were found "not later than the spring of 1958" at Aquatic Park, Berkeley, near the shore of San Francisco Bay. Other collections in 1958 were in both fresh and brackish waters tributary to San Francisco Bay, and by January 1962 this cyprinodont had been found as far south in the Bay as the Palo Alto Yacht Harbor. The species had become well established about San Francisco Bay and its contiguous waters with a vast increase in numbers (Hubbs and Miller 1965). Possibly an earlier "published" record is that of Ruth (1964) who, according to Wang (1986), reported the existence of this fish in the San Francisco Bay Area. (We have not seen the report by Ruth.)

The next records of this small fish came from Irvine Lake, a reservoir in Orange County fed largely with Colorado River water. Nine specimens were seined from the lake on 5 November 1963 and 18 June 1964. The most plausible assumption is that they were brought in from the Pecos River, New Mexico, by the U.S. Fish and Wildlife Service with stockings of game fishes in 1942, 1943, 1946, or 1948 (Hubbs and Miller 1965).

Although this supposition appears quite reasonable, no equivalent reason can be found for the occurrence of this cyprinodont in the San Francisco Bay area. No records of any recent stocking there by the U.S. Fish and Wildlife Service are known. Hubbs and Miller (1965) theorized that the rainwater killifish may have been transported to the Bay as eggs on eastern oysters (Crassostrea virginica) from the East Coast of the United States, but admitted that it might also have been introduced in ballast water.

Other occurrences of the rainwater killifish are known for California. On 22 April 1976, specimens were collected from Arroyo Seco Creek, a tributary of Vail Lake, Riverside County. It was assumed that the rainwater killifish was introduced with game fishes during stocking, but no source was indicated (McCoid and St. Amant 1980). Hubbs and Miller (1965), however, referred to a shipment of game fishes from the Pecos River stocked in Vail Lake on 20 November 1948. This might indicate the source. Swift et al. (1993) stated that a population was established in 1980 in the campus lagoon of the University of California at Santa Barbara near Goleta Point, Santa Barbara County.

The rainwater killifish is established in California and may be expected in both freshwater and saline environments. Its small size precludes its use as a game or food fish, and it is not considered a predator. Possibly, it may have some use as a bait fish and be transported to other areas because of such use—a practice definitely illegal and possibly harmful.

4.29. Western mosquitofish, Gambusia affinis (Baird & Girard)[76]

At one time, many areas of California were plagued by mosquitoes. In general, the resident species were harmless to humans—aside from their annoying qualities—but in some areas Anopheles mosquitoes also carried malaria, which could be fatal. Salt marshes along San Francisco Bay and other aquatic areas provided a medium for mosquito development, and early attempts to eradicate their larvae involved drainage, the use of copper sulfate, and oiling. The first scientific mosquito control campaign in the state was instituted by the California Experiment Station in 1905 in the Burlingame region of San Mateo County.

Circa 1906, David Starr Jordan felt that "... the only fish likely to destroy mosquito larvae to any extent in the San Francisco Bay region would be the [native] stickleback (Gasterosteus cataphractus) . " The Experiment Station felt, however, that fish were not an important factor in mosquito control, and continued drainage and the application of oil as its principal methods (Quayle 1906).

In about 1912, rice culture was started in California, especially in the Central Valley which was admirably suited for this crop. Flooding of the fields for about five months of the year also resulted in the production of myriad mosquitoes, and the first studies of this phenomenon showed that about 70% of the mosquitoes were anopheline or malaria bearing.

It was considered out of the question to apply any larvicide or oil to combat mosquitoes in this food crop. The first attempts to control these dangerous pests, therefore, involved only the elimination of breeding places outside the rice fields, and the use of quinine prophylaxis. In fact, it is of interest to note that when work began on this problem in about 1916, Stanley Freeborn, the distinguished entomologist and later Chancellor of the University of California at Davis, felt that although fish and dragonflies seemed to be the most important natural enemies of mosquitoes in Californian rice fields, they were handicapped to such an extent that their influence was of little importance (Freeborn 1916). But that was before the mosquitofish was introduced, and it is of interest to note that even at that time Gambusia was considered by many to be an important enemy of Anopheles (see, for example, Le Prince 1922).[77]

[76] The mosquitofish found in California has been listed under the name Gambusia patruelis by several authors; others have used the name G. affinis or the trinomial, G.a. affinis. Following a review of the literature by Mallars and Fowler (1970) and the statements in Swift et al. (1993), it appeared that Gambusia affinis was the only member of this genus that had been recorded from California. Shapovalov et al. (1981), following the advice of both C.L. Hubbs and W.I. Follett, used the trinomial G.a. affinis (Baird & Girard) or western mosquitofish. However, more recent studies have demonstrated that both G.a. affinis and G.a. holbrooki merit full species status, and that the latter has also been introduced into California. See the description of the Eastern mosquitofish (Gambusia holbrooki) for more details.

[77] Although the mosquitofish was introduced originally primarily to control the larvae of the Anopheles mosquito, which carries malaria, it is also of use in controlling Aedes which may cause encephalitis.

This small fish, native to the southern United States and northern Mexico, was introduced into California in 1922 from Texas by the California State Board of Public Health for mosquito control. So much has been written about its introduction and subsequent use that it seems futile to try to list the many accounts concerning its presence in California. It may be useful, however, to quote from a paper issued by the Mosquito Control Association of California:

"The first California introduction occurred in April, 1922 when 590 Gambusia affinis were transported from Austin, Texas to a lily pond at Sutter's Fort, Sacramento by the California State Board of Health. The species became well established in California, largely through the efforts of Louva G. Lenert and Edward Stuart, of the mosquito control program, California State Board of Health. In 1923, they established some 25 hatcheries from Redding in the north to Santa Ana in the south [about 830 km or 70% of the length of the state, airline] from which Gambusia affinis were distributed to 24 counties [out of 52] during antimalarial and mosquito control work" (Mallars and Fowler 1970).

The earliest published record of its introduction into California known to us is that of Lenert (1925). Differing somewhat from the preceding account, he stated that 600 mosquitofish were received from Austin, Texas, and that an additional shipment, apparently of about 300 fish, was received from Hearne, Texas, in May 1922. Both shipments were stocked in the lily pond at Sutter's Fort, where the fish were permitted to propagate unmolested until July 1922. "Hatcheries" were then established at Anderson and Oroville, 600 fish being sent to each place. No further plants were made until the following year because of "technical complications" with other departments of the State Board of Health. After the "complications" were worked out, general distribution was undertaken. A map showed the plants of mosquitofish made in California from 1 March 1923 to 1 July 1924. Plants were made from Modoc and Siskiyou counties on the north as far south as the Colorado River area in Riverside County. It also was noted that it was thought necessary to require payment by the consignees for all shipments of fish that were made. Due to "depredation" by game fish from an adjoining pool, the Sutter's Fort hatchery was abandoned and a new one established in North Sacramento.

Lenert and Stuart (1926) gave an account of planting mosquitofish in 30 California counties during the period July 1924 through June 1926. It seems obvious that the mosquitofish has received the widest planned introduction into Californian waters of any introduced species of fish. It also was noted in this report that the Steinhart Aquarium of San Francisco was an active supporter of its use for mosquito control, and that the Aquarium was supplied with a large number, which it would distribute to anyone desiring them. A. Seale, then Superintendent of

Steinhart Aquarium and an exponent of the use of Gambusia affinis for mosquito control, had previously reported on its use in Hawaii and the Philippines and its ability to maintain itself in the presence of voracious species such as the introduced largemouth bass (Seale 1917).

Jordan (1927) said that he "... first brought the value of Gambusia to public notice in the *Scientific American* in May 1926," and devoted much of his article to his endeavors and those of other ichthyologists from Stanford University to secure the use of fish which could be introduced to eat mosquitoes. He also discussed observations on the presence of "Gambusia patruelis" in his garden pool in California. His earlier article in the *Scientific American* (Jordan 1926) said that he sent Seale from Stanford in 1904 to secure fishes to combat mosquitoes in Hawaii. He also said that Gambusia had not yet been introduced into Europe.

From all accounts, Jordan had a remarkable memory, but in this case—where he referred to himself as a "fish sharp"—he does seem to have forgotten (or never knew) that Gambusia had been introduced into California four years before his publication of 1926, and that it had been introduced into Europe at least as early as 1919–21 (Welcomme 1988). Another nonindigenous organism, the eucalyptus of Australia, had also been introduced into southern Europe for malarial control at an even earlier time.

Our paper has mentioned Seale's discussion of Gambusia in Hawaii, and Herre (1959) partially corroborated both Jordan (1926) and Seale (1917). Herre (1959) stated that Jordan recommended that Seale go to Texas to obtain mosquito-eating fishes for Hawaii, and that Seale did indeed take Gambusia to Hawaii and the Philippines. During his stay in the Philippines from 1907 to about 1917, Seale continued his distribution of Gambusia, and during the next two decades it was widely distributed throughout the world.

Strangely enough, an early account of the introduction of the mosquitofish into California appeared in an aquarium journal in an article by Jones (1932). This article differed from those of Lenert (1925) and Mallars and Fowler (1970) only by saying that the first import in 1922 was of 590 fish and that the two first imports from Texas aggregated 1090 fish. For all practical purposes, the next report appeared in the *Public Health Weekly Bulletin* of the California State Department of Public Health (Anon. 1935) under the same title as in Jones (1932). No new information on the advent of the mosquitofish in California was given.

At first, its introduction was opposed by the California Fish and Game Commission who felt that Gambusia might be injurious to the larvae of striped bass, American shad, and other fishes (Rockefeller Foundation 1924). This opposition was soon dropped, however, and the Division of Fish and Game, itself, praised its introduction (CFG 1928) and distributed many of these topminnows to mosquito-plagued areas (California Division of Fish and Game Report for 1930–32, p.

29–33).[78] In 1951, it even supplied Gambusia to the U.S. Navy in Guam (records of the California Department of Fish and Game).

Mosquitofish still are stocked in both public and private waters by mosquito abatement districts both by surface transportation and by air. Being an adaptable fish with rather wide temperature tolerances, able to withstand brackish water and harsh desert aquatic habitats, live in very shallow pools and sewage oxidation ponds, survive septic tanks, and rather resistant to pesticides and herbicides, it now occurs in many localities throughout the state. The sloughs and ditches of the Central Valley harbor many of them and they are abundant along the Colorado River and in the Imperial Valley. These are warm waters, but the mosquitofish is also found in various southern and northern California reservoirs, in coastal lagoons, and has even been taken at reasonably high elevations; e.g. Hume Lake in Fresno County at 5200 ft. It is probably found in every county in the state.

Aside from its wide use for mosquito control in California, Gambusia has been used as live bait, forage fish for black bass at the old Friant Bass Hatchery (this practice was discontinued), and as an aquarium fish.[79] All of these activities have contributed to its dispersal. Its dispersal for mosquito control has also been considered responsible for the transplant of other fishes to areas where they are not native. For example, Miller (1945) believed that the occurrence of the arroyo chub (Gila orcutti) , a native California cyprinid, in the Santa Ynez River was due to its inclusion in a planting of Gambusia affinis in that drainage.

Although the introduction of the mosquitofish seems to have been worthwhile from a public health standpoint, it has received considerable criticism from ichthyologists and aquarists for its effect on other fishes. (The early criticism by the California Fish and Game Commission of its supposed effect on the young of some introduced food and game fishes has already been noted.) Evermann and Clark (1931) stated that it appeared to be driving out the native desert pupfish (Cyprinodon macularius) in the Imperial Valley and areas around the Salton Sea. R.R. Miller also felt that the mosquitofish was eliminating the desert pupfish in the same area (pers. comm. to W.A.D. 1 December 1942). Myers (1965) was firm in his belief that the mosquitofish "... is a very dangerous fish to introduce into a place where it does not occur naturally.... Gambusia is a very destructive creature, not only to fishes of its own small size but also to much larger fishes." He also felt that the mosquitofish was little or no better as a mosquito destroyer than

[78] The term "topminnow" has been applied both to the Cyprinodontidae (killifishes) and the Poeciliidae (livebearers).

[79] The mosquitofish has been introduced into many states, various island groups in the South Pacific, and to every continent (see especially Gerberich and Laird 1966 and Welcomme 1988). Laird (1969) stated that by the time modern synthetic organic pesticides appeared on the scene, Gambusia affinis had a wider distribution than any other freshwater fish.

many other less dangerous species. Mellen and Lanier (1935) claimed, "They are quarrelsome as a rule and given to ripping the fins of even larger fishes...." This is certainly true. One of us (W.A.D.) has seen Gambusia kill small green sunfish in aquariums. J.O. Snyder felt that the introduction of Gambusia may have had a more deleterious effect on the native fishes of California than all the other introductions combined (pers. comm. to W.A.D.).

Excellent summaries of worldwide studies implicating Gambusia affinis in the depletion of indigenous fishes are presented by Schoenherr (1981) and Courtenay and Meffe (1989). In the United States, native southwestern cyprinodonts and poeciliids are particularly vulnerable to Gambusia. In California, this includes, among others, the desert pupfish, the Owens pupfish (Cyprinodon radiosus) , and the Amargosa pupfish (C. nevadensis amargosa) . [80]

Predation by Gambusia on juveniles of the native species and behavioral interactions are means of displacement (Meffe 1984, 1985). A factor limiting even greater inroads by Gambusia on indigenous species in desert streams is offered by Meffe (1984): "Replacement is most rapid in localities that rarely or never flood, while long-term coexistence may occur in frequently flooded habitats."

In some situations Gambusia affinis appears to coexist with native fishes. Schoenherr (1988) reported that mosquitofish and desert pupfish are able to coexist in the Salton Sea and its drains, and that of all the fishes introduced into this area, the mosquitofish is one of the lesser threats. In addition, Bell (1978) questioned Miller's (1961) contention that Gambusia affinis was primarily responsible for the extinction or near extinction of the unarmored threespine stickleback (Gasterosteus aculeatus williamsoni) from the Los Angeles Plain. Bell found that the two species coexisted in the Santa Clara River system of Ventura and Los Angeles counties.

Native amphibians and invertebrates also seem to suffer from the presence of Gambusia affinis (Jennings and Hayes 1994). Shaffer et al. (1993), in their survey of the California tiger salamander (Ambystoma californiense) , found that there was a strong negative association between the mosquitofish and the California tiger salamander, as well as between the mosquitofish and other native amphibians and native invertebrates.

It is of considerable interest that the native pupfish had been suggested by Kennedy (1916) (who also mentioned the use of the stickleback, Gasterosteus) and by Snyder (1917a) for mosquito control in California several years before Gambusia was introduced for that purpose.[81] Even earlier, Scofield (1915) reviewed the use of the native threespine stickleback (Gasterosteus aculeatus) in

[80] The native Owens pupfish was once held under permit as a research colony for mosquito control at the Butte County Mosquito Abatement District (Coykendall 1980).

[81] It is believed that sticklebacks were the only fish in Lake Merced, San Francisco County, when it first was proposed by the California Acclimatization Society in 1871 to stock it with trout. They were felt to be enemies of small trout but forage at a later date (Alta California, 5 May 1873).

mosquito control work in the San Francisco Bay region and suggested, "It may be one of the activities of the State Fish and Game Commission to supply fish for mosquito extermination just as they now supply fish for food and sport." He felt, however, that "topminnows" would be better in rice fields to control malaria mosquitoes and that it was probable that they would be introduced there. He noted that "The angler will profit directly ..." from mosquito control. Hubbs (1919) also suggested the stocking of the threespine stickleback for this purpose and believed that (unlike topminnows) it would be "... largely immune to the attack of larger fishes." He also felt, however, that "topminnows" would be more efficient in controlling malaria mosquitos in swamp lands and in rice lands along the Sacramento River. Studies by Danielson (1968), however, disclosed that the Amargosa pupfish was superior to Gambusia affinis at cropping mosquito larvae in simulated reeds.

There also seems to be some evidence that the mosquitofish can disrupt some food chains by reducing the populations of predacious invertebrates (Hoy et al. 1972; Hurlburt et al. 1972). Gambusia may also have one more bad mark. A microsporidian infection, Glugea, has been found in mosquitofish in California (Orange County), but its impact on mosquitofish populations is unknown, and the organism is not known from other species of fish in California (Crandall and Bowser 1982).

Despite such comments, the advent of Gambusia in California waters appears to have been inevitable in view of its worldwide reputation of reducing mosquito populations. (The mosquitofish had been well distributed in Mexico, Central America, Peru, Italy, and parts of Asia before being introduced into California.) Furthermore, the section of the California Code of Regulations (Title 14) of the Fish and Game Commission governing private fish stocking now authorizes, with a few exceptions, the planting of Gambusia affinis for purposes of mosquito control without obtaining a permit from the Department of Fish and Game. The Entomology Committee of the California Mosquito Control Association has been quite objective in its approach to mosquito control work involving the use of fish. It has reviewed the literature, both pro and con, and informed its members of the existing controversy (see especially Mallars and Fowler 1970). Many of the pros and cons of its place in mosquito abatement in California and elsewhere were also discussed in Coykendall (1980).

There seems to be little question that the introduction of the mosquitofish into California waters has been useful in reducing both the annoyance and danger from mosquito attacks and as an alternative to the use of chemicals such as parathion.[82] From the conservation standpoint, either to those who enjoy fish for

[82] In recent years, the use of fish for mosquito control has been supplemented by the use of sprays which are considered harmless to humans; e.g. bacteriological toxins and antimosquito growth hormones.

food or sport or to those who treasure our heritage of native fishes, its introduction may have been disastrous.

4.30. Sailfin molly, Poecilia latipinna (Lesueur)

This popular aquarium fish, which has a black variation called the "black molly," was formerly known scientifically as Mollienesia latipinna. It is a native of coastal fresh, brackish, and salt water of the southern United States and northern Mexico.

Shapovalov et al. (1959) stated, "In recent years this species has become established in canals and ditches tributary to the Salton Sea, in the vicinity of the Riverside-Imperial County Line." In January 1964, St. Amant (1966a) reported finding it in a small pond and its tributary 5 miles north of the Salton Sea, Imperial County, directly below a tropical or ornamental fish farm. The sailfin molly was found along with other tropical fishes when St. Amant tried to eliminate a population of Mozambique tilapia (Tilapia mossambica) which was in the pond. Whether or not this particular population was eradicated is unknown. St. Amant (1967, p. 13) reported the sailfin molly as established and extremely abundant in the Salton Sea and its tributaries, and Black (1980) found it to be well established in its canals and drains, where it was by far the most abundant species, as well as in the shallow margins of the Sea itself. It was also found in the lower Colorado River (Minckley 1982). Mollies continued to be very abundant in waters tributary to the Salton Sea, as well as in the shallows of the Sea, according to a 1991 survey (Lau and Boehm 1991). Although the survey did not distinguish the sailfin molly from the shortfin molly, we assume that the former remained the more abundant species.

Swift et al. (1993) also described the existence of several other sailfin molly populations in: a coastal, tidal slough in Oxnard (Ventura County); Ballona Marsh (Los Angeles County); and the Santa Ana River near Prado Reservoir (Riverside and Orange counties).

The sailfin molly has been introduced into Hawaii and into many countries for mosquito control purposes. In their summary, Courtenay and Meffe (1989) observed that control was not always successful and that endemic fishes have been negatively impacted by such introductions. Along with the redbelly tilapia (Tilapia zilli) , the sailfin molly has been implicated in the severe decline of the native desert pupfish (Black 1980; Schoenherr 1981, 1988).

One of the mollies—perhaps this one—has been used as bait for orangemouth corvina (Cynoscion xanthulus) in the Salton Sea (Black 1974; OC 1978).

Requirements for warm water (about 23.8° C for breeding) preclude its widespread distribution in California, and its size (maximum length about 125 mm) its use for anything but bait. Its competition with native pupfish has been noted.

4.31. Shortfin molly, Poecilia mexicana Steindachner

The original range of Poecilia mexicana includes the Atlantic and Pacific slopes of southern Mexico and Central America, the Caribbean slope of Colombia, and the West Indies.

An aquarium fish, the shortfin molly was first reported by St. Amant (1966a) who found it in a small pond and its tributary 5 miles north of the Salton Sea, Imperial County, directly below a tropical or ornamental fish farm in January 1964. The shortfin molly was found when St. Amant tried to eliminate a population of Mozambique tilapia which was in the pond. Whether or not this particular population was eliminated is unknown. The shortfin molly was included among several exotic species collected on 13 January 1967 from a small ditch below the Hot Mineral Spa adjacent to Del Rancho El Sargent, a tropical fish farm in Imperial County (St. Amant 1970). Other collections of the shortfin molly were made in 1968 from the Westminster flood control channel in Orange County (St. Amant and Hoover 1969), in 1969 and 1970 from the Avenue 82 drain ditch four miles east of Oasis in Riverside County (St. Amant and Sharp 1971), and in 1974 from the Johnson Avenue canal one mile south of Mecca in Riverside County (Mearns 1975). The specimens from the Westminster flood control channel were erroneously reported as P. sphenops according to unpublished notes of C.L. Hubbs and W.I. Follett. Populations of shortfin molly have persisted in scattered locations in the drains and natural watercourses entering the Salton Sea and in the Sea itself (Black 1980; Lau and Boehm 1991). As recently as 1994, A.A. Schoenherr (26 September 1994 pers. comm.) found them in three out of 21 collection localities. The shortfin molly is much less abundant and has a smaller distribution in the area than the sailfin molly.

Swift et al. (1993) maintained, "This species is restricted to a small area south of Mecca near the Salton Sea, and to a few areas of the lower Colorado River (Schoenherr 1979; Lau and Boehm 1991)." However, Schoenherr's (1979) study was confined to a canal at the north end of the Salton Sea and the mollies were identified as Poecilia sphenops and P. latipinna; and Lau and Boehm (1991) did not sample the lower Colorado River and did not separate P. mexicana from P. latipinna. Nevertheless, the lower Colorado River in Imperial County supports P. mexicana which is widespread but much less abundant than P. latipinna and Gambusia affinis (Minckley 1979).

When introduced outside of its native range, the shortfin molly can deplete populations of endemic fishes. Courtenay and Meffe (1989) summarized studies in southern Nevada that documented this phenomenon. Scoppettone (1993) identified predation as the likely mechanism by which it caused the decline of Moapa dace (Moapa coriacea) in the upper Muddy River, Nevada.

The shortfin molly has become a permanent member of the California fish fauna, but, as with the sailfin molly, its small size and requirement for warm water preclude a wide distribution in California.

4.32. Porthole livebearer, Poeciliopsis gracilis (Heckel)

A native of streams on both the Pacific and Atlantic slopes of southern Mexico and Guatemala, the porthole livebearer was collected for the first time in California on 27 July 1974 in an irrigation canal near Mecca, Riverside County (Mearns 1975). Only four specimens were taken, but 12 additional ones were collected at the same site on 17 November 1974 and others were observed there. Mearns felt (owing to the appearance of recently born young, the wide range of sizes, and the persistence of the fish for at least four months) that it was a reproducing resident of the canal. He also felt that the introduction was recent, possibly early in 1974. Presumably, it was made by direct releases by aquarists or escape from a nearby tropical or ornamental fish farm.

Additional collections of this species were made in 1980 according to a personal communication by J.A. St. Amant in Shapovalov et al. (1981). W.R. Courtenay, in Courtenay et al. (1986), noted that the species, according to his personal observation, "... remains extant there ..." but did not give the date of his observation. A 1991 survey of drains entering the Salton Sea and of shallow pools along the shoreline of the Sea revealed that this species was established in at least six drains entering the north end (Lau and Boehm 1991). In 1994, A.A. Schoenherr (26 September 1994 pers. comm.) found them at five localities in the same general area, but three of the sites differed from those reported by Lau and Boehm.

Dependence of this species on warm water limits its range in California, and small size precludes its use as either a food or game fish. Mearns (1975) felt that it might compete with native fishes such as the desert pupfish.

4.33. Inland silverside, Menidia beryllina (Cope)

Although most fishes deliberately introduced into Californian waters have been food or game fishes, the introduction of the inland silverside, a fish of the eastern United States, was made to test its effectiveness in controlling aquatic midges. Briefly, the primary purpose of the use of this fish was to institute biological control, particularly of the "Clear Lake gnat" (Chaoborus astictopus) , a midge associated with this lake for many years and considered a major nuisance. Any significant reduction of the population of the "gnat" might alleviate the problems and minimize the use of pesticides. The background for its introduction as Menidia audens, which included trials of the brook silverside (Labidesthes sicculus) , threadfin shad, and white bass, is documented in Cook and Moore (1970).

Following permission from the Fish and Game Commission to introduce the inland silverside into the Blue Lakes, Lake County, approximately 6000 of these fish were put into Upper Blue Lake in September 1967 and about 3000 planted in both Lower Blue Lake and Clear Lake. The plants in Lower Blue Lake were made in September 1967; those in Clear Lake in late September or early October of 1967. All of the fish stocked were young-of-the-year ranging from 50 to 70 mm in length. They had been obtained originally from Lake Texoma, Oklahoma. The plant in Clear Lake was an "afterthought" and had not been authorized by the Fish and Game Commission (Cook and Moore 1970). Within a year, progeny from the original plants were abundant in both Lower Blue Lake and Clear Lake, and since then a virtual explosion of silversides has taken place in these waters. It may now be the most abundant littoral-zone fish species in Clear Lake.

From Clear Lake, the inland silverside had a water route to the central Sacramento River system. Moyle et al. (1974a) reported its presence in Cache Creek (outlet of Clear Lake) and Putah Creek in 1972 and 1973, and Meinz and Mecum (1977) reported its presence and reproduction in the Sacramento-San Joaquin Delta in 1975 and 1976. From here the silverside can reach southern California waters through artificial canals. Swift et al. (1993) described its presence in such waters saying that it was reported in Castaic, Pyramid, and Silverwood lakes and Skinner Reservoir as early as 1988. Populations resulting from both authorized and unauthorized introductions in reservoirs in Alameda and Santa Clara counties as early as the period of 1968–73 were also described by Moyle et al. (1974a).

The inland silverside is apparently well established in California today, especially in eutrophic waters such as those of Clear Lake. Its initial role was to combat "gnats," reduce algae (a point never proved), and to furnish forage to game fishes. It has, however, also been used as a bait fish, and is routinely imported into California for bioassay testing. In Clear Lake, it constituted most of the diet of black and white crappie (Li et al. 1976). McGinnis (1984) condemned its introduction and blamed it in part for the decline of the striped bass. In 1971, the Department of Fish and Game restricted further introductions of this species because of concern for its high reproductive potential and possible damage to existing fisheries (Fisher 1973). Hurlbert et al. (1972) have suggested that, since the inland silverside also feeds heavily on herbivorous zooplankters, its introduction into Clear Lake may actually increase phytoplankton production and thus make the Lake even more eutrophic.

Its controversial role in California is discussed at some length by Moyle (1976b); we generally disapprove of its introduction.

4.34. Brook stickleback, Culaea inconstans (Kirtland)

One of the latest additions to the introduced fishes of California is the brook stickleback. This species is native to Nova Scotia west to Iowa, Nebraska, and Montana, and in Canada to British Columbia and southern Northwest Territories. An apparent relict population survives in northeastern New Mexico, and introduced populations are found elsewhere in the United States.

The details that follow concerning the establishment of the brook stickleback in California were provided by D.R. Maria, Fishery Biologist with the Department of Fish and Game (7 December 1993 and 6 September 1994 letters to A.J.C.). Shaun Smith of the Department's Yreka Stream Improvement Center was the first to recognize the brook stickleback as distinct from the native threespine stickleback. He submitted specimens on 14 June 1991 to Maria who identified them as brook sticklebacks. This was confirmed by P.B. Moyle in a 27 September 1991 letter to Maria.[83]

The first specimens were trapped in Mill Creek (a tributary of Shackleford Creek, thence the Scott River) during juvenile steelhead rescue operations. Additional brook sticklebacks were trapped in Shackleford, Kidder, and Patterson creeks, all tributary to the Scott River during the period 14 June to 8 July 1991. They also have been observed in French and Etna creeks, tributary to the Scott River, and at scattered locations in the mainstem Scott River downstream to about 20 miles from its confluence with the Klamath River. All of these locations are in Siskiyou County. They may be expected to enter additional waters in the lower Scott and Klamath River drainages, but sampling as recent as 1994 failed to find them.

The brook stickleback appears to be confined to the lower ends of the tributary streams where they enter the valley floor. Here the gradient is low and submerged aquatic vegetation is prevalent due to nutrient loading from farming practices in the drainage. These conditions are somewhat consistent with previous statements (e.g. Lee and Gilbert 1980) that the brook stickleback prefers cool, clear, heavily weeded, spring-fed streams and ponds.

The origin of the brook stickleback in California is unknown. According to Ludwig and Leitch (1996), it is not a bait species, but they found it well represented in bait fish samples purchased from vendors in two Midwestern states where it is native. Although this finding does raise the possibility of its introduction to California via the bait bucket, it is difficult to believe that bait fish used in the Scott River could have been brought there from a far distant point. Maria referred to an Oregon fishery biologist who noted that this species is not found in the upper Klamath River basin in Oregon. Maria concluded, "Because of their widespread distribution in the drainage when they were discovered, it is likely they may have been in the Scott River basin for a number of years but were finally discovered only because somebody noticed these fish as being 'different' and brought them in for identification."

Although the brook stickleback could undoubtedly exist elsewhere in California, its non-utilitarian status plus its rather specialized habitat needs indicate that it will have a very limited distribution in the state.

[83] Although Maria did not publish his findings, Moyle (1993) did insert a notice of the brook stickleback's occurrence in the Scott River, saying that it "... is now widely distributed ..." there. No mention was made of the source of his information.

4.35. White bass, Morone chrysops (Rafinesque)[84]

One of the most controversial of the fish introduced into California is the white bass. Its introduction was not especially controversial, but later developments made both the species and the Department of Fish and Game's actions the subject of many articles in the popular press.

The species, a smaller "cousin" of the anadromous striped bass, is native to the central United States, especially the Mississippi drainage.

The California Acclimatization Society had proposed its introduction as early as 1871 (Alta California, 13 February 1871), but it was not until June 1895 that 12 yearling white bass, under the name Roccus chrysops, from Illinois were sent to the Sisson (Mt. Shasta) Hatchery by the U.S. Fish Commission (U.S. Fish Commission Report for 1895, p. 68; California Fish Commission Report for 1895–96, p. 31).[85] All of them died within a year and a half after their arrival (Shebley 1917).

Apparently, no further consideration was given to its introduction until about 1951 when C.A. Woodhull prepared a report for the California Division of Fish and Game, "The White Bass, Lepibema chrysops (Rafinesque): Its Life History and Some Factors Influencing its Possible Introduction into California Waters." The possible reduction of the striped bass population if the white bass were planted in the Central Valley was discussed, and its planting in California at that time was not recommended (California Fish and Game Commission Report for 1950–52, p. 187).

The matter of its introduction then remained quiescent until about 1964 when a new report was prepared evaluating (through literature survey, correspondence, and a visit to some areas where white bass were important) the desirability of introducing white bass into California reservoirs (Chadwick and von Geldern 1964). The report did not mention Woodhull's paper, but it may not have been known to the authors at that time. Furthermore, in a later report, Chadwick et al. (1966) did mention Woodhull's unpublished report, pointing out that times had changed, and that the threadfin shad was not present in California in 1951 but by 1964 had become an abundant forage fish in many of its reservoirs. The major determination of the 1964 report was that the white bass would fulfill a need for an easily caught pelagic game fish that would utilize pelagic forage fish (i.e. the threadfin) without threatening other fisheries, primarily those for striped bass. In fact, the 1964 report said specifically: "... except for a possible scarcity of suitable spawning areas [usually running waters], they are suitable for our larger reservoirs which have threadfin shad populations.... They would probably establish a population in the Sacramento-San Joaquin Delta which would compete

[84] See also "Striped Bass" in the Hypothetical Introductions section of this paper.

[85] The statement of Evermann and Clark (1931, p. 67) that these fish were delivered in 1925 is a lapsus calami.

with striped bass and king salmon. However, the Delta is probably better striped bass than white bass habitat, so striped bass should continue as the dominant species. They would undoubtedly eat young king salmon, but we doubt that this would affect the salmon population significantly."

Another article also championed the introduction of the white bass to California, pointing out, "... the white bass may be just the fish we need to increase fish production in our warmwater reservoirs.... White bass are known to coexist in the same waters with many other species of warmwater game fishes ... probably because the white bass feeds in the open waters of large lakes and reservoirs, where the other species are less often found.... Eastern biologists generally agree that white bass are not detrimental to other game fish species, so we do not believe that their introduction would adversely affect existing reservoir fisheries.... Their effects on Delta fisheries ... should be negligible, since the white bass is primarily a lake and reservoir fish and does not develop large populations in rivers" (von Geldern 1965b).

The same issue of the publication had an insert saying, "The California Fish and Game Commission has approved the DFG's [Department of Fish and Game] request to plant white bass in Nacimiento Lake [a reservoir] early in 1966." Apparently, that insert was erroneous, since another more authoritative article said, "Following Fish and Game Commission approval, about 160 fingerlings (four to six inches) [of white bass] were planted in Nacimiento Reservoir, San Luis Obispo County, on November 17, 1965. They had been seined from Lake McConaughy, a reservoir in ... Nebraska ... and flown from Nebraska by commercial airline. They constitute the first plant of this species in California.... An additional 64 adults (23 males and 41 females) were released in Nacimiento Reservoir on February 17, 1966.... They were obtained from Tenkiller Reservoir, ... Oklahoma.... They were flown to California ... [by] ... the California Department of Fish and Game.... All fish planted appeared to be in excellent condition...." (von Geldern 1966). Shannon (1966) also said that 160 white bass were planted in Nacimiento in 1965, and if successful should add to the future reservoir and lake fishing pleasure of many California fishermen. These accounts of the introduction of white bass into California (to Lake Nacimiento) were supplemented by an article which recapitulated the first two stockings (although saying that the first plant was of 150 fingerlings in September 1965) and added that about 200 adults from Utah were planted in 1967, and about 700 fingerlings from Nevada in July 1969 (Puckett et al. 1970).[86] The Lake was closed to the take of white bass from 1966 to 1969 to assist in its establishment.

[86] This article said that in addition to the first plant, more plantings were made in the reservoir in 1966, 1967, and 1968 — a statement which does not agree with the more detailed one in the same article. This was cleared up in a 17 September 1968 letter from State biologist K.A. Hashagen, Jr., to C.E. von Geldern, Jr. The release of 700 yearlings and one adult was made on 22 and 23 July 1968.

As no evidence of reproduction by the white bass was determinable through electrofishing experiments from 1965 through 1968, it was considered that its impact on the Lake was negligible (von Geldern 1971). But early in 1970 a few white bass were reported caught, and in July 1970 Department of Fish and Game personnel captured white bass with seines and an electroshocker, showing that the species had spawned successfully (Puckett et al. 1970). Nacimiento became a mecca for white bass anglers. The species also occurred in the Nacimiento River above the reservoir and in the Salinas River below Nacimiento and San Antonio reservoirs (California 1987).

In 1966, a proposal for the introduction of white bass into the lower Colorado River below Lake Havasu was turned down by the interstate Colorado River Wildlife Council because of probable conflict with the striped bass program underway in that area (OC 1966c). However, in December 1968, the first introduction of this species was made by the California Department of Fish and Game into Palo Verde Lagoon below Blythe. Thirty-two white bass, 6 to 8 inches long, were released. These fish, from Lahontan Reservoir in Nevada, were provided by Nevada's Fish and Game Commission, and the introduction was approved by Arizona's Game and Fish Department. Additional plants were made in 1969 but the species failed to become established (OC 1969b, Shapovalov et al. 1981).

Lake Nacimiento had originally been selected, not only because it seemed to meet the requirements for a white bass/threadfin shad combination, but because the Nacimiento River was tributary to a coastal stream with no physical connection with the Sacramento-San Joaquin River system. White bass would, therefore, not have access to the Delta region. The success of the white bass fishery at Nacimiento brought about requests from many anglers to stock the species in other areas, but the Department and the Fish and Game Commission resisted these requests.

In 1977, however, it was verified that white bass were present in Lake Kaweah, a reservoir in Tulare County. Apparently, the fish had been transported illegally to this reservoir by anglers who wanted the species to be closely available. By 1979, white bass were numerous here and reproducing successfully (California 1987).

The Department's concerns about potential impacts of the white bass on the fishery resources of the Delta changed radically from the mid-1960s to the mid-1970s. During this period, populations of striped bass and chinook salmon that depend on the Delta for their well-being underwent dramatic declines. It was feared that predation by white bass on these species would seriously worsen their situations.

The Department of Fish and Game considered several options for controlling their spread. The most radical control method, chemical treatment to remove the white bass, was vehemently protested by local anglers, and it was rumored that such a move would merely result in their illegal reintroduction into Kaweah as well as into other reservoirs. Another option was the planting of Kaweah for several years with large numbers of juvenile striped bass in the hope that the larger species would prey upon and eventually control the white bass. This move was protested by a local angling club which received a court injunction to prevent the stocking of striped bass. Meanwhile, in order to prevent further transport of white bass, a special regulation was enacted which stated that any white bass caught anywhere in California had to be killed or returned immediately to the water from which it was taken (Gleason 1984).

The objection to the stocking of striped bass was resolved by stocking "sunshine bass," a hybrid of the white bass and striped bass. These fish have many of the characteristics of white bass and provide very popular reservoir fisheries, principally in the southeastern states.[87] They have very low reproductive capability and were expected to compete with and depress the white bass population in Kaweah. About 240,000 sunshine bass fry were stocked in Kaweah in 1983, but no obvious impact on white bass was observed.

Record rainfalls in California in 1982 and 1983 filled its reservoirs, and by the end of the second winter, Lake Kaweah had water running over its spillway, down the Kaweah River, and into the Tulare Lake basin, flooding about 120 square miles of the "lake" that had been leveed, dried, and farmed. After two years of flooding, farmers (primarily cotton growers) decided to drain their lands, put them back into production, and also save two "lakeshore" towns. The easiest method of draining was to pump the excess water into the "North Fork of the Kings River," a Central Valley waterway which would result in a water connection leading to the San Joaquin River and the Delta. Under an emergency proclamation issued by the U.S. Corps of Engineers during the spring of 1983, reclamation districts and land companies remade the channel along some 29 miles of the Kings River to dewater the half-dry lake and drain its water north into the Delta region.

This created a "no-win" situation for the principals concerned. The farmers and the Corps of Engineers were adamant in their desire to divert the water north and thereby restore agriculture in the southern San Joaquin Valley. Conversely, the Department of Fish and Game teamed up with various sportsmen's and environmental

[87] Sunshine bass fry produced by eastern fish farmers are regularly imported into southern California by commercial aquaculturists. California growers rear large numbers for sale by fish markets and restaurants. In August 1992, some of these hybrids were introduced as sport fish into Irvine and Anaheim lakes, Orange County. The Commission allows California aquaculturists to work with pure white bass and to sell live sunshine bass but only south of the Tehachapis.

In California, all such hybrids are termed sunshine bass. However, the American Fisheries Society recommended the term "palmetto bass" for offspring of female striped bass crossed with male white bass, and "sunshine bass" for the reciprocal cross (Anon. 1991). Apparently, the palmetto bass is the more popular hybrid among California aquaculturists.

groups to see that Tulare Lake water bearing white bass, now characterized by many as "predatory" and "voracious," would not reach the Delta. At stake were several threatened and endangered fishes as well as important sport and commercial species. Among the measures used was erection of a barrier (perforated plate screen) to allow drainage of Tulare Lake water but prevent passage of white bass into the Delta region. Some white bass above the barrier were also eradicated with chemicals. Since such action involved the use of "pesticides" on private property without consent of the owner, it took a ruling by a State District Court of Appeal to legalize this action (Sport Fishing Institute 1985). The controversy reached the popular press and provoked the issuance of many strong statements. See, for example: *San Francisco Chronicle* (1983), Champion (1983), Gilliam (1983), Smoley and Porteous (1983), and Freeman (1984) as well as some "rejoinders" by the Department of Fish and Game; e.g. Gleason (1984). The extent of the argument can be determined by noting some of the titles of articles in newspapers such as the *San Francisco Chronicle*: "Fishy Business," "Flood Project Called 'Time Bomb' for Delta," "A Troublesome Fish," "Beware the White Bass," and "The Great White Bass Threat."

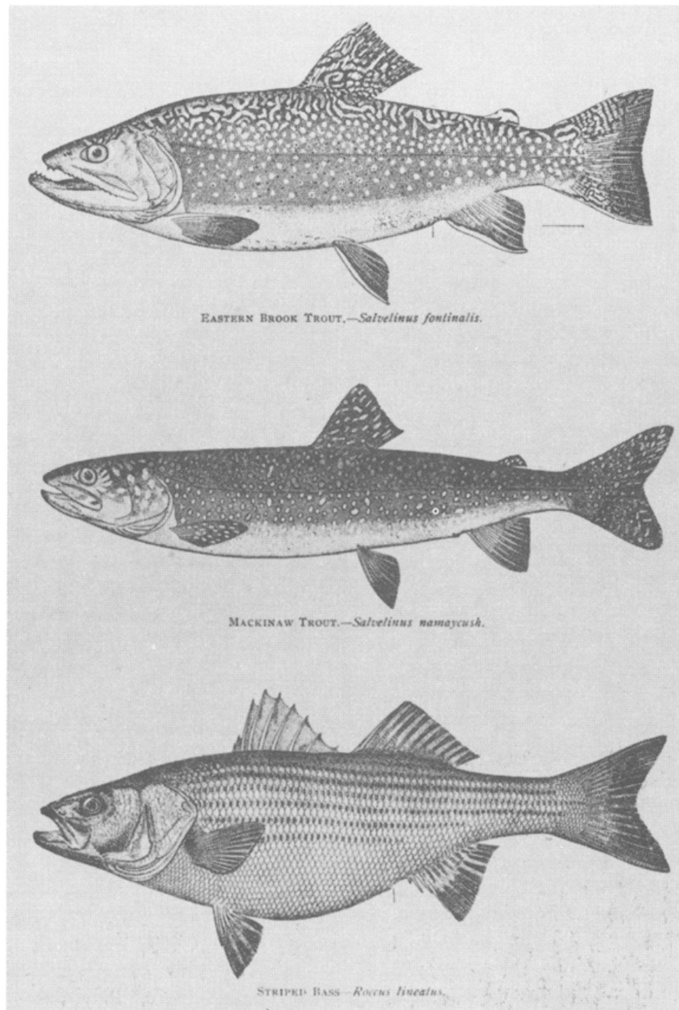
The chemical treatment in 1987 of Lake Kaweah and downstream waters of the Tulare Lake basin was one of the largest ever carried out in the United States, and certainly California's largest. The white bass achieved its widest distribution in California in the mid-1980s prior to the chemical treatment operation (California 1987). In addition to the reservoir itself, white bass were found in the Kaweah River immediately above the reservoir. Large numbers escaped into waters downstream of Lake Kaweah during the record 1982–83 flood runoff. A large population became established in the flooded Tulare Lake basin and connecting waterways. They may have reproduced in these waters. The Department and cooperating agencies constructed fish barriers to prevent white bass from escaping northwards into the San Joaquin River and Delta. An environmental impact report was completed and after two years of preparation and planning, the treatment was initiated. The reservoir and all waters downstream from the dam, including Tulare Lake basin and connecting waterways, were rotenoned in the fall of 1987. The complex, time-consuming, and costly operation was well executed. Apparently, a complete kill of white bass was achieved. Total cost of the project, including barriers, law enforcement, public relations, equipment, treatment, monitoring, etc., was about $7.5 million (State biologist N.A. Villa, pers. comm.).

Despite the massive effort and successful eradication of white bass from Lake Kaweah and the Tulare Lake basin, the threat remains. White bass not only continue to thrive in Lake Nacimiento, but are apparently reproducing successfully in Pine Flat Reservoir in Fresno County. The latter reservoir is directly connected to the Delta via the Kings and San Joaquin rivers, particularly during years of high runoff. Success Reservoir, Tulare County, also was suspected of harboring white bass (a single adult was recorded in 1987), but it was chemically treated in 1988 and is no longer considered a threat.

Small numbers of white bass have been documented in Pine Flat Reservoir since 1977. Despite intensive sampling with seines, gill nets, and electroshockers, especially prior to the 1987 Kaweah treatment, only 30 individuals were captured through 1991. From 1992 through 1994, 47 white bass were recorded, most of them yearlings, despite a much-reduced sampling effort. It is feared that the population will experience an "explosion" similar to that which occurred in Lake Kaweah and downstream waters following high runoff in 1982–83. The Department hoped to treat Pine Flat chemically in the autumn of 1991 or 1992 when low water levels prevailed. However, the operation was postponed due to strong local opposition, the need to prepare a lengthy, complex environmental document, and the Department's poor financial position which has worsened with time. (Estimated treatment costs ranged from $1.3 to $3.3 million, depending on water level.) There are also strong convictions, both within and outside the Department, that Pine Flat should not be treated unless Lake Nacimiento is also treated. The important aquatic resources of the Central Valley continue to be threatened by the white bass.

Angling regulations adopted by the Fish and Game Commission on the take of white bass paralleled the changing status of this species in California. From 1966 through 1969, when successful establishment was the only concern, it was illegal to take or possess white bass. Once established, a five-fish daily bag and possession limit and an all-year open season were invoked at Lake Nacimiento. These regulations remained in effect from 1970 through 1974, but the bag limit was increased from five to 10 for the 1975 through 1980 seasons when it became apparent that the Lake Nacimiento white bass population could support additional harvest. Statewide white bass regulations adopted by the Commission in 1981 demonstrate the strong concerns about the threat of illegal movement of these fish. The bag limit was increased to 25 fish and in 1984 to unlimited take. The new regulations made it illegal to possess or transport live white bass and required the immediate killing of any retained fish or the immediate release of any unwanted fish. In 1989 this was strengthened by adding that any white bass kept must be immediately killed by removing the head or cutting through the gills.

Like it or not, the introduction of the white bass into Lake Nacimiento was believed beneficial and was conducted well by the Department of Fish and Game. Some naivete, however, was exhibited in thinking that fish can be confined to a particular water in view of their well-known ability to "escape," and in this case the ability of human beings to transport fish, however illegally, from one place to another. The general situation with respect to the role of the white bass in this regard was well expressed by Gleason (1984).



Fish illustrations from Smith (1896) and biennial reports of the State Board of Fish Commissioners of the State of California (eastern brook trout, mackinaw trout, and striped bass).

4.36. Striped bass, Morone saxatilis (Walbaum)[88]

The success of the anadromous striped bass on the west coast of North America has been called "... one of the greatest feats of acclimatization of new species of fish in the history of fishculture...." by Shebley (1917). This statement, or some variation of it, has appeared in so many articles on the striped bass that it would be breaking a precedent not to repeat it. Craig (1928) has stated that its successful introduction is probably rivaled only by the introduction of American shad into California and trout into New Zealand.

The striped bass is native to the eastern seaboard from the St. Lawrence River to Louisiana. About 135 fish from the Navesink River, New Jersey, most of them not over 3 inches long, were brought by rail and planted in the Carquinez Strait (Martinez) circa 12 July 1879. These were brought out by Livingston Stone at the request of S.R. Throckmorton, Chairman of the California Fish Commission. Originally from New Jersey, Throckmorton also suggested the place of capture.

An amusing account of how it took a poacher to make this capture appears in Seton (1974). About 11 months after this first planting in California, there was brought to Throckmorton on or about 1 July 1880 "... a very handsome striped bass taken in this harbor [San Francisco], measuring 12½ inches in length and weighing one pound." The first shad taken in California had been carefully preserved in alcohol and presented to the California Academy of Sciences through Mr. Throckmorton (*Forest and Stream*, 21 May 1874; California Academy of Sciences 1875), but apparently his initial scientific tendencies were later outweighed by his gustatory nature, since his report on one of the first striped bass taken in California mentions its flavor as being "... fully up to the best specimens of the fish at the East...." (Throckmorton 1882).

There were reports of other captures of striped bass in California, but the strong desire of its Fish Commissioners, especially Throckmorton, to establish it firmly led J.G. Woodbury of the Commission to secure about 300 more from the Shrewsbury River, New Jersey, and plant them close to the first stocking locality in Suisun Bay near Army Point on 25 July 1882. From this meager stock has originated the abundant supply of the Pacific Coast today. Primary sources of references for the introduction of striped bass to California are: Mason (1882); Stone (1882); Throckmorton (1882); California Fish Commission Report for 1878–79, p. 14; *Ibid.* 1881–82, p. 5–7; Woodbury (1890b).

As with the accounts of so many fishes introduced into California, the number of fish planted, the dates of planting, the source of the stock, and even the stocker will be found to vary in subsequent publications, even those prepared within a

[88] Imported as Roccus lineatus, a number of systematists term this fish Roccus saxatilis. See the section on white bass for information on the introduction of white bass X striped bass hybrids. There is also a "striped bass" in the "Hypothetical Introductions" section of this paper which, however, is not the fish discussed here.

few years of the events. For example, the number of striped bass planted in 1879 appears to be given as 132 in most publications. Although this figure seems to be erroneous, the exact number of striped bass planted initially is not of importance. It has not been thought worthwhile to list all of the variations which have been disclosed, but among the most serious errors of fact concerning the introduction of striped bass into California are those which follow. Jordan (1915) said that it and the shad were "... both planted about 1878 from the Potomac and the Schuylkill rivers...." E.D. (1920a) said that 150 were planted in 1874 and that 400 were sent to California in 1882 by the U.S. Bureau of Fisheries. Surprisingly enough, Stone (1882) twice stated that the striped bass he brought to California came from the "Neversink" in New Jersey, as does the California Fish Commission Report for 1878–79. CFG (1922c) also credited the source of the first plant in California to the "Neversink"—which is, of course, a fabled trout stream in the Catskills. As Sir Walter Scott said in about 1820, "This is a mistake into which the Author has been led by trusting to his memory, and so confounding two places...." (Scott 1950). Or, Stone (1882) may have been "corrected" by someone. The California Fish Commission Report for 1895–96 said that only 100 striped bass were planted in 1879 and 350 in 1882. The Report for 1905–06 also stated that the initial plant was only of 100 fish. West (1944) compounded the error by saying that they were transferred from the Roanoke River, near Weldon, South Carolina. Sport Fishing Institute (1955a) stated that the California striped bass came from Delaware, but corrected this misstatement two months later (Sport Fishing Institute 1955b). But why go on?

There have also been a number of transplants of striped bass by the State along the coast using California stock, beginning in 1899. Possibly their dispersal was hastened by these transplants, but there were reports that they had been taken as far north as British Columbia in 1884 (California Fish Commission Report for 1883–84, p. 10) and from San Diego to the Oregon line in 1887 (U.S. Fish Commission Bulletin for 1887, p. 50). Smith and Kendall (1898) said that two striped bass were seined at Redondo Beach in September 1894, and gave its normal Pacific range to the north to be the Russian River.

Today, on the Pacific Coast, striped bass populations are centered in the San Joaquin-Sacramento Estuary with emphasis on San Francisco Bay, with a small population in Coos Bay, Oregon. Apparently, the species usually requires estuarial water for a portion of its life cycle. The fish is known to range from Vancouver Island to about 40 km below the California/Mexico border, and is also found in areas such as Tomales Bay and the Russian River (Seymour 1979). Less than 10% of the California catch is made in the ocean (White 1986 and references therein).

The early history of the striped bass fishery in California was well summarized in Smith (1896); Scofield and Bryant (1926); Craig (1928); E.C. Scofield (1931); and Skinner (1962). Ten years after the initial introduction, a commercial fishery using gill nets had started and flourished for many years. The history of this fishery up to 1927 was summarized by Craig (1928) as follows: "... in 1899 they were supplying a total annual catch of over 1,200,000 pounds. This period of large yearly catches continued until 1915, after which, with the exception of 1918, the catches were much lower. This drop in total catch upon careful analysis appears to be due to withdrawal of men and boats from the fishery [to Monterey] and restrictive legislation. During the years from 1920 to 1927, inclusive, the catch per unit of gear and effort for a constant unit of time has become greater, which strongly indicates an increased abundance or availability of bass to the fishermen." During the last 10 years of its life, the commercial fishery for striped bass in California averaged about 658,000 lb annually (Skinner 1962).

Restrictions on market fishing started at an early date and increased in severity; some of these restrictions are outlined in CFG (1922c, 1925b). Circa 1933, the sale of striped bass was prohibited except for those taken in certain restricted areas during three months of the shad season (Farley 1934). Commercial fishing for striped bass in California was entirely prohibited by law in 1935.[89] Incidentally, this final action was taken despite the opinion of fishery workers that the striped bass population in California was actually becoming more abundant, the protection given it was entirely adequate, and that it could support both a commercial and sport fishery. Since the subject was a controversial one and obscured by much ill-informed testimony, it is of especial interest to read the detailed analyses of Craig (1928, 1930), E.C. Scofield (1931), and Clark (1933).

The sport fishery, on the other hand, gained momentum slowly. In fact, the success of the first angling seemed quite disappointing according to Smith (1896). The State Board of Fish Commissioners considered that the greatest value of the striped bass lay "... unquestionably in its commercial and economic importance and not in its qualities as a game fish...." (California Fish Commission Report for 1891–92, p. 37). However, by the turn of the century, a great many striped bass clubs had been organized (California Fish Commission Report for 1903–04, p. 36), and finally, the sport fishery for striped bass surpassed the old commercial one, and ranked second in popularity only to that for trout despite its concentration in San Francisco Bay and the Delta. Serious biological study on the sport fishery for striped bass started in 1946. The striped bass became a major sport fish in California, and there were many anglers who fished exclusively for it. By 1968, striped bass fishing constituted about 60% of all angling dependent upon the Sacramento-San Joaquin Estuary including the ocean and river Pacific salmon fisheries (Chadwick 1968). Bait fishing, trolling, spin fishing, surf fishing, and even fly fishing are among the methods used for its capture.

Management of the striped bass in California has consisted of three measures: restrictions on capture, transfers to various coastal and inland areas, and artificial

[89] Nichols (1966) in a widely distributed Fishery Leaflet of the U.S. Fish and Wildlife Service, erroneously gave the date as 1931.

propagation. Its importance as a sport fish and as one associated with changes in water transfers and water quality in the Delta has also made it a much studied fish. Restrictions on the commercial catch have already been outlined. There have also been restrictions on the sport fishery, consisting largely of limits on size and number.

Transplants of striped bass into California coastal waters began at an early time. At least as early as 1899 and up to 1933, the State made a number of plants, using netted fish, along the entire California coast. It was the feeling of some of the California Fish Commissioners that such plants would overcome the difficulty of the striped bass to make the long voyage through salt water to reach other freshwater streams (California Fish Commission Report for 1903–04, p. 37). Records of these transplants (varying of course as to details) will be found in: CFG (1917a); Scofield (1919); Scofield and Bryant (1926); California Fish Commission Report for 1903–04, p. 38; *Ibid.* 1905–06, p. 42–43; California Fish and Game Commission Report for 1909–10, p. 25–26; *Ibid.* 1916–18, p. 75; *Ibid.* 1918–20, p. 125; *Ibid.* 1932–34, p. 82–83-G.

For example, seining in San Pablo Bay in 1916 resulted in shipments of small striped bass to various points in San Luis Obispo County. Other shipments of seined striped bass were sent to Newport Bay, Anaheim Bay, Bolsa Chica River, and Sunset Beach in Orange County, and to Mission Bay, San Diego County.

In noting that several small striped bass had been taken in the San Diego River near its outlet to Mission Bay in 1919, N.B. Scofield (1919) said that striped bass had never before been reported south of Monterey Bay, and in discussing a reported catch of striped bass at San Diego in 1931, he (N.B. Scofield 1931) said that it was "... the first verified record of striped bass being taken south of Monterey." His statements are contrary to much earlier reports that by 1887 this species had been recorded south as far as San Diego, but it is, of course, possible that these early reports were erroneous. Radovich (1963) was also a subscriber to this belief. He believed that striped bass on the Pacific Coast were confined mainly between Monterey and the Russian River until about 1900 and that unlike their Atlantic coast relatives they did not make extensive coastal migrations. Walford (1932) pointed out that fish caught at San Clemente (between Los Angeles and San Diego) in 1931 and identified as striped bass were actually the young of the native salema or big-eyed bass (Xenistius californiensis) . W.L. Scofield (1939) stated that a striped bass of 30–31 lb was taken at Oceanside (between San Clemente and San Diego) in 1938, and that this was an authentic record. He also said that there were several records of true stripers caught in Newport Bay, and reiterated that the 1919 records near Mission Bay were authentic. CC (1940a) also said that only two authentic records existed of striped bass caught in the southern region of the California coast.

In view of these records (both planting and capture or lack of capture), it seems a bit strange that the Department of Fish and Game should again attempt to transfer striped bass to southern California coastal waters in the mid-1970s. In saying that the Department of Fish and Game wished to improve ocean sport fishing, Hubbard (1973) credited the then Director of Fish and Game (G.R. Arnett) as saying, "We looked at a number of species of fish before choosing stripers for this program. We decided to go ahead with this fish because it already occurs naturally, although in very small numbers, as far south as San Diego Bay. This means that the habitat offers a reasonable chance of survival for stocked stripers, and we won't be faced with problems that might arise through introduction of a species entirely new to the southland."

Horn et al. (1984) said that each April from 1974 to 1977, the Department of Fish and Game stocked 10,000 to 14,000 juvenile striped bass (100–150 mm standard length) into the upper Newport Bay Estuary. These plants were obviously quite costly (the first plant from the Central Valleys Hatchery involved the use of both truck and ship), and, since the Newport plants were labeled as "initial," it does demonstrate that "history" is quickly forgotten (Young 1974). Horn et al. (1984) said that some striped bass survived in Newport Bay, circa 1978–79, but suggested that they constituted a nonbreeding population. In a popular account, Whitaker (1993) said that striped bass were planted during the 1980s in Long Beach Harbor and are now caught in fair numbers.

Transplants of striped bass have also been made into the Salton Sea on various occasions. The records in Table 2, derived from the official records of the Division of Fish and Game, differ in some respects from those recorded elsewhere. The differences are not considered of importance, however, as none of the plants succeeded in establishing a population of striped bass here.[90] (See Coleman 1929; CFG 1930f; CFG 1931a; CFG 1932e; California Department of Fish and Game Report for 1928–30, p. 18; Neale 1931b; Shebley 1931, p. 65).

Transplants of striped bass, with the concurrence of Arizona and Nevada, have also been made into the lower Colorado River. The first plant was made on 15 April 1959 near Blythe, Riverside County. The 938 small stripers which were planted had been seined from the San Joaquin River (St. Amant 1959). For some inexplicable reason, Minckley (1973, p. 211) indicated quite erroneously that the source of this plant was the Santee-Cooper Reservoir of South Carolina.

Plants in the River made by the State totalled 95,414 individuals between 15 April 1959 and August 1964. Fishing for this species has been good throughout the California section of the Colorado River. The first verified catch here of a legal-size striped bass was made in March 1960 (OC 1960b). In May 1966, young striped bass that had to be offspring of the transplants were found in the city water plant in Brawley, and in 1968 there was positive proof that striped bass had spawned in the River itself as well as in the Imperial Valley canal system (OC

[90] There was a vague report by CFG (1930e) that "Striped bass seem to be holding their own in the Salton Sea," but we suspect that the author was overoptimistic or that striped mullet (Mugil cephalus) were confused with the striped bass.

1968a). Swift et al. (1993) stated that striped bass migrate from Lake Havasu into the Imperial Valley and the Colorado River delta in Mexico, back up through the Alamo and New rivers, and are considered to be self-sustaining. They also said that a small number have strayed into Lake Cahuilla near Indio at the end of the Coachella Canal.

The striped bass has also been transplanted into a number of freshwater reservoirs where it has created some trophy fishing, and into some reservoirs too warm to support trout. The reasons for planting it in one reservoir (Lake Mendocino) in 1967 were not only to create a new trophy fishery but to improve fishing for largemouth bass by reducing a population of stunted bluegills (OC 1967c). Attempts to establish naturally reproducing stocks in fresh water have had limited success in California, as is true elsewhere in the United States. Nevertheless, the striped bass has become established in Millerton Lake, a reservoir on the San Joaquin River. First stocked there during the 1955–57 period, it was not until September 1959 that it was certain that it had reproduced (OC 1960c; Wilson and Christenson 1965).

California has also served as a source of striped bass sent to other states such as Nevada (OC 1965) and Hawaii (E.D. 1920a), and even to Japan (CFG 1929c).

Surprisingly enough—considering the beliefs of early fish culturists—inquiries by the U.S. Fish Commission in 1896 indicated that there was no need to initiate artificial propagation of striped bass (U.S. Fish Commission Report for 1897, p. XXI), although Smith (1898, p. CXLII) felt that "When the conditions change, as they probably will in time, the artificial propagation of striped bass in California will become desirable." By 1907, this early sanguinity had lapsed and the first attempt in California was made. Convinced of the advisability of attempting to increase the supply of striped bass through artificial propagation, the California Fish and Game Commissioners constructed a hatchery building at Bouldin Island on the San Joaquin River. With but few funds available, they cooperated with the U.S. Bureau of Fisheries with the result that Capt. G.H. Lambson, in charge of Federal salmon-hatching work in California, together with three Federal workers from Baird and a representative of the California Commission, ran the hatchery. With ripe eggs supplied by commercial fishermen, the hatchery functioned until 1910. It was then abandoned after a series of unsuccessful years (Scofield and Coleman 1910; Scofield and Bryant 1926; Leitritz 1970).

Shebley (1913b) recommended that artificial propagation of striped bass be taken up again because "... it is of great economic value to the people." (The reader will recall that the striped bass in California was primarily a commercial fish at the time.) Shebley (1913b) asked the State Legislature to appropriate a special fund for this purpose, but no action was taken. It was not until 1981 that any stocking of artificially propagated striped bass was carried out in California.

Meanwhile, the sport fishery (as has been related) gained dominance. In a popular article, Calhoun (1950) wrote that roughly 200,000 individuals fished 2 million days for striped bass in California and caught about 2 million fish averaging about 4 lb each. He estimated the value of the striped bass fishery in California at $10 million annually. Although the fishery for striped bass in California was then in its "golden" days, he also pointed out the dangers to this resource from water pollution and water diversion through pumps, and the necessity for continued research. About 20 years later, the Stanford Research Institute estimated the net annual benefit to the State of the sport fishery for striped bass at about $7 million (Altouney et al. 1966). Projections by the Institute for the striped bass fishery in the San Francisco Bay and Delta areas yielded estimates of $13.14 million annually for 1970 and $36.78 million for 2020. These estimates, especially the latter figure, were based on the assumption that striped bass fishing effort would increase in direct proportion to the projected increase in human population. For a variety of reasons, some of which are detailed below, the assumption proved incorrect.

During the early 1960s, the adult striped bass population was estimated at 2.3 to 3 million fish. By 1975 it was considered that the adult striped bass population in California was relatively stable, between 1.5 and 2 million fish. Approximately 15% of the adult bass were caught by anglers each year while 15 to 30% of them died of natural causes (Heubach 1975). Since then the striped bass population in California has suffered a decline. Studies have shown that the adult striped bass population was only about 1 million fish in the early 1980s, and then declined to about 600,000 adults in the early 1990s. The abundance of young also has declined substantially. It is considered that the fishery is in danger of becoming an inconsequential fraction of the state's sport fishery.

Stevens et al. (1985) and Delisle et al. (1989) provided a history of efforts to determine the causes of the striped bass decline. The causes, as cited in the latter publication, are as follows: i) Delta water diversions; ii) reduced Delta outflows; iii) low San Joaquin River flows; iv) water pollution, toxic chemicals, tracemetals; v) dredging and spoil disposal; vi) bay-fill projects; vii) illegal take and poaching; viii) diseases and parasites; ix) annual die-off of adult bass; and x) commercial bay shrimp fishery. It is generally conceded that the single major problem is the loss of young fish to water diversions from the Delta over the past 35 years.

Since 1961 the Department's Bay-Delta Project has been studying the ecology of the Delta with emphasis on factors responsible for decline of the striped bass. The results have appeared in numerous technical publications. More recently, the Department and other State and Federal agencies have formed the Interagency Ecological Studies Program for the Sacramento—San Joaquin Estuary to guide the many investigations. Findings are published as technical reports.

A major attempt to restore the population was stocking of hatchery-reared striped bass (Delisle 1986; Delisle and Coey 1994). This started in Bay-Delta waters in 1981 by the State with subsequent aid by private aquaculturists. About 11 million hatchery-reared striped bass fingerlings and yearlings were released in the Delta and San Pablo Bay from 1981 through 1991, almost all of them reared by private aquaculturists. Over half of these fish were marked or tagged to evaluate the program. The fraction of legal-size hatchery-produced stripers in the sport fishery ranged from 1% in 1984 to over 12% in 1991. Estimated returns were 1.04% for yearlings, 0.38% for advanced fingerlings, and 0.07% for fingerlings. On a cost basis, to put a legal-size hatchery striper in the creel averaged $106/fish for yearlings, $237/fish for advanced fingerlings, and $1071/fish for fingerlings. It is apparent that striped bass stocking is expensive.

Large-scale stocking of privately-produced hatchery striped bass was terminated in 1992 because of possible predation by stripers on native fishes (e.g. winter-run chinook salmon smolts, delta smelt, and splittail [Pogonichthys macrolepidotus]) listed by the State and Federal governments as endangered, threatened, or species of special concern. However, stocking continued at a much lower level in 1993 (28,000 yearlings), 1994 (37,000 yearlings), 1995 (100,000 yearlings), and 1996 (100,000 yearlings and two-year olds) using striped bass salvaged at the Delta fish screens and reared in net pens before release. The future of this program is uncertain, but it is likely to continue.

The stocking of striped bass in some reservoirs has been quite successful, although the resulting fishery is, of course, an artificial one.

Although many features of the life history of the striped bass have been studied in California, most of them have not been discussed here. It is of interest historically, however, to record that with respect to this species in California, the first life history study was made by E.C. Scofield (1931), one of the first food studies showing that salmonids might form a part of its diet was made by Shapovalov (1936), its larvae were first found in 1939 and its free eggs in 1940 (Hatton 1940b), and its actual spawning was first observed by Woodhull (1947).

In summary, we subscribe to the belief that ecological conditions have so changed in the Delta and San Francisco Bay that the future of the more "natural" striped bass fishery in California rests primarily on restoration of the original habitat. Extreme losses at water diversions and changes in water quality seem to be the main factors in altering the once abundant striped bass resource of California.[91]

[91] Perhaps the most ironic aspect of the introduction of the striped bass into California from the Navesink River, New Jersey in 1879 is that "... the stay-at-home Navesink River stripers ultimately were extirpated possibly as a result of dam construction in the upper reaches of the River's tributaries." The Navesink was restocked with striped bass fingerlings in 1984 (Sport Fishing Institute 1984).

4.37. Green sunfish, Lepomis cyanellus Rafinesque Bluegill, Lepomis macrochirus Rafinesque

The history of the introduction into California of the green sunfish and the bluegill, native to eastern and southern North America, must be discussed together as the records are confusing. There may even have been shipments of sunfishes other than those mentioned in this paper.[92]

A few green sunfish from Illinois were first introduced into Lake Cuyamaca, San Diego County, by the U.S. Fish Commission in 1891. Possibly, some were also planted in the Feather River at the same time (California Fish Commission Report for 1895–96, p. 29). The number planted was not listed. Shebley (1922) listed 10 green sunfish as having been distributed in 1891 by the California Fish Commission. Possibly, he was alluding to this plant; possibly to some other shipment; possibly this record is a lapsus calami. Smith (1896) stated that the deposition of "sunfish" in Lake Cuyamaca in 1891 was accidental. This may be true since the U.S. Fish Commission's Report for 1892 does not list sunfish along with the other fishes which it reported it planted in Cuyamaca in 1891. Evermann and Clark (1931) suggested that those brought into the state in 1891 were mistaken for bluegills. Or, possibly, they were brought in as forage for the other fishes in the shipment. San Diego newspaper accounts, however, did list "sunfish, 300" as having been stocked in Cuyamaca in 1891, so conjecture seems hopeless. (See "striped bass" in the "Hypothetical Introductions" section of this paper.)

At any rate, we believe that green sunfish were planted in Lake Cuyamaca because specimens taken from the Lake by a Mr. Fletcher of the California Fish Commission were identified as this species by David Starr Jordan (Smith 1896, p. 441).[93] Jordan (1925) merely said that the green sunfish was introduced as food for the bass. He intimated that the bass were smallmouth. If true, then the first black bass introduced into Lake Cuyamaca were smallmouth rather than largemouth. (See the section on black basses in general.) In 1896, the State Fish

[92] The "Mottled Sunfish" listed in State fish rescue reports (see California Division of Fish and Game Report for 1936–38, p. 96–97-F, 96–97-K; Ibid. 1938–40, p. 75) was believed by some rescue workers to be a hybrid, and specimens sent to C.L. Hubbs and R.R. Miller were identified as hybrids of the green sunfish and bluegill. State fish rescue workers also recognized another "variety" of sunfish, known to them as the "Snowstorm." Specimens of these fish have never been subjected to critical examination. "Mottled perch" were also listed in some State fish rescue records; see, for example, Neale (1934). We have never determined the identity of these fish and know that the lists of rescued fish were often inaccurate. "Perch" and true sunfish were and are often confused.

[93] The specimens were probably taken from the Lake in 1896 since Smith (1896) says on page 438, "Mr. Arthur G. Fletcher, of the California fish Commission, visited Lake Cuyamaca in January, 1896...."

Commission removed 116 adult and fingerling green sunfish from the Lake and planted them in several public waters throughout the state, including some in the Sacramento-San Joaquin drainage. See California Fish Commission Report for 1895–96, p. 73, for details.

In 1895, 36 green sunfish were planted by the U.S. Fish Commission in Lake Elsinore, Riverside County, and the Bolsa Chica River, Orange County, and 12 "sunfish," evidently the same species, were delivered to the Sisson (Mt. Shasta) Hatchery (U.S. Fish Commission Report for 1895, p. 72; California Fish Commission Report for 1895–96, p. 30–31).[94] Although he did not specify the species planted, Smith (1896, p. 441) said that 18 sunfish were planted in Lake Elsinore, 18 in the Bolsa Chica River, and 12 yearlings delivered to Sisson. Shebley (1917) merely corroborated him. In any event, 1895 appears to be the last date in planting records available to us on which green sunfish are definitely recorded as having entered the state, except for the account by Vogelsang (1931) mentioned below. Shapovalov (1939) said that both green sunfish and bluegill were introduced into California in 1895, but corrected this error later (Shapovalov 1965, 1970).

"Sunfish" were held at Sisson Hatchery for several years. (California Fish Commission Report for 1901–02, p. 19; *Ibid.* 1909–10, p. 87–89; and others.) In at least one of these reports, they were specified as green sunfish (California Fish Commission Report for 1897–98, p. 38), and in the 1903–04 Report, p. 20, they were listed as L. cyanellus. Shebley (1922) listed a number of "distributions" following the plants already mentioned. These began in 1902 and by 1919 almost 9000 were recorded as having been distributed by the State. It can be assumed, then, that this species was afforded some opportunity to establish itself in several public waters, but it does not seem to have been recorded as actually taken.

The date of the first introduction of the bluegill into California is questionable. Smith (1896, p. 441) said that small plants of this species and the green sunfish had been made in public waters of California by the U.S. Fish Commission, but indicated on the same page that he was not certain which of the numerous species of sunfish were brought here. Moreover, the only specific stockings of sunfish which he mentioned (in 1891 and 1895) were apparently the plants of green sunfish which have already been described. Shebley (1917) gave just about the same history and, although one might deduce from the remarks of these authors that both the green sunfish and the bluegill were introduced in the 1890s, the first specific record of the latter's introduction is 1908. Evermann and Clark (1931) stated, "The date of introduction and number of individuals of this species [the bluegill] is uncertain as they, along with the green sunfish were introduced merely as sunfishes, about 1890 and 1891." We doubt that any of the preceding "authorities"

[94] California (1981) stated that the 1895 plants in the Bolsa Chica River and Lake Elsinore were bluegill, but we find no evidence that this was the species stocked.

had any more information on the subject than we have. We have listed all of the primary references pertaining to the early introductions of sunfishes with which we are acquainted, and can provide no further help in solving this problem.

It may be true that the bluegill did enter the state at an early date, but the first clear record of its introduction seems to have been in 1908 (October or November, depending on the source). In that year, it was brought from Meredosia, Illinois, by the U.S. Bureau of Fisheries at the State's request. Varying accounts of its introduction were given by: the U.S. Fish Commission Report for 1909, p. 16, 69, 92, 98; California Fish and Game Commission Report for 1909–10, p. 47–48; Scofield (1916a); Shebley (1917); Vogelsang (1931).

Vogelsang (1931) said, "In order that the date of the first successful introduction of the crappie, calico bass, blue gill and green sunfishes and the yellow perch may be historically correct, may I be permitted to offer the following data relative thereto...." He then described how in return for a favor to the U.S. Commissioner of Fisheries, the State of California was sent a carload of fish from the United States collecting station (fish rescue) at Meredosia, Illinois. (Vogelsang, a lawyer and angler, who was then Chief Deputy of the California Fish and Game Commission, had testified before an Appropriation Committee of the U.S. House of Representatives as to the value of the U.S. Fish Commission.) He stated that he chose the fishes mentioned in order to supply both food and sport to Californians, and that the choice had the approval of the Federal fish cultursts. The carload of fish arrived in October 1908 and he described the distribution of its contents from Lassen County on the north, southward to Orange and Riverside counties. Vogelsang's (1931) account, which seems to be quite straight-forward (if a bit fatuous), is backed up by his letter of 11 September 1908 to David Starr Jordan in which he said, "...we expect to receive next month a shipment of fresh water fish from the east such as Crappie and Blue Gill Sun Fish...," alluded to his trip to Washington, D.C. in January 1908 where he arranged with officials of the U.S. Fish Commission to have a variety of freshwater fishes found in the Missouri Valley sent to California, spoke of asking specifically for yellow perch, and suggested that it would be of advantage to plant the "Crappie and Sun Fish" in southern California.

Vogelsang (1931) was incorrect in saying, "While it is true that a previous attempt had been made in the year 1891 to introduce these fishes, the records also show that none of them survived...." It should also be noted that none of the other accounts of the 1908 introduction cited above list the green sunfish as having been brought in with the shipment. Our surmise is that Vogelsang's account (written about 23 years after the introduction) was based on an imperfect memory and without recourse to standard records, but is essentially correct as to the date of the introduction.

The account of the California Fish and Game Commission's Report for 1909–10 concerning the 1908 importation was headed "New Food and Game Fishes." It did not mention any previous introduction of the bluegill, which it called "... the blue gilled sunfish (Lepomis pallidus) ..." Along with the crappie and yellow perch, which it mentioned in the shipment, it was considered a panfish adapted to the smaller bodies of water at low elevations which would afford both food and sport. The 1909–10 Report also stated, "... some specimens of young bream and the blue-gilled sunfish have been received at our office, which were taken in waters of the Sacramento Valley, indicating that they are increasing." Although the implication that the "bream" and "blue-gilled sunfish" are two different species is somewhat confusing, this statement may also imply that the fish had not previously been resident in the Sacramento Valley. Bryant (1921a, p. 76) also indicated that the 1908 introduction constituted an "introduction of new food fishes," but his statement was based only on literature search. Scofield (1916a) stated that the bluegill was little known at the time (circa 1916). CFG (1917b) stated, "... bluegill sunfish and calico bass were planted in the Sacramento and San Joaquin rivers about ten years ago...." Neale (1928) indicated that both "crappies and sunfishes" were introduced into the Central Valley at some time after 1904 "... upon requisition by our fish cultural department from the U.S. Bureau of Fisheries." There is a report by Wohlschlag and Woodhull (1953) on Salt Springs Valley Reservoir, Calaveras County, which said in part, "Incomplete records made around 1900 indicate that ... bluegill ... [and] black crappie ... had been introduced," but the vagueness of this record casts doubt on its authenticity. D.E. Wohlschlag (in 1993) did not recall the source of the information, and agrees with our conclusion that the record may be dubious (pers. comm.). Apparently, there are no published records of bluegill plants by the State alone until 1914 (Shebley 1922) which may also indicate that the fish was not present until 1908.

In trying to track down the advent of bluegill and green sunfish in most of the waters of northern California, we have queried a number of "old timers" who were also assiduous fishermen. All of them seemed to agree that bluegill (and probably green sunfish as well) were absent or at least not abundant until after 1908. L.G. Smith, ardent fisherman and head of the Fresno County Sportsmen's Spiny-rayed Fish Committee, told W.A.D. (20 May 1941) that he thought bluegill and crappie appeared in the San Joaquin Valley in about 1910. L. Phillips, former Hatchery Inspector for the California Division of Fish and Game, believed that he first saw bluegill and black crappie in the Delta around 1912. R.C. Welch, former warden of the California Department of Fish and Game, wrote W.A.D. (5 March 1943) that he recalled catching bluegill for the first time in 1915 in the San Joaquin River. A. Woodard (on State fish rescue crews for many years) wrote W.A.D. (11 February 1943) that he believed he first caught bluegill and green sunfish around 1912 in San Joaquin overflows. F.A. Bullard (who started working for the Division of Fish and Game as a warden in 1910) wrote W.A.D. (28

February 1943) that bluegill and crappie began to show up in the lower Kings River drainage in about 1920.

Aside from such accounts—admittedly from memory alone—we have examined both popular and scientific literature in the hope of finding some record of these introduced fishes. For example, Payne (1913), in his account of the game birds and fishes of the Pacific Coast, mentioned only the black basses and the striped bass among the introduced fishes. Bryant (1921a) indicated that the 1908 introduction of the bluegill (and crappie) was the first in California.

Unfortunately, few scientists recorded introduced fishes in their accounts of ichthyological surveys in the state. Snyder (1917b) did record taking bluegill from the Susan River, Lassen County, in 1911, saying that it was reported to have been introduced there in October 1908. With respect to his other surveys, however, Snyder, who explored many California waters, told W.A.D. that he usually recorded only the native species and that he didn't want to waste preservative on introduced forms. Perhaps the most compelling written information came from Rutter (1908) and Ellis (1915). Based on his large collections of fish made in 1898 and 1899, Rutter (1908) listed only six species of introduced fishes known from the Sacramento-San Joaquin basin. None of the sunfishes (Lepomis) are listed.[95]

Ellis (1915), a Captain of Deputy Fish and Game Wardens, and the original of a character in one of Stewart Edward White's books, wrote an excellent history of fish planting during the 1870–1915 period in the southern Sierra Nevada and San Joaquin Valley. The first mention of "crappies, bream [probably bluegill], and yellow perch" in his account was a description of the plant made in 1908 in the San Joaquin and Kings rivers. In another manuscript (undated) he said, "Bluegill or bream began showing about 1917 near Mendota and Firebaugh on the San Joaquin."

The combined anecdotal evidence of the observers cited above plus the published history indicate that the bluegill and possibly the green sunfish were not introduced successfully into California until 1908, although there may have been some sporadic earlier occurrences, especially of the green sunfish.

From these original introductions, subsequent plants from holding ponds or by fish rescue crews and private individuals, and by their own spread through stream channels and over flooded areas, the bluegill and green sunfish have been dispersed widely. Both species are common throughout the streams, ponds, and dredger cuts of the Central Valley where they are the most numerous of centrarchids. Green sunfish outnumber the bluegill there according to former State

[95] Rutter died in 1903, although his paper concerning collections made in 1898 and 1899 (and a report of the presence of the smallmouth bass) was not published until 1908. The only introduced fish species he listed as known from the basin at that time were shad, carp, white catfish, brown bullhead, striped bass, and smallmouth bass.

fish rescue workers. Foothill reservoirs on the western slope of the Sierra and many southern California reservoirs contain them in large numbers. Both species are present in the Colorado River drainage and evidence a hardiness to muddy or alkaline waters. The green sunfish has also been recorded from the Klamath and Eel systems and has been taken at an altitude of 5100 ft in Lake Arrowhead, 5200 ft in Hume Lake, and 5858 ft in Martis Lake. The bluegill is also known from the Klamath drainage and seems to hold a higher altitude record, 6650 ft in Big Bear Lake. The Department of Fish and Game's "Warmwater Game Fishes of California" (California 1981) said that the green sunfish is "... found in most of our lakes...." Since "most of our lakes" are high mountain waters which contain trout only, the statement is obviously incorrect. Both green sunfish and bluegill, however, are found in many of the warm waters of the state and if found in the cooler, higher trout waters have often been eliminated.

Fishermen often do not distinguish between green sunfish and bluegill, simply calling them "perch" or "sunperch" or referring to both as "bluegills." In some parts of the state the two species hybridize, and both sunfish also hybridize with other species of sunfish introduced into California; e.g. the pumpkinseed and redear sunfish (Childers 1967).

The green sunfish is often found in rocky places and appears to be associated with smallmouth bass more often than is the bluegill. In fact, it was considered to be a good forage fish for smallmouth bass at the Central Valleys Hatchery. It is a provider of sport fishing although its small size makes it of less importance than the bluegill. Small individuals are often caught by children on the simplest of equipment: two feet of line and a baited hook (not a bent pin). Their little dried carcasses are a common sight at some lake piers. They seem to exhibit a high tolerance to copper sulfate, and are often found in ponds on California golf courses where this chemical is used for plant control. They are sometimes used as bait fish, alive or dead, although this practice is illegal in almost all public waters.

At one time, green sunfish were stocked in large numbers through the combined efforts of the California Division of Fish and Game and some sportsmen's clubs. Some of these fish were raised in rearing ponds, and some were the result of fish rescue from overflow areas. However, there is considerable evidence to show that the green sunfish has a slow growth rate and predatory habits. (See, for example, Hopkirk 1973, p. 108.) In 1944 it was classed by the California Division of Fish and Game as an undesirable fish (in comparison with the bluegill) for stocking, although still retaining its status as a "gamefish" under State law (Dill 1946, p. 63). Since that time it has been exterminated purposefully by the State in some trout waters (OC 1959b).[96] Like the common carp, it is considered

[96] For example, in 1977 green sunfish and brown and rainbow trout were eradicated from 70-acre Martis Lake in Nevada County by chemical treatment. This is a Fish and Game Commission-designated Wild Trout Water. The treatment was expected to develop this potential and to establish the lake as a refuge for the Lahontan cutthroat trout. By 1986, however, the green sunfish and brown and rainbow trout had recovered and displaced the Lahontan cutthroat trout.

by some to be a "good invader" that thrives in altered habitats (Moyle and Yoshiyama 1994).

Conversely, the bluegill is considered a much better small game fish or panfish as it grows to a larger size. It has also had far more use in California (and throughout the United States) as one of the ichthyo-components of farm ponds, being planted especially with largemouth bass. See, for example, Woodhull (1953) and Vanicek and Miller (1973). It has often been stocked in larger waters as a source of food for larger fish and, like the green sunfish, was used at one time as forage for smallmouth bass at Central Valleys Hatchery. Possibly, its value as a forage fish and panfish in large waters has offset its habit of preying on the eggs of black bass.

The commonest bluegill in California is believed to be the northern bluegill, Lepomis macrochirus macrochirus Rafinesque, and was apparently the first to be introduced. According to Miller (1952), "the southwestern bluegill [Lepomis macrochirus speciosus (Baird and Girard)] ... is also now evidently established in the Colorado River through introduction ... (*fide* [sic] C. L. Hubbs in a letter of 10 May 1951, to R.D. Beland, and letter from Beland of 23 August 1951 to W.A.D.)."[97] Shapovalov et al. (1959) said that there is no demonstrable evidence that it has become established in the fresh waters of California today.

The southeastern or Florida bluegill, Lepomis macrochirus purpurescens Cope, was definitely introduced into Perris Lake, Riverside County, by the California Department of Fish and Game on 5 June 1975 when 88 adult fish were released (Henry 1979). These fish, obtained from the Florida Game and Fish Commission, were flown by commercial air freight from Florida to Los Angeles on 4 June 1975. The Fish and Game Commission had approved the "experimental" introduction of this subspecies in 1975. It was introduced into the state because a number of studies in California impoundments had shown that the common or northern bluegill, L.m. macrochirus, had exhibited a tendency toward slow growth or small size, and that the southeastern bluegill was reported to exhibit faster growth, larger size, and superior overall sporting qualities. Perris Lake was selected as the initial introduction site because the northern bluegill was not present. The fish reproduced, progeny were collected in July 1976, and the initial year-class was considered exceptional (Henry 1979). Shapovalov et al. (1981) reported that the southeastern bluegill was firmly established in Perris Lake, and that specimens had been collected from there and stocked in several ponds for experimentation and use as broodstock for future plants. Additional plants were made in northern California waters in New Hogan Reservoir, Calaveras County, and Bass Lake, El Dorado County (State biologist C.E. von Geldern, Jr., pers. comm.).

[97] The "fide" is probably a printer's error for "vide."

The early promise of the southeastern bluegill was shattered following underwater observations by Department of Fish and Game fishery biologists at Perris Lake. They found that this subspecies was unusually aggressive, driving adult Alabama spotted bass (Micropterus punctulatus henshalli) from their nests and feeding on their eggs. C.E. Von Geldern, Jr. (pers. comm.) feels that these observations were overdrawn. The Department decided not to extend its range in California. In California it is now probably confined to Perris Lake and the several waters where the original releases took place.

The introduction of the green sunfish to California was probably a mistake. There is some possibility that redear x green sunfish hybrids may have superior growth. Nevertheless, the waters of California would be better off without this fish. Moyle (1976b) referred to its adverse impacts through competition and predation on other game fishes and native nongame fishes (especially the California roach, Hesperoleucus symmetricus) . Marsh and Langhorst (1988) determined that predation by introduced fishes apparently caused significant mortality of larval wild razorback suckers in Lake Mohave, a mainstream Colorado River reservoir in Arizona-Nevada. Forty percent of the green sunfish captured over a 24-hour period contained an average of four razorback suckers. There are also strong indications that the green sunfish and other introduced centrarchids are responsible for the decline of native ranid frogs in California (Hayes and Jennings 1986; Jennings and Hayes 1994), and for the destruction of California tiger salamander populations in California (Shaffer et al. 1993).

On the other hand, the bluegill, being a superior panfish, has increased the recreational pleasure of many people.

4.38. Pumpkinseed, Lepomis gibbosus (Linnaeus)

The pumpkinseed is native to eastern North America. Its presence in California was first recorded by Curtis (1949) who stated that until 1948 there were only two authentic records in the state: one from near Mecca, Riverside County, in 1939, and one from Modoc County in 1946. He also stated that an importation of the pumpkinseed occurred in 1948, when a number were furnished by the U.S. Fish and Wildlife Service for planting by the owners in Irvine Lake, Orange County. He provided no detail concerning any of these introductions, and dismissed the matter by saying "... the pumpkinseed is so rare [in California] that it can for all practical purposes be disregarded."

The paucity of information given here made it desirable for Dill et al. (1955) to augment this history by a more extended account of the bases for these statements, correct a typographical error in Curtis (1949), and add some new information concerning the pumpkinseed in California. The information is summarized below.

The pumpkinseed near Mecca were in an artesian-fed private pond and had probably been sent there by the U.S. Bureau of Fisheries in about 1918. They had been seen there by R.R. Miller and R.G. Miller on 25 May 1939, but had disappeared by 1943. Prior to that time they had been distributed from this pond to other private waters in southern California, but all had apparently perished. The pumpkinseed was taken from the Susan River, Lassen County, by: C.L. Hubbs in 1942; State biologist N.A. Jorgensen, Jr. in 1953; and State biologists J.B. Kimsey, R.R. Bell, and W.L. Turner in 1954. It was also taken in Antelope Creek, a tributary of Lost River, Modoc County, by W.I. Follett of the California Academy of Sciences in 1942. (Curtis's Modoc County record of "1946" was a typographical error.) The Irvine Lake record was based on field identification following receipt of a mixed shipment of warmwater fishes from the U.S. Fish and Wildlife Service at Dexter, New Mexico, on 15 November 1948. The fate of these fish was unknown.

Positive records were also furnished of the occurrence of breeding pumpkinseed in mining dredge holes along the upper Klamath River, in the quieter waters of the upper River, and in Copco Lake, Siskiyou County, in 1951 and 1953. No information was furnished as to the origin of this species in Lassen or Modoc County or in the upper Klamath drainage. It was noted that the Lost River (Modoc County) is connected with the Klamath by a series of canals, but that the Susan River has no connection with either stream. (It ends in a plays, Honey Lake.)

Added to this information (provided by Dill et al. 1955), and omitted from their account, is a record of "bream" sent to California for planting in "Dunn's Pond, Mecca" and "Ellen's Pond, San Diego" in 1919 by the U.S. Fish Commission (U.S. Fish Commission Report for 1919, p. 67). Possibly these were pumpkinseed. We can also add the statement by Miller (1968) that a reservoir on a ranch in Lucerne Valley, San Bernardino County, supported a sizeable population of pumpkinseed on 6 September 1940. The reservoir was drained in 1941 and it is assumed that the fish were lost.

Pumpkinseed have been stocked in Hemet Reservoir, Riverside County, but their success has not been evaluated (Hubbell 1966). Moyle (1976b), without giving a reference, said that the species was established in Big Bear Lake, San Bernardino County. Leidy (1983) found it in San Ramon Creek (Walnut Creek basin, tributary to Suisun Bay) in 1980, and spoke of a possible record of it in 1980 in the Delta. Wang (1986) also reported it at Lafayette Reservoir, Contra Costa County. State biologist R.J. Decoto (15 May 1995 pers. comm.) collected them from Davis Lake in Plumas County.

Some partial records of the origin of the pumpkinseed in California have been given above, and it is likely that its limited presence in quite different localities demonstrates that it has been introduced several times. We suggest that its presence in the Susan River dates from an introduction made in 1908 by the U.S. Fish Commission at the request of C.A. Vogelsang of the California Commission. In theory, these fish were bluegill or green sunfish, but since the shipment originated in Meredosia, Illinois, it may well have included some pumpkinseed. (See the section on green sunfish and bluegill for more information.)

There is some evidence to indicate that the pumpkinseed may have been a resident of the Sacramento Valley at least as early as 1930. In an article on freshwater fishes found in California that may be kept in aquaria or garden pools, Seale (1930a) listed "Sunfish, Eupomotis euryoris, " and the Steinhart Aquarium accession list for 1931 recorded "Apomotis euryorus" as collected near Willows. The identification was made by A. Seale, but the specimens were not saved. Hubbs and Hubbs (1932) have proved that the nominal species "Lepomis euryorus" (i.e. Eupomotis euryoris or Apomotis euryorus) is a hybrid between the green sunfish and the pumpkinseed. Although we know that both of these species are resident in California, the pumpkinseed has not yet been recorded from near Willows, despite intensive collecting. (The foregoing information appeared in Shapovalov et al. 1981, p. 34.) Possibly the recording of this hybrid was based on a misidentification.

It is obvious that the presence of the pumpkinseed in California is quite limited. Based on their work in Lassen County, Kimsey and Bell (1956) suggested that it may have limited use in marginal centrarchid waters, particularly ponds and lakes where cool temperatures inhibit bluegill spawning and growth.

4.39. Warmouth, Lepomis gulosus (Cuvier)

Native to much of the southern, central, and eastern United States, the warmouth has been introduced west of the Rockies, but its initial occurrence in California is not clear despite assertions to the contrary.

Smith (1896) and Shebley (1917) stated that in 1891, 400 yearling warmouth from Illinois were planted in Lake Cuyamaca, San Diego County, and 100 released in the Feather River near Gridley, Butte County. Shebley (1917) also said that these fish were planted by the U.S. Fish Commission. Both authors also stated that in 1895, 12 warmouth were delivered to the California Fish Commission. These were said to have been placed in ponds at the State's Sisson (Mt. Shasta) Hatchery (California Fish Commission Report for 1895–96, p. 30–31), and Shebley (1917) said that all of them died before spawning.

Unfortunately, neither Smith (1896) nor Shebley (1917), nor Evermann and Clark (1931), who gave the same history, referred to the sources of their information, and doubt must be cast upon their record of an 1891 introduction of this species for the following reasons.[98] Warmouth are not mentioned in the San Diego newspapers covering the 1891 plant in Lake Cuyamaca by the U.S. Fish Commission. Although the fish plants made in both Lake Cuyamaca and in the Feather River in 1891 are listed in detail in the U.S. Fish Commission Report for

[98] Evermann and Clark (1931) differed from these accounts only in saying that the Cuyamaca and Feather River plants were made in 1921 — an obvious misprint although accepted by Moyle (1976b).

1892, and in the California Fish Commission Report for 1895–96, there is no mention of warmouth among the fish planted in 1891 or at these localities in either of these reports. They do, however, record the "Rock Bass" as having been introduced in that year: 400 in Lake Cuyamaca and 100 in the Feather River. Since these records for the rock bass were omitted by Smith (1896), Shebley (1917), and Evermann and Clark (1931), two alternate conclusions may be drawn: i) Smith (1896) may have confused the records for these two species, and the later authors have simply perpetuated his error, or ii) Smith may have discovered that the fish planted in 1891 were actually the warmouth and that the original governmental records were in error. It may be noted that he considered the warmouth to closely resemble the rock bass in size and habits. (See also the account of the rock bass. We are inclined to believe that Smith's account is correct.)

Even the account of the 1895 introduction is somewhat confusing. It is substantiated by the California Fish Commission Report for 1895–96, p. 30–31, which also adds that eight "warmouth bass," from a shipment by the U.S. Fish Commission, were planted in the Bolsa Chica River, Orange County, in the same year. But the U.S. Fish Commission Report for 1895 does not list any warmouth as being sent to California in 1895. It does list a shipment of 48 "sunfish" in that year, but apparently all of these can be accounted for.

Although the introduction of the warmouth and rock bass is shrouded in mystery, we do know that the warmouth, anyway, is present today in California in considerable numbers. Among the first published accounts which credit its occurrence in the state are those of: Neale (1931a) which merely said that it is present; California Division of Fish and Game Report for 1938–40, p. 75, 87; Murphy's (1941) key to the fishes of the Sacramento—San Joaquin basin; and Erkkila et al. (1950) who collected it in the Delta during the 1946–49 period. The California Report (*loc. cit.*) recorded "Warmouth and Rock Bass" as rescued in 1938 and "Warmouth Bass" as rescued in 1939. (As mentioned elsewhere, it is now believed that most of the fish rescue records of the "Rock Bass" apply only to the warmouth.)

The warmouth is fairly common in the Central Valley and Delta, and is also known from Lake Amador, Amador County; Lake McClure, Merced County; and the San Joaquin River below Friant Dam. Warmouth in the Central Valley could have come from the Feather River. California (1981) said that the Feather River plant of 1891 was successful, but this, like our supposition, appears to be only conjecture. In 1961, one was found in the lower Colorado River near Blythe and several more have been taken in the River in this area (Lanse 1965). California (1981) said it was "discovered" in the Colorado River in 1963. It is also known from Lake Hughes in San Diego County, and anglers have reported it from other southern California reservoirs. Possibly it exists here, but it is known that the green sunfish is often called "warmouth bass" in the southern part of the state. Both species have a large mouth, unlike the bluegill. The warmouth hybridizes with the green sunfish, bluegill, and pumpkinseed.

Like all of the centrarchids, its original distribution in the state has been hastened through transplantation by State fish rescue crews. In 1939, for example, a few warmouth were placed in Bass Lake, Madera County.

Apparently, they are one of the least numerous and least known of the introduced centrachids, but rescue records indicate that they are much more abundant than our only native sunfish, the Sacramento perch (Archoplites interruptus) .

Warmouth are especially abundant in muddy areas, and appear to be increasing. of the introduced centrarchids, they seem to be a rather worthwhile addition as a small game fish.

4.40. Redear sunfish, Lepomis microlophus (Günther)

The redear sunfish or "shellcracker," native to the Gulf and lower Atlantic slopes of the United States, was first found in California in 1951. State biologist R.D. Beland seined several from the lower Colorado River and from an oxbow lake below Headgate Rock Dam on 27 April 1951. He ascribed its presence to plants made in the Headgate Rock Dam area by the Arizona Game and Fish Department in 1948 or 1949 and felt that it was established in the River (Beland 1953). California (1981) said that it was planted in 1948 in the Headgate Rock Dam area, which seems to be an assumption.

Following recommendations (based primarily on a literature search) by Beland to the Department of Fish and Game, the California Fish and Game Commission on 30 April 1954 approved the importation and propagation of redear sunfish to investigate the possibility of this fish as a substitute in the bluegill/largemouth bass combination in state waters. It was proposed that it be introduced into a small southern California reservoir for observation. Noting that it was already established in the Colorado River, the Commission also considered that the redear was a desirable panfish, did not stunt as readily as the bluegill, was somewhat less prolific, did not tend to overpopulate, and reached a better size in farm ponds. It was also stated that an initial broodstock could be obtained from the U.S. Fish and Wildlife Service in Albuquerque, New Mexico (Minutes, meeting of 30 April 1954, California Fish and Game Commission).

The first redear sunfish deliberately brought into the state came from this source in 1954, but were stocked by the Department of Fish and Game. A total of 3960 fingerlings was obtained and planted in private ponds and several southern California reservoirs, including Piru Reservoir in Ventura County and Pudding-stone Reservoir in Los Angeles County (pers. comm. by R.D. Beland). They produced excellent fishing. In January 1955, 120 fingerlings and, in the autumn of 1956, 66 adult redear sunfish were transferred to Central Valleys Hatchery from southern California. Over this time span, a number of private ponds in the San Joaquin Valley also were stocked. Progeny from successive successful spawn ings at Central Valleys Hatchery have since been stocked in numerous warmwater habitats throughout the state. Starting in 1962, they were planted in San Diego County reservoirs to prey on snails known to be vectors of parasites of sunfish and black bass (Swift et al. 1993).

Redear sunfish have been planted in many waters throughout the state. Moyle (1976b)—after alluding to their introduction into waters in southern California and the Central Valley—somewhat cynically but very truthfully said, "Given the proclivity of sportsmen (and biologists) for moving fish around, they can be expected elsewhere in the state as well." In fact, Moyle and Daniels (1982) later recorded this species from a farm pond draining into Rush Creek, Modoc County.

The redear sunfish is indeed well established now in California, particularly in Central Valley reservoirs and ponds, and appears to have been a good choice.

4.41. Black basses in general

This section of the paper refers only to the initial plants in California of smallmouth and largemouth bass in the nineteenth century and the confusion surrounding them. The history of the individual species and subspecies of black basses in California is detailed separately in the accounts that follow.

According to Henshall (1904) in his famed "Book of the Black Bass," "The scientific history of the black bass is a most unsatisfactory one." Hubbs and Bailey (1940) reiterated this statement. Similarly, the history of the introduction into California of two of the black basses, the northern largemouth bass and the smallmouth bass, is unsatisfactory. Only the early history of the introduction of the catfishes into California is as uncertain. This is true, primarily, because the early records, both Californian and Federal, spoke only of "black bass," and the initial plants may have been of either species or both. Various later writers have made statements concerning the matter: e.g. Smith (1896) who believed that the smallmouth was the first black bass to be introduced into California (in 1874), Shebley (1917) who corroborated him, Curtis (1949) who said that both species were introduced into California in 1874, Skinner (1962) who stated that it was the largemouth that was first introduced into California in 1874, and Moyle (1976b) who followed the lead of Skinner (1962) and Curtis (1949), and later Moyle (1976a) that of Shebley (1917). We believe, since none of the later writers had any more real knowledge of the situation than we have, that most such accounts are merely conjecture, but Smith (1896) was at least the earliest of the writers mentioned above.

Again, it really does not matter today which of these two species, the largemouth or the smallmouth, was introduced first. Each of them has long been established in California, and the relative size of their populations, their distribution, and their management are of more importance.

The California Acclimatization Society had considered the introduction of "black bass" as early as 1871 (Alta California, 13 February 1871), and we know from the literature that the first "black bass" were brought to California in 1874 by Livingston Stone at the request of the California Fish Commission. Seventy-three adults from Lake Champlain, Vermont, were planted in Napa Creek, and 12 small ones from the St. Joseph River, Michigan, in Napa and Alameda creeks (California Fish Commission Report for 1874–75; Stone 1875, 1876a). The statement by the California Fish Commissioners in their 1874–75 Report was obviously based on Stone (1875) in the same issue. Both species of black bass were present in the same source waters.[99] Smith (1896, p. 442) said that these first-introduced fish appear to have been smallmouth. Robbins and MacCrimmon (1974) said that these and Stone's later 1879 plant were smallmouth, but their statement is based only on literature search, as is ours.

In speaking of the fish from St. Joseph River planted in Alameda Creek, a table on p. 32 of the California Fish Commission Report of 1874–75 called them "Grystes fasciatus"; the fish from Lake Champlain planted in 1874 are not named scientifically in this table. (It is assumed that the table was made by Stone 1875.) However, Stone (1876a) used the name Micropterus salmoides for all the 1874 plants in California; although later, in speaking of "Black Bass" from Lake Champlain, Stone (1877) called them "Grystes fasciatus. "

It is reported that these fish increased, but it was believed that most of them were caught by anglers, and in 1879 Stone again brought "black bass" from Cold Spring Trout Ponds in New Hampshire to California (Stone 1882). The original source of these fish is unknown, although Stone (1877) said that survivors of "black bass" from Lake Champlain and the Missisquoi River were in the Cold Spring Trout Ponds at that date or close to it. He called them "Grystes fasciatus. " Twenty-two adults of the 1879 shipment were placed in the Crystal Springs Reservoir of the Spring Valley Water Company in San Mateo County (California Fish Commission Report for 1878–79, p. 14). The 1880 report of the California Fish Commission, p. 12, in speaking of "Black bass—Micropterus nigricans," said that the fish were placed in the Napa River in 1873, an incorrect date. With respect to the fish planted in 1879 in the Crystal Springs Reservoir, it said that officers of the Spring Valley Water Company had assured the Fish Commission that the lake would be preserved and no fish allowed to be caught until the Fish

[99] In Robbins and MacCrimmon's (1974) comprehensive account of the black basses, they pointed out that although the smallmouth and largemouth basses were apparently native to Lake Champlain, the largemouth is not abundant there, and that it was 1887 or 1888 before the latter species was mentioned in any of the Vermont Fish Commission reports. On the other hand, Merriam (1884) said, "Black bass Micropterus salmoides (Lac.) Henshall is said to be one of the principal market fish of Lake Champlain," but he may not have been referring to the largemouth. Robbins and MacCrimmon (1974) said there is ample evidence to show that the largemouth was not introduced into California in 1874 together with the smallmouth. However, the sources they quote to prove this point are at best all secondary or tertiary references.

Commission granted permission, and that if the fish increased, the State could take them at all times for public distribution. The Report also said that the fish were rapidly increasing in numbers. Without providing a date, the 1880 report also stated, on p. 12, that the Sportsman's Club of San Francisco had imported a number of "black bass—Micropterus nigricans" and planted them in a lake in Alameda. (It is assumed that this referred to the county.) Woodbury (1890a) amplifies this statement by saying that "Black bass" were brought out by Seth Green at the expense of a sportsman's club and placed in Temescal Lake, Alameda County, and that some other waters were stocked with their young. Woodbury claimed that these were the first black bass brought to California, but Smith (1896, p. 442) pointed out that Woodbury had overlooked the black bass carried by Stone in 1874, and that the Temescal Lake fish probably constituted the second lot transplanted to California.

Green himself (1879) stated that he had sent 113 mature "black bass" to California in the spring of 1878 and that 99 had arrived in good order. Although Green did not give the scientific name of the species of black bass he sent to California, his other remarks indicate that he distinguished between "black bass" which needed rivers or lakes with rocky bottoms and "Oswego bass" which were suitable for waters with a mud bottom. Green (1875) also distinguished between the "black" and the "Oswego" bass, and his comments also indicate that his "black bass" was probably the smallmouth. From such remarks, we judge that the smallmouth bass was the one sent to California by Green.

"Black bass" are reported to have been stocked privately in Oriole Lake, Tulare County, in 1880 (Evermann 1906). Ellis (1915) followed this up by saying that they were "supposed black bass." This is an early record, but since none survived the records are useless in determining the species. A similar record is given by Ellis (1915) for stocking black bass (without known survivors) in Weaver Lake, Tulare County, in 1895. Ellis (1915) also reported the stocking of "black bass" in: the lower Kings River in 1895, 1897, and 1898; the lower San Joaquin River in 1897 and 1898; Bass Lake, Madera County, in 1902; the lower Kaweah River in 1902; the lower Kern River in 1912; and Shaver Lake, Fresno County, in 1912. No source is given except for those planted in Shaver Lake, which are said to have come from the lower Kings River. (We do know that at least during the 1938–51 period, the only black bass known from either Bass or Shaver Lake were largemouth bass. We also know that during the same period, smallmouth bass were found in the foothill area of the Kern and Kings rivers, and that largemouth bass thrived in the Kings River on the plain.) The same Ellis (MS, date unknown) said that the "black bass" planted in the Kings River in 1895 were from the State Fish Commission. Unfortunately, in neither manuscript does Ellis actually record the presence of black bass except to say that in 1920 the "crappie" planted in the Kings and San Joaquin in 1908 turned out to be smallmouth bass. (We feel that he was actually referring to the offspring of the "black bass" planted at an earlier date.)

There is also a report under the title "Large-mouth Black Bass" that "In the Fresno-Kings section of the San Joaquin Valley, where black bass were first planted in 1895 and 1897, they have shown remarkable increase" (California Fish and Game Report for 1909–10, p. 37). This report agrees with Ellis (1915) as to the dates of planting this area, and is repeated in the account of the northern largemouth bass which appears in this paper. We do know that C. Rutter's extensive collections in the Sacramento-San Joaquin basin in 1898 and 1899 included only the smallmouth among the black basses (Rutter 1908).

Buss (1974) stated, "... the smallmouth [bass] arrived in California from Lake Ontario via New York." In a personal communication, he told us that in an article he wrote for the Pennsylvania Angler, October 1967, p. 16–18, he noted that the smallmouth bass was introduced into California in 1874 and the largemouth in 1888. He could not recall the source of this information, except that it appeared in a 19th century popular magazine. The 1874 date is obvious, but neither we nor Buss know where the 1888 date came from nor why Lake Ontario was specified as the source.

The California Fish Commissioners sometimes eschewed the use of scientific names for their introductions. For example, in one report they considered it proper "... to avoid Latin nomenclature, and to call them by the good old Saxon or provincial names by which they have been known to our fishermen and people...." (California Fish Commission Report for 1893–94, p. 11–12). Unfortunately, this Report simply referred to "black bass."[100] However, they sometimes did use scientific names for their early introductions of black bass. often the use of a scientific name aids one in determining what species was reported. Conversely, the use of a common name may also aid. Let us try.

The California Fish Commission Report for 1874–75, p. 5, spoke of the 1874 plant in Napa and Alameda creeks only as "Black bass" or "Grystes fasciatus. " A table on p. 32 of this Report, probably by Stone (1875), called the fish stocked in Alameda Creek "Grystes fasciatus. " However, Stone (1876a) called these same fish "Micropterus salmoides. " At an even earlier date Stone (1874a) stated, "The California Acclimatizing Society ... has successfully introduced from the East the black bass (Grystes fasciatus) . ..." One assumes that he alluded to introductions made circa 1872. Since Stone himself (Stone 1876a) called the black bass he introduced in 1874 Micropterus salmoides and the California Fish Commission Report for 1874–75 called these same fish Grystes fasciatus, as apparently did Stone (1875), one is further confused. Furthermore, in view of most statements,

[100] Even as late as 1937, the Progressive Fish-Culturist, which had a considerable influence on both hatcherymen and fishery biologists, permitted the use in a paper of such a loose term as "bass" to indicate what were probably smallmouth bass or Micropterus dolomieu (see Snyder 1937).

one is not at all sure that the fish said to have been introduced by the California Acclimatization Society were ever planted in public waters. If we accept today's nomenclature, we would assume that Stone was referring to the largemouth bass. On the other hand, one notes that Milner (1874, p. 525) in the Report of the U.S. Fish Commission for 1872–73 said that "Micropterus salmoides" is better adapted for clear streams and lakes and "M. nigricans" for grassy and shallow lakes and ponds. (Today's biologist would say that Milner's "Micropterus salmoides" was the smallmouth.) The same Report (p. xxix) said that the black bass brought out as far as Nebraska by Stone in his wrecked aquarium car of 1873 were "Micropterus salmoides, " but Stone (1880) called the "black bass" "Grystes nigricans. " At an earlier date, however, Stone (1877) called the "Black Bass" from Lake Champlain and the Missisquoi River "Grystes fasciatus. " Henshall (1904) pointed out rather consistently that during the 19th century, many people termed the present Micropterus dolomieu the "black bass," and our present M. salmoides or largemouth bass the "Oswego bass." With reference to Henshall's (1904) comprehensive list of synonyms for the two major species of black bass, we have found no use of the specific name "fasciatus" for any except the smallmouth bass. On the other hand, the specific name "nigricans" has been used in the past for both these species as has the entire name Micropterus salmoides. Denmead (1950) pointed out that "About 1850, scientists called both largemouths and smallmouths Micropterus salmoides, a name later applied mostly to largemouths," and Webster (1980) felt "... that there was no early distinction between [what we now know as] dolomieui and salmoides. " In short (because we could augment this discussion), the use of neither scientific nor common name at an early time helps greatly in determining whether the largemouth or the smallmouth was the first black bass planted in California.

It seems quite obvious that the scientific name of the two black basses not only varied decidedly but was used indiscriminately by such men as Stone and the other early introducers of fishes to California. Even more recently, Evermann and Clark (1931) and Brown (1939) have added further confusion as to the question of which species entered California first or as to where black bass were first planted. Still, the indications from earlier accounts are that it was the smallmouth that first entered California.

Some of the later accounts also indicated that the largemouth bass did not reach California until after the debut of the smallmouth. For example, the California Fish Commission Report for 1888–90, p. 3, said, "Black bass have been distributed ... throughout the state. The increase of these fish at Crystal Springs, San Mateo County, has been rapid and is the source from which our supply has been obtained." (The reader will recall that Crystal Springs Reservoir was first stocked with 22 "black bass" in 1879 with the proviso that the State could use their progeny for stocking.) Woodbury (1890a) in the same report, p. 22, said with respect to "Black bass," "When waters are stocked with them, they are here to stay, if fair play is shown them ... once they become stocked with Black bass it is done for all time." On page 40 he then said, "Many have asked for the introduction of the Big-Mouthed Black bass from the Southern states for planting in our warmer waters...." And in the Report for 1893–94, on p. 31, the California Fish Commission said, "We now have their [U.S. Fish Commission's] promise to forward a carload of large-mouthed black bass ... for introduction into our waters."[101]

In 1895, the U.S. Fish Commission did deliver about 2650 "Largemouth Black Bass (Micropterus salmoides) from Quincy, Illinois" to California.[102] The expense from Ogden, Utah, to California was borne jointly by the Spring Valley Water Company and the California Commission. One thousand were planted in Crystal Springs Reservoir on 14 June 1895 (California Fish Commission Report for 1895–96, p. 30, 72). A table following p. 58 of this same Report shows 1450 "Large-mouth Black Bass (Micropterus salmoides) " as brought from without the state for the first time in 1895 and planted by the California Commission. (Other details concerning the plants of largemouth in this year are found in our specific account of the largemouth.)

Our questions are: Why should the State have planted Crystal Springs with largemouth bass in 1895, if the species were already there, if the Fish Commission believed that further stocking of "black bass" was unnecessary, and if the State drew on this lake for its source of "black bass"? And why should the Spring Valley Water Company have paid part of the shipping expense from Ogden? The answer seems to be that the largemouth was not there.

One may also note that the tables of distribution and fish planting by the State and published by the State do not indicate the stocking of largemouth bass until 1895. (Shebley's 1922 table is excepted. It mentions "distribution" of largemouth bass for the first time in 1891.)

Most of our conclusions are conjectures, but at least they are reasoned conjectures. It is our belief that the sum of the evidence given above, as well as all of

[101] In a list of the fish distributed by the U.S. Fish Commission from 1871 to 1884, of the black basses only "Micropterus dolomieu Lacépède. small-mouth black bass" is mentioned (Bean 1884).

The first specific mention of largemouth bass in California in the California Fish Commission's biennial reports that we have found is in the Report for 1895–96: planted in Cuyamaca and the Feather River by the U.S. Commission in 1891, p. 29, and at Sisson circa 1895–96, p. 25. We have not determined the source of the Sisson fish, although they appear to have been from Quincy, Illinois (Ibid. p. 72; Shebley 1917, p. 6). Shebley was the head of the Sisson (Mt. Shasta) Hatchery at the time.

[102] We do know that in 1897 the major source of largemouth bass for the U.S. Fish Commission seemed to be Quincy, Illinois. This was probably also true in 1895 and earlier. For example, in 1890, the "black bass" sent to Utah by the U.S. Fish Commission from the Illinois River were "Oswego bass" or "large-mouthed black bass" (Sharp 1898).

Smith's (1896) account on the subject, indicate that the first black bass to be introduced into California was the smallmouth, known today as Micropterus dolomieu. [103]

However, to compound the confusion, Stone (1875, p. 2) stated that on his trip across the continent in 1874, he secured "Additional Bass at Niles, Michigan, Mississippi Catfish (Grystes salmoides) , or Mississippi Bass, at the Elkhorn River...." (This is just the way it was written.) And on page 28, he said that at the Elkhorn River, Nebraska, he took on "... Western Bass and Mississippi Catfish." There is no record in this account or any others either of the death of these "Mississippi" or "Western" bass, or their subsequent planting in California.

In short, we do not know whether smallmouth bass or largemouth bass, or both species, were brought to California in 1874 or which species was planted first. But, i) why would Stone have secured these fish from the Elkhorn (since he already had some "black bass" from the east); ii) why did he differentiate between "Western" or "Mississippi" bass and "black bass"; iii) why did he use both scientific names, Grystes fasciatus and G. salmoides; and iv) finally, why did he not mention "Western Bass" in his later account (Stone 1876a)?

We have some suspicion that Stone may have picked up some largemouth bass. Robbins and MacCrimmon (1974) said that only largemouth might have been found in the Elkhorn at that time. But, in the absence of any witnesses or any other known accounts, we merely mention these accounts as among those mysteries concerning the first establishment of Micropterus in California.[104]

Whether or not there was ever any question as to the first species of black bass imported, it apparently did seem clear to some of the California fish culturists of the day that lowland waters such as Clear Lake or Tulare Lake were more appropriate for black bass than the higher (trout) lakes such as Tahoe or Donner.[105] Dunn (1889) also felt that if "black bass" "... would not destroy the young shad and salmon, the Sacramento would be an admirable stream to place bass in between the junction of the Feather River and Red Bluff." This statement was echoed by Woodbury (1890a, p. 23). Although "... not overconfident that it would be safe for the young salmon to have the Black bass planted in either the Sacramento or San Joaquin rivers," he very realistically pointed out that "... in time, these fish will find their way into these rivers clandestinely by private parties, if not done so openly by the Fish Commission." In this regard, Woodbury seems to have been

[103] Smith (1896) at least had the opportunity to make inquiries of Californians who had information.

[104] It is also clear that the genetic integrity of even native stocks of black bass has been altered (Whitmore and Hollier 1988).

[105] This was, however, not clear to all of them. For example, the Fish Commissioners of 1883–84 expressed the belief that they would do well in "... all of our large lakes, such as Bigler [Tahoe], Donner, Webber, Clear, and Tulare...." (California Fish Commission Report for 1883–84, p. 11).

far ahead of some of the more recent fishery workers who have made "experimental" or "isolated" introductions.

4.42. Redeye bass, Micropterus coosae Hubbs & Bailey

The original range of the redeye bass is quite restricted; it includes streams in Alabama, Georgia, Tennessee, Florida, North Carolina, and South Carolina. In their native waters, redeye bass are said to be the brook trout of the warmwater game fishes because of their similarity in size, habitat preference, food, feeding habits, desirability, and gameness (Parsons 1954).

The importation of the redeye bass, under the name "Coosa Bass," was approved by the California Fish and Game Commission on the basis of a recommendation by the Department of Fish and Game on 28 August 1953 that it was well suited to those small coastal and interior streams which are too warm for trout and too small for other bass species. It was considered that there were many such streams that produce virtually no fishing and that the redeye bass might be the answer. It was also considered that the characteristics of some of the smaller southern California streams closely approximated the native habitat of this species (minutes of the 28 August 1953 meeting of the Commission).

Individuals of this species were secured from Sheeds Creek, tributary to the Conasauga River in Tennessee, and 39 reached California alive, flown here on 11 November 1953.[106] They were placed at the State's Central Valleys Hatchery, Elk Grove, from where they were destined to be stocked "experimentally" in 1954 (Kimsey 1954). In March 1954, nests of the redeye bass were noted, and their fry first seen in May 1954. Apparently, due to infestation and consequent competition by other species of fish, all of the redeye bass at the Hatchery perished. This was known in August 1955 (Kimsey 1957).

Attempts to establish the redeye bass in California were made again in 1962 and 1964, with fish from Tennessee and Georgia being released in five streams. All of the fish released in 1962 were fingerlings; those planted in 1964 were yearlings. The streams, dates of planting, and number of fish follow: Alder Creek, Sacramento County (510 fish on 10 July 1962); South Fork Stanislaus River, Tuolumne County (510 on 12 July 1962); Sisquoc River, Santa Barbara County (1180 on 22 July 1962 and 207 on 10 September 1962); Santa Margarita River, San Diego County (39 on 8 May 1964); Dry Creek, Nevada County (30 on 22 October 1964) (Goodson 1966b).

OC (1962) differed from a more "official" announcement by Goodson (1966b) in saying that "About 1,300 young Coosa bass" were planted in the Sisquoc River drainage, but added that one of the plant's purposes was "... to improve trout

[106] These redeye bass were flown to California on a different flight than the one which brought threadfin shad to California in 1953 (pers. comm. from State biologist P.A. Douglas, 1992) contrary to a 1953 press release of the Department.

fishing in other stretches of the river by reducing the rough fish (chubs) population," and that an "... inspection showed that already this year's small chubs ... had been almost completely eliminated in the pools where the predatory little bass were stocked." California (1981, p. 10) said, "In 1962, fish from Atlanta, Georgia, were planted in six small streams and Lake Oroville," another statement at variance from both preceding accounts.

Regardless of the small differences in all accounts of the original introductions, it is known that the redeye bass has become established in California. On 25 October 1978, 79 of 92 fish collected by electrofishing in the South Fork of the Stanislaus between elevations of 450 and 650 m were redeye bass. The other fish were native minnows (two species), Sacramento sucker (Catostomus occidentalis) , and brown trout. Both presumed young-of-the-year (30 to 53 mm FL) and adults (100 to 191 mm FL) were taken (Lambert 1980). They continue to be abundant in this stream. According to Swift et al. (1993), "The Santa Margarita fish survived at least into 1987, the Santa Ana fish have not been recollected, and the status of the Sisquoc fish is not known." They are probably no longer present in Alder Creek, Dry Creek, or the Sisquoc River.

State biologist D.P. Lee (6 May 1994 pers. comm.) recounted the status of the redeye bass in Lake Oroville (Butte County) and New Melones Reservoir (Calaveras and Tuolumne counties). Remaining broodstock held at Central Valleys Hatchery were released in Oroville in 1969. The population became very abundant and remained so until recent years when, for reasons unknown, it declined to a low level. When the expanded New Melones Reservoir was completed in 1979, it flooded a portion of the South Fork Stanislaus River supporting redeye bass. The redeye population attained a high density in the reservoir until recently when, again for reasons unknown, numbers plummeted.

The place of the redeye bass in California appears to be in small warmwater streams such as those of the foothills which have long been problematic waters to the fish manager.

4.43. Smallmouth bass, Micropterus dolomieu Lacepède

The smallmouth bass was originally limited to the central and eastern United States north to southern Quebec.

As pointed out in a preceding section, we believe that the smallmouth bass was the first of the black basses (Micropterus) to be introduced into California, a belief which coincides with that of most other authors. If our reasoning is correct, then the first smallmouth bass was stocked here in 1874, followed by plants made in 1878 and 1879 (California Fish Commission Report for 1874–75, p. 5; Stone 1875, 1876a, 1882; Green 1879).[107] The introduction of this fish met with considerable

[107] It is true that the "Distribution Table" on p. 75 of the California Fish Commission Report for 1893–94 lists the first and only out-of-state plants by the California Fish Commission of "Black Bass Micropterus dolomieu" in 1874 and 1879, but, as has been explained previously, neither these tables nor the scientific name can be relied upon.

success, and it appears to have been stocked in many waters throughout the state.

Many of the early plants stemmed from the progeny of the bass planted in lakes of the Spring Valley Water Company in San Mateo County; we assume that these were smallmouth. Furthermore, Smith (1896, p. 443) stated that in 1888 the Nevada Fish Commission exchanged brook trout for smallmouth bass with the Spring Valley Water Company.

Apparently, the Russian River was one of the streams successfully planted from here. Dunn (1889), writing in April 1887, said that black bass taken from Crystal Springs Reservoir circa 1878 and planted near Guerneville had spread up and down the stream. The Russian River also functioned as a source of black bass, presumably smallmouth. "The black bass fry distributed in the past two years were mainly taken from the landlocked overflow waters from Russian River. This river has become the best stocked bass stream in the State, and is the only one now affording black bass fishing.... In the distribution of black bass we have aimed to stock all suitable waters. Particular attention has been given to the waters of the San Joaquin Valley" (California Fish Commission Report for 1897–98, p. 42). Smith (1896) also discussed the Russian River as a principal source for the State of black bass—presumably smallmouth.[108]

Since most of the early records for many years, even after the time that we know that the largemouth bass was present in California, indicated only that the fish stocked were "black bass," it is impossible now to determine what species was planted. We do know, however, that in one of the few early cases where the species was indicated, the number of smallmouth bass greatly exceeded that of the largemouth. For example, in 1897, a total of 14,815 fry and 1937 adult smallmouth were reported distributed by the State while only 750 fry and 205 adult largemouth were distributed. In 1898, the records show 6000 fry and 2330 adult smallmouth distributed and no largemouth (California Fish Commission Report for 1897–98, p. 42). Furthermore, Rutter's extensive collections made in the Sacramento-San Joaquin basin in 1898 and 1899 included among the black basses only the smallmouth (Rutter 1908).

As the years passed, however, the smallmouth bass was said to have declined in numbers. Shebley (1931) said: "The small mouth bass was planted extensively

[108] The Russian River maintained its image as a smallmouth bass stream for many years. During the period of 1952–54, when Pintler and Johnson (1956) chemically treated portions of the Russian River drainage in order to control "rough fish," the predominant black bass found was the smallmouth; only a few largemouth bass were found in sloughs. As late as 1970–71, of the two black basses, only the smallmouth was taken from the Russian River near Cloverdale, Mendocino County, according to Anderson (1972).

throughout the state between thirty and forty years ago. They increased for a number of years, but owing to changed climatic conditions and physical properties of the waters in this state they have gradually disappeared and only scattering remnants of these fish are to be found in a few localities, where they were numberous a quarter of a century ago. It is doubtful whether they will ever thrive again in the waters of this state, as conditions are not suitable for this species." Shebley went on to intimate that, in addition to changed conditions in streams of California, the largemouth bass had taken over territory formerly populated by the smallmouth.

Despite such reports, the popularity of the smallmouth bass as a game fish remained high. Repeated requests were received by the Division of Fish and Game for planting it, and the Division worked for a time with sportsmen's clubs in an effort to rear smallmouth using wild stock (see, for example, CFG 1930a).

Eventually artificial propagation of the smallmouth in California was undertaken during the period 1932–37 at an experimental hatchery at the town of Friant near Fresno. It was demonstrated here that the smallmouth could be propagated successfully and transported for long distances, and 104,449 fish were recorded as being planted during the 1932–36 period (e.g. in Kerckhoff Lake on the San Joaquin River). A permanent station, the Central Valleys Hatchery, was then constructed at the town of Elk Grove, near Sacramento, using well water. Brood fish were obtained in 1937 from local wild stock and fed on netted forage fish: native cyprinids and catostomids and at least two introduced fishes, the bluegill and mosquitofish.[109] The fry were fed on cladocerans. The first harvest of smallmouth fingerlings was made in 1938. Smallmouth bass were propagated for some years, and streams such as the Feather, American, Stanislaus, and Merced were stocked from here. Emphasis was placed on stocking the smallmouth in the lower but rapid portions of such streams (see Brown 1937, 1940). It is also known that a number of San Diego reservoirs were planted from Friant during the 1933–35 period, and that these were the first plants of smallmouth made in San Diego County (records of the San Diego Water Company). E.H. Glidden, a State game warden and compiler of fish planting data in San Diego County for many years, corroborated this statement (pers. comm.), as do his unpublished notes.

In 1944, a program to determine the compatibility of various warmwater fishes was undertaken at the Central Valleys Hatchery, and there was a reduction in the propagation of smallmouth (Leitritz 1970).

Despite the early and later stocking of smallmouth bass, probably throughout the state, it never achieved the success of its companion, the largemouth bass.

[109] Myers (1965) said that the hatchery at Friant had to discontinue using the mosquitofish as a forage fish because it was destroying a large population of the young bass. Nevertheless, mosquitofish were used at the later hatchery under the same supervision.

This is especially true of farm, urban, and subdivision ponds, the Delta, and waters south of the Tehachapis.

Beland (1953) recorded the first stocking of smallmouth bass in the lower Colorado River in August 1950 when 3200 fingerlings from the Central Valleys Hatchery were stocked below Lake Havasu. He stated that the species had been recovered but that there was no proof of its spawning. They are now locally abundant in the lower Colorado River (Minckley 1982; Swift et al. 1993).

Swift et al. (1993) reported that the smallmouth is much less common than the largemouth in southern California being "... known from the Santa Ynez River ... and a few ... southern California reservoirs; Morris Dam, San Gabriel River and Pyramid Lake, Los Angeles County; Lake Hemet, San Diego County; and Lake Arrowhead and Big Bear Lake, San Bernardino County...."

In northern California, the smallmouth bass coexists with the largemouth and spotted bass in almost all of the many Central Valley foothill reservoirs. It is also abundant in other reservoirs such as Trinity (Trinity County), Mendocino (Mendocino County), San Antonio (Monterey County), Del Valle (Alameda County), and Nacimiento (San Luis Obispo County). As reservoirs age it is not uncommon for smallmouth to replace largemouth as the dominant black bass. Pelzman et al. (1980) explained this phenomenon: "Smallmouth now constitute a sizeable segment of the catch at older reservoirs where habitat in the form of trees and brush has deteriorated, leaving largely rocky areas which are more suited for production of smallmouth than of largemouth bass." Prominent examples of this transition are Folsom (El Dorado, Placer, and Sacramento counties), Oroville (Butte County), and Shasta (Shasta County).

Although the occurrence of smallmouth bass in streams is spotty and the fish tend to be small, such waters provide a unique type of recreation for California anglers. Besides the Russian River, the better smallmouth populations are found in lower Cottonwood Creek above its confluence with the Sacramento River, lower Feather River above its confluence with the Sacramento River, the Sacramento River from Sacramento upstream to the mouth of the Feather River, Cache Creek downstream from Clear Lake, Putah Creek above Lake Berryessa, Cosumnes River in the Sloughhouse area, and Merced River from Lake McClure upstream to the mouth of the South Fork Merced River (State biologist D.P. Lee, 11 May 1994 pers. comm.).

Like its experience with southern forms of other centrarchids, the California Department of Fish and Game became interested in the management potential of the Neosho smallmouth bass, native to the middle Arkansas River drainages. It was described by Hubbs and Bailey (1940) as Micropterus dolomieu velox, a form distinct from M. d. dolomieu, the northern smallmouth bass. Subsequent taxonomic studies, however, concluded that the Neosho form was not a valid subspecies (Robison and Buchanan 1984 and references therein). Regardless of the taxonomic question, the Neosho form was regarded as superior to the northern form in food conversion, growth, and fighting ability. One or two loads of Neosho smallmouth fry were air shipped to California in 1975 or 1977 and reared at Central Valleys Hatchery (State fish culturist M.C. Cochran pers. comm.). However, they did not survive and apparently none were released into California waters.

Because of its popularity among California anglers, the smallmouth bass, like the largemouth bass, can be considered a worthwhile introduction into the state. However, also like the largemouth, the smallmouth has its downside—negatively impacting native nongame fishes. Brown and Moyle (1994) observed that an increase in the abundance and distribution of the smallmouth bass in the Kings River drainage was correlated with a decline in the native hardhead (Mylopharodon conocephalus) in the same area. The smallmouth bass probably has depressed populations of indigenous California nongame fishes in other midelevation streams and rivers where they encounter native cyprinids, catostomids, and cottids. Regarding Arizona streams, Minckley (1973, p. 219) observed, "The smallmouth seem to have totally suppressed reproductive success by the local, native fish species, I suppose as a result of direct predation on the newly-hatched young."

4.44. Northern spotted bass, Micropterus punctulatus punctulatus (Rafinesque)

The early shipments of fish from the eastern United States introduced into California came by train, subject to long delays, changes of different waters en route, varying temperatures, and poor aeration. The trips were hard on the fish and hard on the fish culturists.[110]

But in 1933, a quick dash by airplane sufficed to bring in several hundred young northern spotted bass from Ohio (J.O.S. 1935; Brown 1939; unpublished records of the California Division of Fish and Game). Leitritz (1970) said that 904 spotted bass fry were received at Friant from Ohio on 10 June 1934, but this was probably a printer's error for 1933, since we have no other records of this import. The importation under the name of Kentucky bass was arranged with the help of T.H. Langlois, then Chief of the Bureau of Fish Propagation of Ohio. The reasons for this importation are unknown to us. Possibly, the importation was made because the spotted bass was supposed to prefer a habitat intermediate to that of the largemouth bass and smallmouth bass which were already present in California. Furthermore, Viosca (1931) had written a glowing account of this species from the angling standpoint; it had a reputation in the South of being a superb fighter on light tackle.

[110] See, for example, Seth Green's trip in 1871 with shad, Livingston Stone's trip in 1874 (California Fish Commission Report for 1874–75, p. 30), or the ill-fated trip of the "aquarium car" of 1873 which was wrecked near Omaha (Ibid. 1872–73, or Stone 1876a).

The scientific name of this black bass when imported was Micropterus pseudaplites, having been described by Hubbs in 1927 as a new species. It was not until later that he discovered that Rafinesque's description had priority and that a number of subspecies were named. The form introduced, now known as the northern spotted bass, is indigenous to the eastern United States, especially the Ohio River.

The spotted bass was first held at the Experimental Bass Hatchery at Friant, and later brought to the Central Valleys Hatchery at Elk Grove. No plants of it were made from the Friant Hatchery, although some spotted bass may have escaped into the San Joaquin River during 1936. If so, this was their first "plant" in California's natural waters. We know that 39,870 were reported as on hand on 31 January 1937 (CC 1937b). The first intentional plant was made in 1937 in the Tuolumne River. Brown (1939) said that they had been planted in the San Joaquin, Tuolumne, Cosumnes, and Kern rivers. The report of plants in the Kern seems to have been false.

official planting records (unpublished) of the California Division of Fish and Game show the first plant of the northern spotted bass to have been in the Tuolumne River in 1937 (4314 fish), followed during the 1938–41 period by more plants in the Tuolumne River and also in the Cosumnes River; Butte County; Amador County; and Lauer Reservoir, Modoc County. In 1941 it was planted in several California reservoirs containing no other fish in order to build up a supply for the future. Little can be determined of its success. Its close resemblance to the other black basses makes it difficult to evaluate its success or spread as reported by sportsmen.

Our last published reports of established populations were those in the Cosumnes River, El Dorado and Sacramento counties; Merle Collins Lake, Yuba County; Lake Oroville and the Feather River below it (California 1981). The genetic purity of some of these stocks is believed questionable and hybridization with previously established smallmouth bass populations may have occurred (Brown et al. 1977). At the present time, the only pure northern spotted bass populations are found in the lowermost reaches of the Cosumnes and Mokelumne rivers (State biologist D.P. Lee, 6 May 1994 pers. comm.). Broodstocks of this subspecies have not been maintained in California's hatchery system. This is one of the reasons why the introduction of the subspecies henshalli or Alabama spotted bass was authorized.

4.45. Alabama spotted bass, Micropterus punctulatus henshalli Hubbs & Bailey

On 6 April 1973, the California Fish and Game Commission authorized the introduction of Alabama spotted bass as part of an "experimental" management program to improve fishing in California reservoirs. The decision was based primarily on the rapid growth and longevity attained by this subspecies in certain oligotrophic impoundments in Alabama (Brown et al. 1977). Aasen and Henry (1981) added that the choice was also dictated by the desire to secure a species of black bass that could spawn successfully in California reservoirs during periods of fluctuating water levels, and could maintain a sizeable population where organic habitat had deteriorated, leaving a predominantly barren or rocky substratum.

The first attempt by the California Department of Fish and Game to introduce the Alabama spotted bass failed, however, when part of the shipment from Alabama died before even leaving that state. It was to have been part of a trade with Alabama for Florida largemouth bass reared in California (*San Francisco Chronicle*, 27 October 1973, p. 43).

The next attempt was successful. About 130 adult Alabama spotted bass were collected from Lewis Smith Lake in Alabama and flown to Ontario, California, on 25 January 1974. Following inspection for diseases and parasites and fin marking, 94 individuals about 25 cm in length and weighing up to 0.9 kg were released into Perris Lake, Riverside County.[111] The remaining bass (aside from six preserved in formalin) were transferred to the State's Central Valleys Hatchery near Sacramento.

Reproduction of the Alabama spotted bass in Perris Lake was first confirmed in July 1974. A few were taken by anglers in 1974 and 1975, and by 1976 it was considered that there was an abundance of large ones in the 809-ha reservoir. One of the largest taken was believed to have the fastest growth for the species recorded to date (Brown et al. 1977).

Reproduction of the bass held at Central Valleys Hatchery furnished fish for a second introduction into Perris Lake in August 1974. In late 1974, between 2000 and 3000 Alabama spotted bass fingerlings from this Hatchery were planted in Millerton Lake, and in early 1975 this plant was supplemented with 150 adults from Perris Lake. Another 300 adults and subadults collected from Perris Lake in March and April 1977 were released in San Vicente Reservoir, San Diego County. Both the Millerton Lake and San Vicente populations are successfully established, and at Millerton Lake the Alabama bass has created an attractive black bass fishery where only a small one existed previously, despite the presence of both the largemouth and smallmouth bass (Fish and von Geldern 1983).

Studies by Aasen and Henry (1981) at Perris Lake indicated that the criteria they mentioned for success were generally met: "... Alabama spotted bass displayed a tendency to spawn deeper and in more open or barren substrate, a definite advantage in some California reservoirs."

Shapovalov et al. (1981) noted that additional Alabama spotted bass from Perris Lake had since been stocked in other reservoirs in California: e.g. New Hogan Reservoir, Calaveras County; Lake Isabella, Kern County; and Lake Oroville,

[111] OC (1974) and OC (1975) said that the number stocked was 100. California (1981) said that the number was 95.

Butte County. In addition to these waters, populations of Alabama spotted bass are currently prospering in Camanche Lake, Calaveras and San Joaquin counties; Folsom Lake, El Dorado, Placer, and Sacramento counties; McClure Lake, Mariposa County; Millerton Lake, Fresno and Madera counties; Pine Flat Reservoir, Fresno County; and Shasta Lake, Shasta County.

Introduction of the Alabama spotted bass has been a notable success, benefiting the many California reservoir anglers.

4.46. Northern largemouth bass, Micropterus salmoides salmoides (Lacepède)

The largemouth bass was originally restricted to northeastern Mexico and the eastern half of the United States north to southern Quebec and Ontario.

It may have been first introduced into California in 1891 when the U.S. Fish Commission is reported to have brought out this species from Quincy, Illinois. This is the date used by most writers on the subject. In that year, Lake Cuyamaca, San Diego County, and the Feather River near Gridley received 1990 and 620 yearlings, respectively. The U.S. Fish Commission Report for 1892 did not say which of the two species of black bass then recognized (largemouth and smallmouth) was planted. Nor, with respect to the Cuyamaca plant, did articles in contemporary San Diego newspapers, which said only "black bass 1500" (see "striped bass" in "Hypothetical Introductions" section). However, the California Fish Commission Report for 1895–96, p. 29, definitely stated, "... 2,610 largemouth black bass (Micropterus salmoides) ..." were stocked in Lake Cuyamaca and 620 in the Feather River near Gridley in 1891. Most other published reports we have examined also indicated that these black bass were largemouth. For example, Smith (1896, p. 443) said, "... 1,900 yearling large-mouth bass ..." were placed in Lake Cuyamaca and 620 in the Feather River near Gridley in 1891.

It is true that largemouth bass were reported to have been stocked in Lake Cuyamaca at an earlier date. Glidden (1931) said that this is shown by records of the California Fish and Game Commission and that "... a Mr. Richardson, Superintendent of the Sisson Hatchery, and Mr. W. Lawrence of the Spring Valley lakes of San Andreas" planted these fish in 1888. Glidden (1931) also said that since this first introduction of black bass into Lake Cuyamaca, other plantings from this original plant were made into other San Diego lakes, including Sweetwater Lake. (Glidden's notes are essentially the same.) However, at a later date, Glidden said that his account was based only on a letter to him by W.H. Shebley (the date was not given), and he also said that he was not really sure that the fish were largemouth bass (pers. comm., 16 February 1943).

We know of no other report citing an 1888 plant in Lake Cuyamaca, and believe that either Shebley or Glidden was mistaken. The California Fish Commissioner's Report for 1888–90, p. 23, 48, showed that Sweetwater Lake was stocked with black bass from the Spring Valley Lakes in 1889. We know that Lawrence was then Superintendent of the Spring Valley Water Company and we also know that at that time these lakes were a source of supply of "black bass" for the State. Possibly, these black bass were smallmouth and it was Sweetwater and not Cuyamaca that was stocked. At a later date, however, the lakes in San Diego County seem to have largemouth bass populations.

Murphy (1951) also recorded two initial plants of largemouth bass, 160 fish each, in Clear Lake, Lake County, in 1888, saying that the shipments were sent by J.A. Richardson as reported in the Report of the State Board of Fish Commissioners for 1889–90. He also recorded a plant (ostensibly of this species) in Clear Lake in 1896 citing the State Report for 1895–96. Again, we believe that the author was mistaken. The State has no reference to a plant of largemouth bass or a plant in Clear Lake in 1888, and there is no California Biennial Report for the years 1889–90. There were two plants of 160 fish each in Clear Lake in 1889 and one of 88 fish in 1890, but in a primary record these are recorded only as "black bass" (California Fish Commission Report for 1888–90, p. 28, 48). Furthermore, Jordan and Gilbert (1895), on the basis of a visit to Clear Lake circa 1893, provided a record of: "Micropterus dolomieu Lacépède. Black bass. Introduced lately; a very few specimens taken." They had no record of another species of black bass in Clear Lake. In a personal communication of 1992, Murphy did not recall the exact circumstances of his statement concerning the early plants of black bass in Clear Lake, but believed that he or his editor assumed that the records referred to the largemouth bass, considering that this eutrophic lake is clearly suited for this species. He also felt that the record of smallmouth (i.e. Micropterus dolomieu) by Jordan and Gilbert (1895) may have been a misidentification since it was not always easy to distinguish between the two species.[112] In this regard, we note that Coleman (1930) recorded the presence of a limited number of smallmouth bass in Clear Lake in 1925, but—as indicated elsewhere in this paper—we do not put much faith in Coleman's identification of fishes. Possibly, smallmouth bass may have resided in Clear Lake at one time, but during the years that Murphy, an excellent biologist, studied it (1946–49), none were taken there.

There is also a report by California (1981, p. 6) that in 1879, 22 largemouth bass from the east were planted in Crystal Springs Reservoir, and that shortly before that, Lake Temescal was planted with largemouth bass. The statement is true except for the identity of the species. We know of no basis for asserting that these fish were largemouth bass (see the section Black basses in general).

[112] It may be noted that among the fishes introduced into California which Jordan (1915) listed, with reference to the black basses, he included only "... the black bass (Micropterus dolomieu) ..." This statement is offered mainly to support our contention that Jordan was often apt to provide erroneous information. We definitely know that both largemouth and smallmouth bass were present in California in 1915.

We return, therefore, to the supposition that the first largemouth bass planted in California were those from Illinois stocked in Cuyamaca and the Feather River in 1891. The reader will note, however, that the only primary reference which calls these fish largemouth is that of the California Fish Commission's Report for 1895–96. This is also the first Report of the California Fish Commission referring specifically to this species. Belief that the species of black bass stocked then was largemouth is somewhat supported by a statement of Robbins and MacCrimmon (1974, p. 122) that most of the bass salvaged and distributed by the United States from Illinois during the 1884–1940 period were largemouth.

It is completely supported by the table showing the distribution of fish taken from Lake Cuyamaca during 1896 by the California Fish Commission. This table shows that "large-Mouth Black Bass (Micropterus salmoides) " were stocked in April and May in waters in southern California, the Central Valley, Clear Lake, and Sonoma County, and taken to Sisson (Mt. Shasta) Hatchery (California Fish Commission Report for 1895–96, p. 73). There is a possibility that the identity of the species was determined by the California Fish Commission and/or David Starr Jordan when a visit was made to the lake in January 1896 (Smith 1896, p. 438).

Apparently, the only other recorded shipment of largemouth bass from outside the state to California is that of about 2660 fingerlings (figures in the same report vary) received by the State from the U.S. Fish Commission in Quincy, Illinois, in 1895. Plants were made in several waters throughout California (Lake Merced, Crystal Springs Reservoir, Buena Vista Lake, Gay Pond in San Diego County, Lake Elsinore in Riverside County), and the remainder of the fish taken to Sisson (Mt. Shasta) Hatchery (U.S. Fish Commission Report for 1895, p. 69; California Fish Commission Report for 1895–96, p. 29–30, 72). Smith's (1896, p. 443) account varied somewhat but is essentially the same. He did omit mention of the fish said to have been planted in Crystal Springs Reservoir and Lake Merced. Although there may be some slight question as to the initial date of this shipment (the California Fish Commission Report for 1897–98, p. 38, stated that the Sisson pond was stocked with "... mature big-mouthed bass imported from the East in 1896"), the distribution or planting tables of the State (see Introduction) agree generally that the import was made in 1895.

Distribution of these acclimatized largemouth bass began shortly after the original importations or plants were made. Most of the distribution was performed by the State from ponds at Mt. Shasta and leased ponds, but private individuals were undoubtedly active, especially at first.

As has been stated before, much of the early distribution may have been of the smallmouth bass which appears to have been more numerous during these first few years, but the domination of the largemouth soon became apparent. By the start of the 20th century, the California Fish Commission was confining its distribution of black bass to the largemouth, having decided that it was much more suitable to the waters of the state (California Fish Commission Report for 1901–02, p. 30).

Largemouth bass even became an unofficial commercial item: "Along the Sacramento River in Butte and Colusa counties, the bass have increased so that a good many fishermen are earning a livelihood by taking them with hook and line" (California Fish Commission Report for 1905–06, p. 57).

In 1909, some half million bass were rescued in the Fresno-Kings County section alone—a forerunner of the extensive fish rescue work done thereafter. In alluding to fish rescue in this area, Ferguson (1913) stated that "black bass" constituted about 10% of all species rescued. We believe that he was speaking of largemouth bass. By 1910, the California Fish and Game Commissioners (Report for 1909–10, p. 36) announced, with reference to the largemouth bass, "The rivers, streams, and sloughs throughout the Sacramento and San Joaquin valleys are teeming with them.... Their range in this State is practically unlimited, so far as a northern or southern latitude is concerned."

Today, the success of the northern largemouth bass in California is well known. It grows to a large size, reproduces abundantly, and is a major freshwater game fish. of the introduced centrachids, only the green sunfish and bluegill surpass it in numbers. (Many of the State fish rescue records showed that the largemouth bass far outranked either of these species in the number rescued. However, more emphasis was placed on saving black bass than sunfish.) It is well distributed throughout the entire state in lower altitude ponds and reservoirs, perhaps reaching its acme of abundance in the warm valley waters of the Sacramento-San Joaquin system. It has furnished excellent fishing in the Colorado River. Notable exceptions to its spread are the Klamath and Eel drainages (the second and third largest river systems of California), and it is seldom found in the high mountain natural lakes.

An early introduction of this species into a coldwater trout lake in California was that of Big Bear Lake, San Bernardino County, around 1920. There have been a number of such introductions (Hume Lake, Fresno County, and Lake Almanor, Plumas County, in 1942). At one time such introductions were decidedly feared. The State's fishery biologists had two classifications for its large lakes: "trout lakes" and "bass lakes." Black bass were considered inimical to the best interests of trout and their growth was slow in cold waters. Today, the theory of two-story reservoirs has changed this concept, and there are a good many large lakes or reservoirs supporting both black bass (in the warmer surface waters) and trout (in the colder depths). There was, however, a very early warning against stocking black bass in trout waters (e.g. in the California Fish Commission Report for 1874–75) which was repeated in many of the Commission's subsequent publications (e.g. CFG 1924). Despite such warnings the State has often deliberately stocked largemouth bass in trout waters. One of the most striking of these introductions was the stocking of this species in Eagle Lake, Lassen County, first in 1901 and 1902 and later, even though a fishery for the native Eagle Lake trout had flourished there for many years. The bass grew to large size (8–10 lb) but vanished in the 1930s. Although at least 12 species of fish not native to Eagle Lake were planted there between 1879 and 1956, the native Eagle Lake trout remains its dominant game fish (Purdy 1988).

Aside from its use as a game fish, black bass (notably the largemouth) have been touted and suggested both for mosquito and algal control in California. With respect to the latter, its tolerance for copper sulfate has been noted (Neale 1916; Gillespie 1917).

The natural increase of the northern largemouth bass has been so great that little consideration has been given to its artificial propagation by the State.[113] There were, however, suggestions that the State should establish rearing ponds to be stocked with black bass by rescue crews, from which requests for lake stocking could be met (CFG 1925a; Shebley 1931). Furthermore, with the consent of the State, a few sportsmen's clubs have held broodstock and made plants of largemouth bass; e.g. CFG (1930d). Although this has done no particular harm, there is some question as to whether it was ever useful. Transplants of wild northern largemouth bass are still carried out by the State, and until recently, large numbers were seined from overflow areas and released into safe waters.

In recent years, plants of the Florida largemouth bass in northern largemouth bass waters has resulted in hybridization and often in an increase in size of the bass taken.

Already widespread in California lakes, reservoirs, farm ponds, sloughs, and slow-moving rivers, in recent years largemouth bass populations have become established in growing numbers of trout lakes and reservoirs, waters marginal for bass growth and waters where the presence of bass restricts options for trout management. These waters tend to be those accessible to boat anglers. We suspect illegal releases of bass by anglers who take bass from one water, retain them alive in live wells, and release them in other waters to expand angling opportunities.

Along with bluegill and channel catfish, the northern largemouth bass and, to a lesser extent, the Florida largemouth bass are very popular in pond management in California. Many thousands are reared annually by private aquaculturists and sold to owners of farm and subdivision ponds, and also to restaurants and food markets for live sale, principally to Asian-Americans. Also, many thousands are imported annually into California for these same purposes.

Its impacts on certain trout populations and on populations of small indigenous fishes seem to be its greatest drawback. Its predatory habits have depleted Arizona populations of cyprinids, cyprinodontids, and poeciliids (Minckley 1973,

[113] The Department experimented with the maintenance stocking of hatchery fingerling and yearling largemouth bass at Clear Lake, Lake Nacimiento, and Merle Collins Reservoir. The program was dropped because the hatchery fish did not behave like their wild counterparts.

p. 225). In California, the largemouth bass has been implicated in the extirpation of the Owens pupfish and the near extirpation of the Owens tui chub (Gila bicolor snyderi) from the Owens Valley Native Fish Sanctuary in Mono County. Both species are designated Endangered by the Federal and State governments. Illegally stocked by anglers, the bass were eradicated with rotenone by the Department of Fish and Game, but they have since been reintroduced, which has raised doubts about the future of the Sanctuary. In a fisheries survey of the San Joaquin River drainage, Brown and Moyle (1994) observed that native fishes were uncommon or absent where largemouth bass were common.

Despite these qualifications, of all the species of warmwater fish present in California, the largemouth bass is one of the most popular, and it appears—at least to the fisherman—to have been a good choice for introduction, furnishing good fishing in many reservoirs, the Delta, and farm ponds. The overall quality of fishing for this species in California may have declined in recent years due primarily, according to von Geldern (1974), to overfishing, aging of reservoirs, and possible competition from the threadfin shad and other planktivorous fish. It still remains a preeminent game fish here.

Today, in California, as is true throughout the United States, interest in fishing for black bass is high. Black bass tournaments have been popular in California since the early 1970s and their popularity continues. Lee et al. (1993) described this practice and its development throughout the state during the 1985–89 period. Among their conclusions were that past studies at major California reservoirs indicated that annual black bass harvest exceeded 45% (which downgraded fishing quality), and that tournament catch-and-release fishing may lead to a reduction in the general rate of harvest.

Although Lee et al. (1993) did not distinguish among the species of black bass fished for in California tournaments, the senior author of that paper has told us that the largemouth bass is the most numerous of those taken followed by spotted bass and smallmouth bass. of the largemouth species (Micropterus salmoides) , the northern subspecies (M.s. salmoides) , often hybridized with the Florida subspecies (M.s. floridanus) , is the most numerous in the tournament catches (pers. comm. by D.P. Lee).

4.47. Florida largemouth bass, Micropterus salmoides floridanus (Lesueur)

A subspecies genetically distinct from the northern largemouth bass (Micropterus s. salmoides) , the Florida largemouth bass was imported into California from Holt State Fish Hatchery near Pensacola, Florida. The introduction was conceived by O.P. Ball, then Lake Superintendent for the City of San Diego, with the advice and encouragement of C.L. Hubbs and coordination with State biologist G.W. McCammon. A shipment of 20,400 fingerlings (about 2 to 2.5 cm long) was flown to California and planted by the State in Upper Otay Reservoir, San Diego County, on 7 May 1959.[114] The expenses were paid by the County of San Diego which hoped that the Floridan subspecies would grow faster and achieve a larger size than the northern largemouth bass, already common in the state (California 1959; OC 1959a). Sasaki (1961) reported in more detail concerning the introduction of the Florida bass, pointing out that Upper Otay Reservoir had been chemically treated to eradicate all fish prior to the introduction.

Upper Otay Reservoir, which is closed to public angling, soon developed a self-sustaining population of Florida bass and served as a brood source for its introduction into other waters. San Diego County reservoirs initially stocked with this subspecies included Lower Otay Reservoir, Sutherland Reservoir, and Lake Wohlford in 1960, and Lake Miramar and El Capitan Reservoir in 1961.

An early experiment concerning growth and blood protein analysis of the Florida and northern largemouth basses indicated that there was little evidence to support extending the range of Florida bass and suggested that further "experiments" might be helpful (Miller 1965). Consequently, from 1965 through 1976, the impact of the Florida subspecies was studied at four southern California reservoirs: Lower Otay, Sutherland, El Capitan, and San Vicente. It was found that: the Florida bass hybridized with the resident northern largemouth bass; the northern bass grew slightly faster than the Florida bass during its first year of life but thereafter the Florida bass grew substantially faster; the Florida bass were less vulnerable to angling than either the northern bass or hybrids; the mean size of bass caught and incidence of trophy specimens increased; increased bass yields were largely associated with the development of hybrid populations; and bluegill yields decreased markedly in reservoirs where Florida bass had been introduced. In general, it was felt that the introduction of the Florida bass had a positive impact on the black bass fisheries of San Diego County, but that additional questions concerning genetic adaptability and their impact on sunfishes should be resolved before further introductions were made in northern waters (Bottroff and Lembeck 1978).[115]

Florida largemouth bass from Upper Otay Reservoir were first stocked in northern California (north of the Tehachapi Mountains) in April 1969 at Clear Lake and Hidden Valley Reservoir, both in Lake County. From 1970 through 1973, they were also stocked in another limited number of northern California waters, but in May 1974 a moratorium on further stocking of this subspecies in northern California was established by the Department of Fish and Game because of its

[114] A shipment earlier in 1959 of 10,000 Florida largemouth bass fingerlings from a Federal hatchery in Florida was flown to California for release in Upper Otay Reservoir, but all fish had to be destroyed because they were heavily parasitized (5 June 1996 pers. comm. from State biologist G. W. McCammon).

[115] The California findings strengthened the school that believed that the Florida bass was indeed, as Bailey and Hubbs (1949) had decided, a subspecies distinct from Micropterus salmoides salmoides with its own genetic traits (Chew 1975).

apparent intolerance to low water temperature and concern that maladaptive genes possibly related to this intolerance would be transmitted to northern largemouth bass populations.

"Experiments" on the Florida largemouth bass, however, were conducted in northern California waters which also contained northern largemouth bass: Folsom Lake, New Hogan Reservoir, Lake Amador, Lake Isabella, and Clear Lake. These studies as well as another at Hidden Valley Reservoir corroborated the results of the initial experiments in San Diego County indicating that introductions of Florida bass into northern bass populations were generally beneficial through reducing high exploitation rates, increasing the mean size of bass in the catch, and producing exceptional fishing for trophy-size bass in some waters. It was generally felt that the Florida largemouth bass would be a desirable addition to selected reservoirs in northern and central California (Pelzman 1980; Week 1984). The 1974 moratorium was lifted in 1980 and since then the Department has introduced Florida largemouth bass into numerous additional waters.

Furthermore, it was considered that the success of this subspecies aided in validating the theory that the introduction of southern stocks of centrarchids was useful (Fisk and von Geldern 1983).[116]

Meanwhile, a flood of popular articles excited the attention of sportsmen by extolling the virtues of the Florida bass (those by Grant 1970 and Garrison 1973 are typical), and several new California angling records for largemouth bass (Florida) were established.

4.48. White crappie, Pomoxis annularis Rafinesque
Black crappie, Pomoxis nigromaculatus (Lesueur)

As for the green sunfish and bluegill, it seems impossible to deal separately with the history of introduction into California of these two species of crappie which have natural residence in eastern and central North America. A number of accounts of their presence merely say "crappie," and mixed shipments may have been made. One or the other member of the genus Pomoxis seems to have been imported from the eastern United States at least four different times: 1891, 1895, 1908, and 1917.[117]

[116] Another southern form of the largemouth bass is the so-called Texas largemouth. It is not a subspecies but rather a domesticated form developed in Texas which found its way into a few southern California waters and has apparently been stocked in some waters on military reservations by the U.S. Fish and Wildlife Service. Specimens from ponds at the Department's Imperial Wildlife Area (Imperial County) were shipped to Central Valleys Hatchery in the mid-1970s. Here they demonstrated rapid growth, early maturity, and ease of handling and adapted readily to an artificial diet (State fish culturist M.D. Cochran, pers. comm.). offspring were stocked in 1978 in several farm ponds in the Sacramento area and in Salt Springs Valley Reservoir (Calaveras County). The status of the farm pond populations is unknown, but fish in the Reservoir were lost when it ran dry.

[117] The statement of Neale (1931a) that "... in 1901 a shipment to Sacramento was extensively released" is probably a misprint for 1908.

Lake Cuyamaca, San Diego County, was planted in 1891 with 285 yearling crappie, apparently of both species, brought out from Quincy, Illinois, by the U.S. Fish Commission (U.S. Fish Commission Report for 1892, p. LXXXV). The California Fish Commission Report for 1895–96, p. 29, stated, "The U.S. Commission of Fish and Fisheries brought out and planted in the waters of the Feather River near Gridley, and in Lake Cuyamaca ... in 1891 ... 285 crappie (Pomoxis annularis and P. sparoides) . ..."[118] Later authors do not seem to record the Feather River plants.

Two San Diegan newspapers stated that "croppies 200" were planted in Lake Cuyamaca in 1891 (see "striped bass" in the "Hypothetical Introductions" section of this paper). Smith (1896), in alluding to plants of crappie made in western waters, said that most of the fish were known to be P. annularis, but that it was certain that they had also included some P. sparoides.

Although 50,000 Pomoxis fry were sent to Sisson (Mt. Shasta) Hatchery, by the U.S. Fish Commission in 1895, none of these survived to be planted (U.S. Fish Commission Report for 1895, p. 71; Smith 1896).

The 1908 allotment by the U.S. Bureau of Fisheries from Meredosia, Illinois, at the request of the California Fish Commission received the widest distribution in public waters of any shipment. A detailed account of the planting of 1090 "crappie" and "strawberry bass" is given in the U.S. Fish Commission Report for 1909, p. 69. Other accounts of this distribution, which differ somewhat in their details, are given by California Fish and Game Commission Report for 1909–10, p. 47–48; Shebley (1917); Vogelsang (1931).[119] The first two references cited above called these fish "crappie (Pomoxis annularis) . " Vogelsang (1931) mentioned both species and stated that the 1908 introduction was the first successful one in California. (See the section on green sunfish and bluegill for further remarks on Vogelsang's 1931 report and his letter of 1908 to ichthyologist C.H. Gilbert on the subject.) At any rate, we know from the above reports that waters in northern, central, and southern California were all planted with crappies from Illinois in 1908.

The last known plant of the "early years" from without the state was described by Glidden (1931), and in a letter to W.A.D. (16 February 1943) he furnished further details. Sixteen "crappie," probably brought out from the East by the U.S. Bureau of Fisheries for exhibit at the San Diego Exposition of 1916, were given to State game warden W. Toms at the close of the Fair. In January 1917, he

[118] The black crappie, also known as the calico bass and strawberry bass, was previously known as Pomoxis sparoides.

[119] Another account of crappie distribution in California was given by Scofield (1916a). Apparently it included planting localities for both the 1891 and 1908 importations and stated that mixed shipments of the two species were made.

planted them in a pond on upper Cottonwood Creek in San Diego County together with 15 "grayling" and six "sunfish." Later, the "crappie" worked their way into Lake Morena (a reservoir) where they furnished fine fishing. It seems probable that these were white crappie. In fact—as will be shown later—the predominant crappie in the San Diego County lakes was the white species. The transference of "crappie" from one San Diego lake to another was so great that no one today can trace their origin (notes of E.H. Glidden).

There is considerable evidence to support the contention of Vogelsang (1931) that the shipment of 1908 marked the first successful introduction of Pomoxis into California. The California Fish Commission Report for 1895–96, p. 29, indicated that crappie from the 1891 plant in Lake Cuyamaca were not established there; at least they were not present in large numbers. Several sportsmen have indicated that crappies were not noticed in the San Joaquin Valley until about 1910. (See section on green sunfish and bluegill.) Scofield (1916a) reported them as being fairly plentiful in several localities in California but little known. A. Woodard (old-time fisherman and State fish rescue foreman) has told W.A.D. that "crappies" increased in the San Joaquin Valley as the water became more turbid, and that, although they did not seem abundant in 1925, by 1930 they became common. CFG (1917b) said that "... bluegill sunfish and calico bass were planted in the Sacramento and San Joaquin rivers about ten years ago...." Bryant (1921a) indicated that "crappie" were first introduced into California in 1908. Neale (1928) indicated that up to 1912, crappies and sunfishes were not present in California in sufficient numbers to justify their removal to other waters for stocking purposes. The earliest published records of distribution by the State itself (presumably from stock within California) are found in Shebley (1922). Small plants were listed as beginning in 1916 for the white crappie and in 1919 for black crappie. It was also reported by CFG (1922a) that "The crappie appears to be taking the place of the Sacramento Perch near Sacramento. This species appears to become more abundant from year to year...." It is true that Wohlschlag and Woodhull (1953) indicated that black crappie may have been introduced into Salt Springs Valley Reservoir, Calaveras County, "around 1900," but the vagueness of this record makes it very uncertain (see the section on green sunfish and bluegill).

In 1931, three articles appeared which seemed to fix both species of crappie as being fairly common or well-established residents of California. Neale (1931a) published an article giving a key to the "... seven important species of the sunfish family [Centrarchidae] found in California," and the popular reprint (of 29,000 copies) showed a white crappie on the cover. Colored plates of both the black crappie and white crappie were included, and Neale stated that both species "... are numerous in the Sacramento and San Joaquin Valley waters...." Evermann and Clark's (1931) list of introduced fishes in California stated that although "The black crappie is ... the one that seems to have survived in largest numbers.... Both species are now well established in several places in the State." And Walford (1931) (who depended on literature or others for much of his knowledge of inland fishes) listed both species in the key which was included in his "Handbook of Common Commercial and Game Fishes of California." All of these articles (especially the first and last) received a wide circulation in view of their popular interest: Neale (1931) because of the colored plates (from the Illinois Natural History Survey), and Walford (1931) because of its photographs giving it the name of "picture book."

For some years it was a widely accepted belief that both species of crappie were well established and common in California, especially in the Central Valley. It seems probable that this belief originated or at least was perpetuated largely by these three papers. Furthermore, the "crappie" and "calico bass" have sometimes been listed as separate species in the California Fish and Game Code, and in many fish rescue records totalling thousands of fish. The implication in some of these records was that "calico bass" were far less abundant than "crappie." See, for example, the California Division of Fish and Game Report for 1938–40, p. 75. On the other hand, only "calico bass" (324,450 of them) were recorded as rescued by the State in 1931 (CFG 1932d). We assume that the two names were used indiscriminately.

There was a specific published record of the occurrence of "Pomoxis annularis" in Clear Lake in 1925 by Coleman (1930). However, he gave its common name as "Calico bass" (which is almost always reserved for P. nigromaculatus) , and it is apparent from much of Coleman's other work that he was not too exact in his identification or choice of names for fishes.[120] Furthermore, later records such as those by Lindquist et al. (1943) based on a survey of 1938–41, and Murphy (1951) based on an intensive study, 1946–49, recorded only the black crappie from Clear Lake. Although both species are now common (Macedo 1991), Week (1982) indicated that the white crappie was unrecorded at Clear Lake during the 1894–1950 period.

It is true that the publications of some other fishery biologists indicated the presence of the white crappie in California, but our inquiries have shown that these accounts were based upon literature, not personal collection or observation. For example, Sumner and Smith (1940) included this species in a list of the fishes of the American and Yuba basins. However, they listed it only because it was presumed to occur there (pers. comm. by O. Smith in 1943), and they also indicated that it was not collected by them. Hatton (1940a) also mentioned it as a species resident in the Central Valley, again only because its presence there had been so generally assumed (pers. comm. of 1941). Murphy (1941) included it in his key to the fishes of the Sacramento-San Joaquin basin. This, too, is a logical inclusion in view of the discussion above, but in a letter to W.A.D. (26 November

[120] Coleman, the State of California's first inland "fishery biologist," was trained in entomology rather than in ichthyology or fishery biology.

1941) he said, "I have never collected Pomoxis annularis. ... I doubt if ... [it] ... is present in California unless it is 'abundant locally' somewhere." Others, including Croker (1937) and Dill and Shapovalov (1939), have also listed both species as successfully established in California, but again their listings were based solely on literature (pers. comm.). Despite all the literature examined, we know of no definite published records of the white crappie in California up to 1944; i.e. instances where the species was positively identified.

In January and May of 1942, collections of the white crappie were made and positively identified by C.A. Woodhull and W.A.D. at the following points: Colorado River at the mouth of the Gila River and at Headgate Rock Dam; head of the Alamo Canal near Andrade; and Haughtelin Lake near Winterhaven. Nowhere was the species common except in Haughtelin Lake, an oxbow derived from the Colorado River in 1920. The black crappie was also taken in 1942 from the same area as well as from Lake Havasu. Neither species was well known by local fishermen who reported seeing "crappies" only within the last few years (Dill 1944). Although the California Division of Fish and Game had planted the black crappie in the Colorado River drainage in sloughs near Blythe in 1938 and in Beal's Slough near Needles in 1939 (from stock within California), the origin of the white crappie in these waters is unknown. As for the other alien fishes found in the Colorado at that time, the number of places and times where and when they may have been introduced are so many that even a most exhaustive search of planting records (published and unpublished) could never indicate the date of the first successful establishment.

The Colorado River flows through or borders on seven states as well as Mexico; it is about 1750 miles long and has a drainage area of about 244,000 square miles. Since any of its states as well as the Federal Government or private individuals may have stocked some portion of its drainage, we have not tried to ferret out the history of all the introduced fishes now found in the Californian waters of the Colorado. Accurate collecting dates would appear to be of greater importance in evaluating the establishment of its introduced fishes. Federal biologist J. Moffett (MS) recorded the black crappie, but not the white, from Lake Mead in 1941, but both species were found in the River in California (i.e. below Lake Mead) in 1942.

M.W. Brown, who directed fish rescue for California from 1934 to 1940, and who was also a fishery biologist, told W.A.D. on 27 January 1940 that he had never seen a white crappie in California, and that the terms "crappie" and "calico bass" appeared to be applied indiscriminately to the black crappie by both sportsmen and rescue crew members. Numerous collectors of fishes including C.H. Fryschlag (his successor) have echoed Brown's statement. In even more recent times, extensive collecting in the Central Valley (see Cope and Erkkila 1952; Hallock et al. 1957; Hallock and Van Woert 1959) during the period of 1939 to about 1959, revealed the presence of only the black crappie. It is certain that the white crappie did not possess the wide distribution in the state (especially in the Central Valley) with which it was once credited. After mentioning that the white crappie was planted in various parts of California following its introduction to Cuyamaca, McClane (1974, p. 1090) said that the white crappie survived only in the San Diego area and in the Colorado River drainage. The source of his information is unknown.

Despite a lack of positive published identification, the white crappie is now known to have been present in southern California prior to Dill's (1944) record of its presence in the Colorado River in 1942. This, however, was not known at the time, and it was not until August 1949 that positive identification was made of any of the crappies in the San Diego County lakes. Two California Division of Fish and Game biologists, G.I. Murphy and W.A. Evans, determined that both species of crappie were present but that the white crappie was by far the dominant one (letter of 16 August 1949 from L. Shapovalov to B. Curtis).

Crappie fishing has been well known in the San Diego lakes for many years, and it is now certain that most of the crappies were the white. In fact, Goodson (1966a) thought it possible that these (and all white crappie in California) were progeny of the fish planted near Morena Reservoir in 1917.

It is also known that the white crappie is now well established in northern California (i.e. north of the Tehachapi Mountains). Recorded information on the first northern plants differs. OC (1951c) says that they took place in May 1951 in East Park Reservoir in Colusa County and Coyote Reservoir in Santa Clara County. This report also says that 2000 fingerlings in all were planted, and that they were the offspring of adults rescued from drying southern California waters in 1950 and transferred to the Division of Fish and Game's Central Valleys Hatchery. However, the Weekly Press Release of the California Department of Fish and Game 24 (25), p.3, (issued 23 June 1954) said that the initial planting of white crappie was of 1400 fingerlings stocked in the fall of 1951 and that another 16,000 were planted in 1952. Hagy (1956) said that in 1951 white crappie from Morena Reservoir, San Diego County, were transferred by the State to East Park Reservoir and Coyote Reservoir. Leitritz (1970) said that white crappie propagated at Central Valleys Hatchery in 1951 were planted in East Park Reservoir and in Bullards Bar Reservoir, Yuba County.

Although it is quite probable that most of the white crappie in northern California are the result of the State's planting circa 1951, it is possible that some of them are the result of a plant which may have been made in Oregon. M. Coots, Fishery Biologist with the Department of Fish and Game, took some white crappies in a fyke net set in the Lost River in Oregon just north of its Modoc County boundary on 4 April 1951. (Their identification was made by Coots, G.W. McCammon, and W.A. Dill—all of the Department of Fish and Game.) As the Lost River is in the Klamath river drainage, its white crappie may have also entered California.

In conversations with State fishery biologists, and in letters to S. Gordon, then consultant to the State Wildlife Conservation Board (WCB), circa 1948–50, R.W. Eschmeyer, special consultant to the WCB, stated that "crappie" (Pomoxis annularis) would probably be the major warmwater game fish in California reservoirs, especially in the south. Eschmeyer based his opinion primarily on his experiences as a fishery biologist for the Tennessee Valley Authority. It is very possible that his remarks were heeded by State workers.

Today both species are widely distributed throughout California in the same type of waters that harbor our other introduced centrarchids; i.e. in the warmer streams and lakes (principally reservoirs). Crappie sometimes stunt in coldwater lakes and in some cases have been removed by chemical treatment. For example, in 1956 stunted crappie were removed from Big Bear Lake, San Bernardino County, through chemical treatment with a report that phenomenal fishing resulted after the lake was restocked with trout (OC 1958b). The species of crappie was unrecorded, but a photograph (OC 1957a) indicated that it was the black crappie. White crappie have also been known to stunt even in warmwater reservoirs such as Isabella (Bartholomew 1966). On the other hand, even lakes over a mile high (e.g. Shaver in Fresno County) have produced good-sized ones (black).

Hatton (1940b) mentions that "crappie" (black) were observed eating chinook salmon fry in the San Joaquin River and, of course, both species may prey on other fishes. The most complete study of the black crappie's food habits in the Delta known to us is that of Turner (1966a) who found that the major fish eaten was the introduced striped bass.

The fishery for crappie is somewhat erratic and fishery managers have problems in trying to create a sustained yield. Nevertheless, crappies provide considerable sport for the angler and are a recognized small game fish. They make extensive use of the pelagic zone in reservoirs, and fishing is often best in the spring months when demand for angling recreation is high. Artificial lures as well as cut or live bait are used for their capture. Goodson (1966a) provided a good account of the place of both species of crappie in California, although his history of their introduction is not completely correct.[121]

In 1981 the Department introduced the Florida strain of black crappie from the State of Florida. Swift et al. (1993) said that the St. John's River was its point of origin. With the cooperation of private groups, the Department stocked Florida black crappie in Clear Lake, Lake County, beginning in 1985 (Macedo 1991).

[121] For example, Vogelsang (1931) did not say that crappie were introduced into California in 1901 nor "infer" that both species were distributed in 1908. He clearly said that they were distributed in 1908. Nor is it true that until 1951 no white crappie had been recorded north of the Tehachapi Mountains. The records may have been incorrect but the species certainly was recorded. Goodson (1966a) was also mistaken in saying that no black crappie had been recorded from the San Diego County lakes (see above).

Plants continued for several years and, although the Floridas are apparently established, no major changes in crappie angling are apparent (R.A. Macedo, 22 September 1995 pers. comm.). It was also released in several reservoirs in southern California, but no follow-up was conducted, and the status of these populations is unknown. The introduction occurred at the time that centrarchids native to the southeastern United States (Florida largemouth bass, Alabama spotted bass, and southeastern bluegill) promised to support outstanding warmwater sport fishing, a promise fulfilled except that for the bluegill. The Florida crappie is not a described subspecies. It was assumed that this strain would achieve greater size in our waters and compete successfully with the threadfin shad. State biologist C.E. von Geldern, Jr., (pers. comm.) maintained that centrarchids that evolved with threadfin shad tend to spawn before them, which enables young-of-the-year centrarchids to feed more extensively on shad-of-the-year than northern centrarchids that spawn later in the year.

The so-called "black-nosed" crappie was introduced into California from Arkansas in 1986. Such crappie possess a black or brown-black stripe that extends along the dorsal ridge from the origin of the dorsal fin to the tip of the upper lip and beneath the lower jaw as well. They constitute a small percentage of black crappie populations from 13 states from Florida north to Wisconsin (Buchanan and Bryant 1973). They can be bred artificially to produce all black-nosed off-spring. The presence of this "natural mark" has some value in mark-and-recapture population studies. The black-nosed crappie held at Central Valleys Hatchery did not survive, and no further introductions were made.

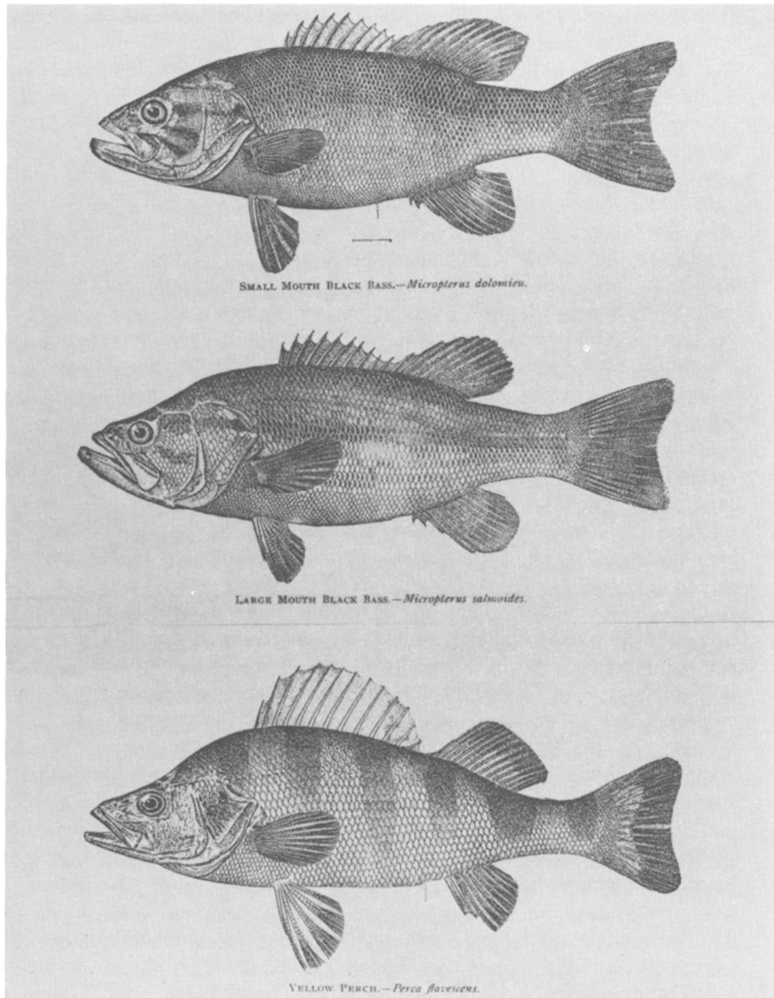
Private aquaculturists occasionally import black crappie into California, apparently for sale to farm pond owners. They comprise a very minor fraction, however, of the total number of fish imported into the state for aquaculture purposes, and the crappie is not significant in farm pond management.

4.49. Yellow perch, Perca flavescens (Mitchill)

There have been three known legal attempts to introduce the yellow perch, common to the northeastern United States and Canada (north temperate waters), into open waters of California, but only two in which the introductions were actually made.[122]

The first attempt to bring this species to California was in 1873 when Livingston Stone carried 110 specimens of yellow perch from the Missisquoi River in Vermont, along with several other species of fish destined for Californian waters,

[122] California (1981) said that there were several importations following the 1891 plant, but since the plants are not recorded and the reference is such a late one, its information has not been considered useful. Moyle (1976b, p. 326) said, "The only official introductions of the yellow perch into California were those made into some southern California reservoirs and the Sacramento River between 1891 and 1918." We believe that this information is not valid.



Fish illustrations from Smith (1896) and biennial reports of the State Board of Fish Commissioners of the State of California (small mouth black bass, large mouth black bass, and yellow perch).

in the first of his famous "aquarium" cars. The entire shipment was lost in a railway accident in Nebraska (Stone 1876b). This attempted introduction received criticism which Stone answered in a letter which appeared in *Forest and Stream* for 19 March 1874, titled, "Is the Yellow Perch a good Fish to Introduce into California?" Stone defended his choice, not only pointing out the virtues of yellow perch from northern climes, but spoke disparagingly of the native fishes of northern and central California, particularly those of Clear Lake and the Sacramento River (Smith 1896, p. 447–448).

With respect to true introductions of the yellow perch, the first was in 1891 when over 6000 yearlings were brought into the state from Quincy, Illinois, by the U.S. Fish Commission. Three thousand adults and young were placed in the Feather River near Gridley; 3980 in Lake Cuyamaca, San Diego County (U.S. Fish Commission Report for 1892, p. XLIX and LXXXIII; California Fish Commission Report for 1895–96, p. 29). Two San Diegan newspapers of 1891 said that 7000 "ringed perch" (another name for yellow perch) were planted in Cuyamaca in 1891. (See the account of "Striped bass" in the section on "Hypothetical Introductions.")

Those in Cuyamaca prospered for a time. Smith (1896, p. 447) stated that an employee of the California Fish Commission reported large numbers taken by anglers, and that David Starr Jordan had identified specimens. In 1896, the State removed 406 adult yellow perch from the Lake and planted them in several widely separated localities, especially in the Sacramento-San Joaquin drainage. (For a complete list of these plants, see California Fish Commission Report for 1895–96, p. 73.) This seems to be the last authentic record for their presence in Lake Cuyamaca. Forty-eight others from Cuyamaca were taken to Sisson (Mt. Shasta) Hatchery where Shebley (1917) said, "...no efforts were made to propagate them to any extent." Three other yellow perch (adults) sent to California by the U.S. Fish Commission in 1895 were also sent to Sisson Hatchery (California Fish Commission Report for 1895–96, p. 38).

One would certainly expect Shebley (1922) to have listed any further distributions from the Sisson stock in his table facing p. 96, and since he recorded no plants of yellow perch in California between 1896 and 1914, it seems probable that none were planted, although the California Fish Commission Report for 1897–98, p. 38, said that yellow perch were held in the Sisson ponds.

There was also survival of the 1891 plant in the Feather River, or at least some of those transplanted to this area in 1896. Neale (1918) reported the presence of large numbers of yellow perch stranded in Nigger Jack Slough near Marysville in 1904 and stated that several thousand small and adult fish were removed to the Feather River.

In 1908 another shipment was received in California from the U.S. Fish Commission at Meredosia, Illinois. According to Vogelsang (1931), he selected the yellow perch (along with crappies and sunfish) to provide sport and food in easily accessible waters and to relieve the drain on trout waters.

It is not clear from the records just how many yellow perch were shipped to California in 1908 or just where all of them were planted. The U.S. Bureau of Fisheries Report for 1909, p. 98, gives a detailed list of the planting of 440 yellow perch (fingerlings, yearlings, and adults). Other planting records for the 1908 shipment are given by: California Fish and Game Commission Report for 1909–10, p. 47–48; Ellis (1915); Shebley (1917); Neale (1918); Vogelsang (1931). These accounts do not agree in all particulars, but the perch seem to have been stocked at several widely separated points throughout the state. In speaking of this 1908 shipment, Bryant (1921a) said that it included both "yellow perch" and "ring perch," but he was obviously alluding to the same species. (See also the account in this paper of the green sunfish and bluegill concerning a letter by C.A. Vogelsang to C.H. Gilbert.)

Neale (1918) reported yellow perch to have a wide distribution in the Central Valley but to be in no wise numerous. He named several specific localities (most of them near Sacramento) where they were to be found at that time. Later he said, "...the yellow perch has been only moderately successful. They will rarely be found in waters where there are no bass" (Neale 1931a). A. Woodard, on State fish rescue crews for 20 years, wrote W.A.D. that yellow perch were fairly common in waters of the San Joaquin Valley, especially in the clear waters of Hood Canal and Snodgrass Slough from 1910 to 1920, but that from 1922 to 1943 he rescued only seven. He said that increase in turbidity of Central Valley waters was concomitant with the decline of the yellow perch.

Many thousands of fish used to be rescued annually from overflow areas by State crews. Yet their records (Neale 1931b, p. 40; 1932, p. 31; 1934, p. 65) showed that only two yellow perch were rescued between 1 August 1928 and 30 June 1933. None have since been reported by rescue crews. Few, if any, have been seen in the Central Valley of late years. State biologist C.A. Woodhull caught one in 1924 from the Kings Island Bridge, San Joaquin County, and local resident R.H. Allen told W.A.D. that it existed in the Hood Canal (San Joaquin drainage) for a time, but that sometime prior to 1941 it had completely disappeared (pers. comms.). The last record of yellow perch from the Central Valley known to us was from Snodgrass Slough in February 1951 when two were caught by an angler who said that the species was occasionally caught here (letter of C.A. Woodhull, who made the identification, to his supervisor, A. Calhoun, 26 February 1951).

Most fishery workers were about to conclude that the yellow perch had almost vanished completely from California, but in May 1946 it was found in Copco Lake, Siskiyou County, by some fishermen who caught four. The fish were identified by E. Murphy and the identification verified by J.H. Wales (both of the California Division of Fish and Game). In 1947, some yellow perch were found in the Klamath River below Copco Lake, and by 14 June 1951 were known to have descended the River to its mouth (letter of 10 March 1947 from Wales to W.A.D; Coots 1956).

Within a few years, yellow perch were numerous and supporting popular fisheries in Copco Lake and Iron Gate Reservoir, and fairly common in the dredgepond backwaters along the Klamath River in California. Only the quieter waters of the Klamath itself supported them. Examination of yellow perch stomachs revealed no salmonids, but it was found that perch would consume salmonid young under artificial conditions (Coots 1956). Additional studies in 1976 showed that 35 out of 44 perch from the Klamath River contained fingerling chinook salmon. It was again pointed out that the yellow perch frequented slack water (Dahle 1979), and studies in 1994 corroborated this statement.

Yellow perch are also present in small private ponds near Copco (pers. comm. from State biologist D. Maria), Lost River near Tulelake, Siskiyou County, and in irrigation canals east of Tulelake in Modoc County (Coots 1956). Yellow perch were also found in Greenhorn Reservoir, near Yreka in Siskiyou County, apparently as a result of an illegal introduction. This population was eliminated by a 1986 rotenone treatment. State biologist E.R. Gerstung (5 December 1994 pers. comm.) identified a 10-inch, angler-caught yellow perch from Rodeo Lagoon in Marin County in 1960. A specimen recorded in 1968 at the John E. Skinner Delta Fish Protective Facility was probably misidentified.

The yellow perch obviously has its devotees among the angling fraternity, some of whom are apparently responsible for at least two fairly recent examples of illegal introductions. Most notable is the presence of a reproducing population of yellow perch in Lafayette Reservoir, Contra Costa County. It was first discovered there in 1984 by fishery biologists of the Department of Fish and Game and the East Bay Municipal Utility District using gill nets and electrofishing gear. Nine perch were collected in May 1984, and additional perch have been collected during subsequent periodic collections into the early 1990s. They are definitely established, but make up only a small fraction of the total warmwater game fishes present. They ranged from about 4.5 to 6.5 inches FL. The Department gave serious consideration to a chemical eradication program to prevent the escape of yellow perch to other waters, particularly those of the Delta. However, the treatment was canceled because of difficulties associated with water use and manipulation, anticipated strong public opposition, and the relatively small perch population.

Another discovery came early in 1990 when the Department chemically treated a large irrigation pond on the Lake Shastina Golf Course in Siskiyou County as part of a grass carp removal program (see the section on grass carp). Two yellow perch were recovered, along with 113 grass carp and various centrarchids.

We expect the yellow perch to gradually expand into additional California waters via illegal releases by anglers.

4.50. Bigscale logperch, Percina macrolepida Stevenson

The bigscale logperch of south central North America (Oklahoma, Texas, and northeastern Mexico) was introduced into California inadvertently by the U.S. Fish and Wildlife Service with a shipment of largemouth bass, bluegill, and possibly black bullhead sometime in 1953. According to a personal communication by M.M. Stevenson in Moyle (1976b), these fish were from the Trinity River in Texas. They were planted in three artificial lakes (Miller, Blackwelder, and Polk) located on the Beale Air Force Base, Yuba County, in the Sacramento River drainage.

The attention of the Department of Fish and Game was drawn to their presence by A. Musseldine of the U.S. Fish and Wildlife Service who took several specimens from these lakes early in March 1958. On 27 March 1958, State biologists J.B. Kimsey, G.W. McCammon, and J.B. Richard seined about a dozen logperch from Miller and Blackwelder lakes where they found breeding populations. As both lakes overflow regularly, it seemed quite possible that the species was now resident in other drainages.

The first notice of this occurrence was by Shapovalov et al. (1959) who termed the fish "Percina caprodes (Rafinesque)." McKechnie (1966) also recorded this occurrence but provided no reference to it and not as much detail concerning it as did the foregoing authors. Since that time, Stevenson (1971) has described the bigscale logperch from Texas, and subsequent examination of the California specimens from the Sacramento River and Sacramento-San Joaquin Delta by Sturgess (1976) revealed them as P. macrolepida-rather than P. caprodes. The distinction in identity was noted by Shapovalov et al. (1981) in their next list.

Meanwhile, Farley (1972) reported that an adult logperch had been seined from a drainage canal east of Fresno Slough in the Mendota Wildlife Area on 20 December 1971, and that logperch had been reported from the California Aqueduct near Tracy in the spring of 1970. Both areas are within the San Joaquin River drainage area, hence the California range of *Percina* had been extended southward.

Extension of the logperch's California range was also described by Moyle et al. (1974a). A logperch was found in Cache Creek near Capay on 2 August 1972, and logperch were seined in Putah Creek on 20 July and 9 October 1973 and reported to have been collected there at other times. Both streams are tributary to the Sacramento River, and a map (Figure 1 in Moyle et al. 1974a) showed records of the species in the lower River although no details were given in the text.

Moyle et al. (1974a) also reported the logperch to be abundant in Del Valle Reservoir, Alameda County, saying that the fish was presumably pumped into the Reservoir from the Sacramento-San Joaquin Delta via the Tracy pumping plant and the South Bay Aqueduct. They concluded by saying that their information indicated that the logperch was well established and widespread in the lower Sacramento-San Joaquin River system. The logperch has also been transported southward to Castaic, Pyramid, and Silverwood lakes in southern California in 1988 and to Irvine Lake in 1990, where it is apparently established (Swift et al. 1993).

A northward spread of the bigscale logperch was documented by Boles (1976) who made collections of the species during the spring of 1974: Feather River near Oroville, and north of its mouth; the Sacramento River just south of the Sutter Bypass; an irrigation canal on the M & R Gun Club near Butte City; Hutchinson Creek west of Plumas Lake; Best Slough and Dry Creek about ½ mile from their junction with Bear River; Miller and Blackwelder lakes. He also reported it taken in Butte Creek, the Yuba River near Honcut, and at Wilson Landing on the Sacramento River northwest of Chico (September 1975). Boles (1976) also pointed out that the dispersal route from the artificial lakes where it was originally planted was not as had been suggested by previous authors, i.e. via Hutchinson Creek to Dry Creek and thence to the Yuba River. He suggested routes (based on his better knowledge of the drainages) via the Bear River to the Feather (and hence to the Sacramento). The bigscale logperch seems to be expanding its populations and is expected to become abundant throughout the lower Sacramento-San Joaquin drainage particularly in the slower, muddier areas.

In a brief review of the species, McKechnie (1966) said, "Log perch add nothing to our fauna and do not benefit our [Californian] fisheries." This is true. Its small size precludes its being a game fish, and it is seldom used as forage for game fish. Interestingly enough, Moyle (1976b) said, "... their populations seem to be depleted in at least part of their native range...so the California populations may be able to serve as a source for their reintroduction into native streams at some future date." This statement is reminiscent of the thoughts of some of the early workers of the State Fish and Game Commission, namely that a shad hatchery should be set up in California primarily to raise fish to ship back to one of their native states.

4.51. "Tilapias" in general

The introduction of "tilapias" (hereafter referred to simply as tilapia) in California stems primarily from the use of several species of these cichlids for the control of nuisance aquatic weeds and insects, especially in southern California canals and drains. Their initial introduction into California, unlike the introduction of most fishes, was not to establish breeding populations of food and/or game fishes but to provide a biological "tool." Fishery biologists (i.e. individuals concerned with the management of fishes by man) have not, therefore, been the primary instigants of the introduction of these fishes. They have, however, studied tilapia both in defense of their actions concerning other fish life and, in some cases, to ascertain their use as food or game fishes. Several agencies have been involved and sometimes there has been conflict between them.

Aquaculturists have also been active in the importation of tilapia stocks for their use, and tilapia are sold in California restaurants and markets. Tilapia have also been introduced into California waters by aquarists. In some cases, the introduction has been inadvertent (see the account of the 1964 introduction of the Mozambique tilapia into waters near the Salton Sea). In other cases, aquarists have "dumped" their former pets into public waters. Tilapia have also been transferred from one water to another by anglers.

The entire question concerning tilapia in California has become very complex, and will not be reported here. It is necessary, however, to understand a few basic facts concerning the group. Tilapia all belong to the family Cichlidae, which is primarily native to Africa, Asia Minor, and Central and South America. Some of them have been used as food fish; some as aquarium fish. Fish culture using tilapia started in Africa circa 1946, and in the early 1950s received considerable attention in both the scientific and popular press. Numerous species were used, but worldwide attention was focused on Tilapia mossambica. Although there were some early critics of their dissemination (e.g. Myers 1955 and the Food and Agriculture Organization in an article by Drake 1955), tilapia were extensively planted in areas far from their native home (e.g. Malaysia, India, and Haiti). Their use as food fish easily cultured in small ponds by villagers was extensively prosecuted in their native lands in Africa primarily because of promotion by colonialists. Furthermore, the became the subject of considerable study as cultivated fish (e.g. in Malacca, Malaysia), and used as pond fish in areas where science went hand in hand with pond fish culture (e.g. in Israel). Excellent accounts of the spread of tilapia culture are those of Atz (1954, 1957).

The use of these fish also attracted considerable attention when it was announced that fertile but exclusively male offspring could be obtained from the crossing of Tilapia mossambica with T. urolepis and, when hybrids were not obtainable, that cichlid monoculture (exclusively of one sex) might be practiced.[123]

Tilapia were also the basis of wild commercial fisheries in parts of Africa (e.g. Lake George in Uganda and Lake Victoria) and caught by anglers in various countries. Their habits were studied extensively by scientists like R.H. Lowe-McConnell. Detailed information on their biology and evolution is found in the classic treatise on the cichlid fishes of the great lakes of Africa by Fryer and Iles (1972).

Furthermore, tilapia became the subject of exhaustive taxonomic research, especially by ichthyologists like E. Trewavas of the United Kingdom and D.F.E. Thys van den Audenaerde of Belgium. This resulted in first a proposal by Trewavas (1973) to replace the name Tilapia with Sarotherodon, mainly for the mouth-brooding

[123] It should be noted that tilapia have a tendency to overpopulate ponds and stunt, so that it is often useful to curtail their reproduction through monoculture, either through the method just described, or through manual sexing or hormonal treatment prior to stocking (Guerrero 1979).

species, and a later proposal by Trewavas (1982) to separate the East African maternal mouthbrooders from Sarotherodon and to designate these as Oreochromis. We have chosen, however, to follow the rationale and practice of the American Fisheries Society for retaining Tilapia as the generic name for all species of tilapia (Robins et al. 1980, 1991), knowing full well that this will not meet with the approval of many systematists or aquarists.

In the United States, extensive research on the various species of tilapia was carried out, especially at Auburn University in Alabama. Tilapia were used as food, for aquatic weed control, as sport fish, and as experimental animals.

In short, there was an era of "tilapiamania," reminiscent of the Dutch "tulipomania" of the 17th century. Tilapia, no matter what one called them scientifically, were considered the wonder fish of the world. Small surprise then that they were introduced into the warmer areas of the United States and, especially in view of the "natural" or ecological concepts of the day, considered by many agencies for the control of nuisance aquatic weeds and insects. Nevertheless, as early as 1970, Lachner et al. (1970) felt that "The Tilapia problem may be one of the worst fish cultural blunders in the United States since the introduction of the carp."

As part of this "frenzy," and particularly because of their introduction into Arizona waters, the California Department of Fish and Game felt it essential to prepare for management of these cichlids, especially Tilapia mossambica, if and when they appeared in California waters. Aims of this program included the possible impacts of tilapia on the established ichthyofauna of southern California, the possibility of their production for aquaculture, and their beneficial utilization for sport, forage, and control of aquatic vegetation and insects. St. Amant (1966b) described in detail the first work of the Department of Fish and Game during the period December 1963–May 1966.

Prior to this time, however, Tilapia mossambica was brought to California and transported to the Chino Fisheries Base of the California Department of Fish and Game from the Arizona Cooperative Wildlife Research Unit in Tucson. It was explained that it would be studied to estimate its usefulness as a forage fish, game fish, and as a control for aquatic plants and midge larvae (OC 1964).

Aside from this study, the California Department, or some of its members, was quite open in considering the possibility of using tilapia for angling. For example, both State biologists J.B. Kimsey and P.A. Douglas were interested in the possible introduction of tilapia to some of the southern coastal lagoons with variable salinities (letter by P.A. Douglas to W.A.D., 11 January 1956). Calhoun (1967) stated that the Department was exploring the possibility of tilapia being reared cheaply for stocking in small, heavily fished urban lakes in summer, and Arnett (1970, p. 2) was quite cognizant of the fact that tilapia could promote angling.

In 1971, the California Fish and Game Commission authorized the introduction of three species of tilapia into California for experiments in insect and aquatic weed control (Pelzman 1973a). It is now (1996) believed that at least five species of tilapia are established in southern California. These have been identified as Tilapia mossambica, T. Zilli, T. urolepis, T. nilotica, and T. aurea, and their history in California is fairly well known (see the specific accounts in this paper concerning them). Nevertheless, the nomenclature of the introduced cichlids in California is not at all certain and there has been disagreement among "authorities" concerning it.

Several species and hybrids have been omitted from the descriptions in this report because we were unsure of their identifications, and they were not included in official lists (Robins et al. 1980, 1991; Courtenay et al. 1984, 1991). These include Barrett's (1983) tentative identification of the redbreast tilapia (Tilapia rendalli) from near Blythe, Riverside County, and T. guineensis which was identified by D.F.E. Thys van den Audenaerde from specimens collected from the north end of the Salton Sea (8 August 1975 letter to C.C. Swift). Finally, Lopez and Ulmer (1983), from samples collected in the Palo Verde Valley of Riverside County, described five pure species and ten possible hybrids, but admitted to identification problems.

It is apparent that a status survey of California tilapia populations is long overdue and should incorporate identifications using the latest scientific methods. A first effort was reported by Costa-Pierce and Doyle (1996) who applied modern genetic procedures to several collections of tilapia from the wild and from aquaculturists in southern California. They claimed that the usual morphometric and meristic measurements were inconclusive and unsuitable in identifying species and hybrids, since the founder tilapia populations of southern California were small and possibly introgressed and hybridized. Using DNA marker studies, they determined three distinct "ecotypes" of southern California tilapias: i) Salton Sea ecotype—an apparent hybrid of Tilapia urolepis hornorum x T. mossambica found in the Salton Sea and in ditches in Niland; ii) Mozambique ecotype—a T. mossambica found in the San Gabriel River; and iii) Niloticus ecotype—a T. nilotica found in the Colorado River near Blythe. This was an excellent beginning, but much more needs to be learned.

We do know that tilapia have invaded the waters of southern California, that they are more tolerant of cold temperatures than was originally thought, and that certain hybrids are not as sterile as originally thought. Evaluation papers on the desirability for California of T. sparrmani (Pelzman 1972) and T. zilli (Pelzman 1973a) demonstrated the interest and concern about this group of fishes by the Department of Fish and Game.

In general, we regret their original introduction and do not approve of their continued dissemination. However, tilapia are here and keeping them confined to their present localities which are primarily south of the Tehachapi Mountains is about all we can do at the moment.

4.52. Blue tilapia, Tilapia aurea (Steindachner)

The original range of the blue tilapia coincides with the Nile, Senegal, and Niger river systems of Africa and the Jordan Valley of Syria. It has been widely introduced in North America because of its value as an aquacultural species (Shelton and Smitherman 1984). For many years it was misidentified as the closely related Nile tilapia (T. nilotica) ; Trewavas (1965) first recognized the two species as distinct.

The original introduction and spread of the blue tilapia in North America is not accurately documented. This species first arrived in the United States in 1957 at Auburn University in Alabama from Israel primarily for aquacultural research but also to assess its potential as a sport fish (Swingle 1960). It was, however, introduced as the Nile tilapia.

Minckley (1973) reported that tilapia were introduced into the lower Colorado River in the early 1960s and immediately began to spread throughout the numerous canals and backwaters. In 1964, T. aurea, again erroneously termed T. nilotica, was reported at the Arizona Game and Fish Department's Page Springs Hatchery. The Arizona Cooperative Fisheries Research Unit stocked offspring of this species plus various hybrids among T. mossambica and T. zilli in cattle-watering tanks and other waters in southern Arizona (Minckley 1973; Barrett 1983).

T. aurea is now the dominant tilapia in Arizona having replaced the T. urolepis hornorum x T. mossambica hybrid that formerly held sway in the lower Colorado River below Laguna Dam (Barrett 1983; Courtenay et al. 1986). As far as we know, pure blue tilapia are not present in the Salton Sea or in the canals and drains of the Coachella, Imperial, or Bard valleys.

Because of its value to the aquaculture industry, the Department and the Fish and Game Commission permit its use in California but only under restrictions designed to prevent escape into public waters. Use is limited to aquaculture facilities south of the Tehachapi Mountains and only to those operations whose water supply is controlled and recirculated. Only processed fish may leave the facility. Two such aquaculture ventures were so authorized in 1992.

Unless use in aquaculture is carefully controlled, escape of the blue tilapia into public waters may lead to unfavorable consequences for sport fish. It poses greater danger in this regard because it is more cold tolerant than most other species of tilapia (Chervinski 1982).

4.53. Mozambique tilapia, Tilapia mossambica (Peters)[124]

The native range of the Mozambique tilapia is the eastward-flowing rivers of Africa, from the lower Zambezi and Shire systems in Mozambique southward in coastal drainages to Algoa Bay in South Africa. The Mozambique tilapia and the

[124] Known to many as Oreochromis mossambicus (Peters).

Wami tilapia (Tilapia urolepis) are closely related, similar in appearance, and hybridize readily. Trewavas (1968) first recognized them as distinct species.

The first verified record of this well-known cichlid in open waters in California was made by State biologist J.A. St. Amant. On 3 January 1964, he observed it in a small pond and its tributary 5 miles north of the Salton Sea in Imperial County, and believed that it had come from a tropical fish farm located directly below the pond. (The identification was made by a number of competent authorities.) Although attempts were made to eradicate the population with rotenone (over 5000 fish were killed), follow-up trips on 2 and 16 June 1965 disclosed the presence of more tilapia in the pond drainage (St. Amant 1966a). Shapovalov et al. (1981) said that this population might no longer exist.

The next published record of free-living tilapia of this species in California appears to be that of Hoover and St. Amant (1970). Mozambique tilapia (identified by E. Trewavas and C.L. Hubbs) were found in the Araz Drain in July 1968 and the Reservation Main Drain in July 1968 and during the period of February–June 1969. Both drains are in Bard Valley, Imperial County. It was the belief of those authors that the tilapia found in Bard Valley had been self-supporting for some six years and had originated from fish in the Yuma Canal system planted by the Arizona Game and Fish Department. They anticipated further dispersal of this species in southern California.

Isolated populations of T. mossambica have been reported from canals and drains in the Imperial Valley, Imperial County, where there are about 3000 miles of irrigation and drainage canals, and the Coachella Valley, Riverside County. There were abundant reproducing populations in Lake Elsinore, Riverside County, and the Salton Sea (Shapovalov et al. 1981). However, they may no longer be found in Lake Elsinore. Courtenay et al. (1986) stated that it was the dominant fish in the Salton Sea in terms of biomass. The popular article by Karr (1986) contains a number of errors, but provides a spirited account of fishing for "tilapia" in the Salton Sea where individuals over 4 lb were reportedly taken. The DNA marker studies employed by Costa-Pierce and Doyle (1996) showed that tilapia collected from the Salton Sea and ditches in Niland were likely hybrids of Tilapia urolepis hornorum x T. mossambica.

Minckley (1982) recorded its presence in the lower Colorado River under the name of Sarotherodon mossambicus or mossambica. According to Barrett (1983), examination of specimens from the Colorado River showed that Tilapia mossambica and T. urolepis hornorum have hybridized to a great extent and are essentially one reproducing population. He identified only a few individuals as either T. mossambica or T. u. hornorum. This hybrid complex was widespread in the lower Colorado River of Arizona and California, but has been largely replaced by T. aurea (Barrett 1983). To test their potential as game fish, the Department stocked these hybrids in the late 1960s in Wiest Lake, Imperial County, and Lake Jennings, San Diego County (Hoover 1971). Low water temperatures apparently prevented their establishment.

The Mozambique tilapia has also established populations in a series of water-courses entering the Pacific Ocean in Los Angeles and Orange counties. Knaggs (1977) described a personal communication from State biologist F. Hoover attesting to the 1973 release of T. mossambica at a number of freshwater locations in southern California. "Several of these locations were within the Pacific slope drainage and during certain times access to the Pacific Ocean was available to these fish."

One of the introductions that led to the establishment of T. mossambica in coastal waters was reported by Legner and Pelsue (1977) and Legner et al. (1980). They described the addition in 1972 of three species of tilapia to the Coyote Creek drainage in the Los Angeles basin to abate chironomid midge problems. The drainage is actually a concrete-paved channel. By the end of the year, the redbelly tilapia (T. zilli) had disappeared, whereas T. mossambica, T. urolepis hornorum, and their hybrids had reproduced and spread out over the entire paved channel. Year around warmwater discharge from an electrical power generating plant permits tilapia to survive in Coyote Creek.

Knaggs (1977) described the first large-scale collection of T. mossambica from the estuarine portion of the San Gabriel River in 1974 (Coyote Creek is tributary to the San Gabriel River). He described a breeding population of T. mossambica from the cement-lined Los Cerritos Flood Control Channel in Long Beach, Los Angeles County, in 1976. It is only about ½ mile from the San Gabriel River estuary. He also reported another breeding population from the Colorado Lagoon in Long Beach in 1976, about 2½ miles west of the San Gabriel River. Since anglers fishing from public piers in the ocean at Seal Beach and Long Beach occasionally take T. mossambica, it appears that this species can move along the coast colonizing suitable freshwater and estuarine habitats. Anglers may also be responsible for the spread of tilapia in coastal waters.

The most recent collection of Tilapia mossambica from coastal waters, 20 specimens from the San Gabriel River, was described by Costa-Pierce and Doyle (1996). Using DNA marker studies, these authors concluded that genetic bottlenecks plus introgression with T. urolepis hornorum put the long-term sustainability of T. mossambica as a distinct species in southern California in doubt.

The first known free-living occurrence of the Mozambique tilapia in California north of the Tehachapi Mountains was at High Rock Spring in Lassen County. Its introduction for commercial aquaculture was approved by the Department of Fish and Game and shipments of T. mossambica from an Idaho grower were received on two occasions in 1983. Unfortunately, tilapia escaped their confines and occupied the spring and downstream channels where they were apparently responsible for the extinction of the High Rock Spring tui chub, Gila bicolor ssp., an undescribed dwarf form of *G. bicolor* (Moyle et al. 1995). The tilapia have since been eradicated by the aquaculturist who is now culturing channel catfish at the site (State biologist P. Chappell, 23 october 1995 pers. comm.).

This was believed to be the only occurrence of Mozambique tilapia in northern California until 30 August and 4 September 1989 when two cichlids identified as Oreochromis mossambicus were seined from a mud-bottomed pond in Lake Success, a reservoir in Tulare County. It is not known how the fish gained access to the reservoir, and the authors hoped that low water temperatures during the winter would prevent it from becoming established (Heyne et al. 1991). A second finding of the Mozambique tilapia in northern California, this time in the Delta, has recently surfaced (State biologist K. Laur, 6 February 1995 pers. comm.). Anglers fishing in Mormon Slough, San Joaquin County, have apparently been harvesting this species for several years. An angler with 30 tilapia taken in October 1994 contacted the Bay-Delta Division office of the Department of Fish and Game in Stockton. Identification was confirmed by P.B. Moyle. The population is evidently established, and its overwinter survival may involve a warm-water discharge of some type. Origin of the tilapia is unknown but a deliberate angler release is suspected.

The role of the Mozambique tilapia in aquaculture is primarily that of a hybrid with other species, particularly the Wami tilapia. When male T. urolepis hornorum are crossed with female T. mossambica, all male or nearly all male offspring are produced (Wohlfarth and Hulata 1981; Shelton and Smitherman 1984). The hybrid is known as the red tilapia and is very popular in the aquaculture industry.

Aside from its use in aquaculture, the Mozambique tilapia and its hybrid with the Wami tilapia have little future in California. The Mozambique tilapia may help control noxious aquatic insects (Hauser et al. 1976), but it is apparently no longer used for that purpose. The decreased interest is due to growing concern about the impacts of tilapia on sport fishes and native nongame fishes (Knaggs 1977; summary by Taylor et al. 1984).

The Mozambique tilapia, or its hybrid with either the Wami or the blue tilapia, is firmly established in the warmer waters of southern California where it has supported a large and popular sport fishery in the Salton Sea and lesser fisheries in canals and drains surrounding the Sea, in a few lakes and ponds, and in drains entering the ocean in Orange and Los Angeles counties. Nevertheless, the Department of Fish and Game has no plans to extend the range of any tilapia in southern California. Illegal releases or movement of fish from one coastal drainage to another via the ocean may eventually lead to range extensions.

4.54. Nile tilapia, Tilapia nilotica (Linnaeus)

The Nile tilapia is native to the Nile River drainage in East Africa and the Congo, Senegal, and Niger River drainages in West Africa.

Adding to the general taxonomic confusion among tilapia species is the difficulty in separating Tilapia aurea or blue tilapia from T. nilotica. For years, the former was misidentified in Israel as the latter (Wohlfarth and Hulata 1981). Apparently they are closely related species that are sympatric in parts of their native ranges. Trewavas (1965) first recognized the two species as distinct.

Until the recent studies by Costa-Pierce and Doyle (1996), the status of the Nile tilapia in the United States was uncertain since establishment in the wild had yet to be confirmed (Robins et al. 1980). Also, the Nile tilapia was excluded from the Courtenay et al. (1991) list of exotic fishes established in the continental United States. Courtenay et al. (1986), however, noted that T. aurea and perhaps a hybrid with T. nilotica were established and locally dominant in the lower Colorado River below Laguna Dam. Barrett (1983) showed that T. aurea specimens exhibit evidence of T. nilotica genes. Finally, and just recently, Costa-Pierce and Doyle (1996) collected 20 T. nilotica from the Colorado River at Blythe, California. The determination was made using DNA marker studies. They noted that its presence here "... implies that the species and its hybrids may be distributed in irrigation and drainage canals in the eastern part of the State." The origin of these fish is unknown. Because of their similarity in appearance, however, it may be that T. nilotica was introduced into Arizona waters at about the same time as T. aurea (see the section on the latter species). Barrett (1983) alluded to this possibility. Thus, the route of T. nilotica from Arizona into the lower Colorado River of California may mirror that of T. aurea.

The Nile tilapia is actively cultured commercially in the United States. Tave and Smitherman (1980) noted that the Auburn University stock of Nile tilapia came from Brazil in 1974, and that the Brazilian stocks came from the Ivory Coast in 1971. This may have been the first release in the United States. Shelton and Smitherman (1984) stated, "The tilapias of principal interest for aquaculture in the United States and throughout much of the world are T. nilotica and T. aurea. ..."

Its use in aquaculture is the only role available to the Nile tilapia in California, and, in fact, it has been eradicated from some aquacultural ponds (letter of State biologist K. Nicol to Department of Fish and Game, Region 5, 22 August 1988). The Department and the Fish and Game Commission restrict such use for aquaculture to operations south of the Tehachapi Mountains and only at those facilities with controlled recirculating water supplies. All fish must be processed before leaving the facility. Two such operations have been authorized by the Commission. Their T. nilotica stock was obtained either from the Philippines or an African source.

4.55. Wami tilapia, Tilapia urolepis Norman

The native range of the Wami tilapia is Zanzibar, a large island off the coast of Tanzania in East Africa, and the Wami River drainage on mainland Tanzania opposite Zanzibar (Trewavas 1968).

Formerly designated Tilapia hornorum Trewavas, this species should now be named *T. urolepis* Norman (Robins et al. 1991), and the subspecies from California identified as T. u. hornorum (Courtenay et al. 1991). The hybrid form (T. mossambica x T. urolepis) is a common aquacultural fish called the red tilapia. The closely related T. u. hornorum and T. mossambica are very similar in appearance. For many years the former was considered the Zanzibar strain of the latter, which was termed the Java strain; the hybrid offspring was known as the Malacca hybrid (McConnell 1966; St. Amant 1966b). The two species were first recognized as distinct by Trewavas (1968).

According to Legner and Pelsue (1977), prior to the 1970s, T. urolepis hornorum and T. mossambica were found in the warmer waters of the Colorado Desert in Imperial and Riverside counties. Using tilapia cultures from the University of Arizona (Tucson), both species were reared at the University of California at Riverside and stocked in the early 1970s in paved drainage channels and recreational lakes in the south coast basin. "Dissemination of these fish expanded as private and public organizations in California subsequently obtained stocking permits to distribute them for weed and insect control.... By 1974 *Tilapia* population densities noticeably had increased in most areas where stocking had been made during the three previous years" (Legner and Pelsue 1977).

The DNA marker studies employed by Costa-Pierce and Doyle (1996) showed that tilapia collected from the Salton Sea and ditches in Niland were likely hybrids of T. urolepis hornorum x T. mossambica.

The Wami tilapia is also established in coastal drainages. "This fish is probably established in California in the Bolsa Chica Flood Control Channel in Huntington Beach, Orange County. It, or a hybrid with T. mossambica, is established in the Cerritos Flood Control Channel, Cerritos Lagoon and the Coyote Creek-San Gabriel River drainage, Long Beach, Los Angeles County...." (Courtenay et al. 1986, p. 697). Because of similarity in appearance, some of the T. mossambica identifications may actually be T. u. hornorum or hybrids of the two. See the species account of the former in this paper since the descriptions may represent the latter or their hybrids.

Aside from its potential role in commercial aquaculture, the Wami tilapia is not expected to achieve further use in California.

4.56. Redbelly tilapia, Tilapia zilli (Gervais)

The native habitat of the redbelly tilapia is the lakes and streams of northern and central Africa east to Jordan. It is a substrate spawner that guards its eggs in contrast with other tilapia species established in California which are maternal mouthbrooders (Fryer and Iles 1972).

The redbelly tilapia was one of the three species of tilapia authorized by the California Fish and Game Commission in 1971 for use in California (Pelzman 1973a). During the late 1960s and early 1970s, it was stocked in several ponds in central California and in numerous waters in southern California for mosquito, midge, and aquatic weed control, largely on an "experimental" basis (Legner and Medved 1973; Pelzman 1973a; Hauser 1975). For example, in 1971, the California Department of Fish and Game granted permission to the Imperial and Coachella Valley Irrigation districts to introduce T. Zilli, and hundreds of thousands have been released into their waters. Although it has long had a reputation for enduring relatively cold water, it was assumed that the species could not survive winter temperatures in California except for the very southeastern portion of the state, and that fish would have to be introduced periodically in order to achieve weed control. However, it was found that the species could overwinter even in central California ponds until killed by the exceptionally cold winter of 1972–73. The Commission then (1974) placed the redbelly tilapia on the prohibited species list (Section 671 of Title 14, California Code of Regulations) for all of the state north of the Tehachapi Mountains, and now it is not known from the northern part of the state.

Legner and Pelsue (1977) further elucidated the early history of redbelly tilapia introductions into southern California. Prior to the 1970s, the University of California (U.C.) at Riverside and at Davis, with funding from water and mosquito abatement districts, established isolated colonies of Tilapia zilli, T. Mossambica, and T. urolepis hornorum which were studied for aquatic weed and insect control. The central California colonies died out as did the southern California populations of T. zilli, but populations of T. urolepis hornorum persisted in certain warm waters in Imperial and Riverside counties. New cultures of the three species were obtained from the University of Arizona and held at U.C. Riverside for further studies (Legner and Pelsue 1977). The Arizona culture of T. zilli originated from three reproductive pairs imported from Israel in 1965 (Legner and Fisher 1980).

The first successful releases of *T. zilli* apparently occurred in 1971 in the Imperial Valley by the Department of Fish and Game from fish obtained from U.C. Riverside and reared at the Department's Chino Fisheries Base. They reproduced and became established in drains entering the Salton Sea in Imperial County (Legner and Pelsue 1977). To combat aquatic weed problems, subsequent releases were made in the mid to late 1970s in canals and drains in the Coachella Valley and similar waters in the Imperial Valley (Legner and Fisher 1980). The warmer waters of the drains facilitated reproduction in contrast with the colder canal waters where annual releases of *T. zilli* were required. For example, despite the release of many thousands of *T. zilli* in the main Coachella Canal during the late

1970s, only six were recovered out of 9100 fish collected during a major sampling program carried out in November 1980 (Minckley et al. 1983). The burden of annual stockings and inadequate weed control led the Coachella Valley Water District and Imperial Irrigation District to select the more efficient and cold-tolerant grass carp (Ctenopharyngodon idella) over Tilapia zilli, and tests and release of the latter species ceased.

Shapovalov et al. (1981) referred to populations of T. zilli existing in certain canals and ditches in Bard Valley, four backwaters of the Colorado River downstream from the Palo Verde Diversion Dam, and in Lake Cahuilla, Riverside County. The status of these populations is unknown. Similarly, Barrett (1983) identified specimens of T. zilli from the lower Colorado River and its backwaters, and from Senator Wash Reservoir in Imperial County.

Stocking in southern California has resulted in the permanent establishment of T. zilli and the likelihood of further spread (Moyle 1976b; Courtenay et al. 1986). It was abundant and breeding in the agricultural drains entering the Salton Sea (Black 1980; Lau and Boehm 1991). However, Black (1980) and Lau and Boehm (1991) did not distinguish the species of tilapia collected in their surveys. Other collections of lesser scope identified T. zilli from individual drains (Schoenherr 1979, 1981, 1985) and from Salt Creek in Riverside County, a natural tributary of the Salton Sea (Schoenherr 1992). T. zilli is believed to be the dominant tilapia in the drains, whereas T. mossambica is apparently the dominant tilapia in the main body of the Salton Sea (Shapovalov et al. 1981; Swift et al. 1993). Schoenherr (1988) noted that the T. mossambica in San Felipe Creek had moved upstream from the Salton Sea.

Although T. zilli is common in the warmer waters of the irrigation drains entering the Salton Sea, it has not colonized coastal waters. Despite their salinity tolerance (Stickney 1986), tilapia have invaded local estuaries only in highly modified channels where power plant effluent keeps the water warm (Swift et al. 1993). Knaggs (1977) described collections of T. zilli from the marine environment. The first captures came from marine waters during a heat treatment at the Huntington Beach electric generating plant in Orange County on 7 December 1974. One specimen of T. zilli was taken in 1976 in Upper Newport Bay. Swift et al. (1993) noted that the Huntington Beach collection took place after heavy winter rains. In 1972, mosquito abatement districts stocked thousands of T. zilli in Coyote Creek, Los Angeles County, a paved coastal drainage channel, but they did not persist (Legner and Pelsue 1977; Legner et al. 1980). The lack of subsequent collections indicated that T. zilli had not established breeding populations in coastal marine and estuarine areas.

Although they did not collect T. zilli, Costa-Pierce and Doyle (1996) surmised that populations of this species in southern California are in a state of decline and will eventually disappear. They attributed this to "... a restricted genetic basis (three reproductive pairs were imported), presenting a severe genetic bottleneck and restricting the environmental adaptability of the species."

T. zilli is clearly an undesirable exotic species. Studies indicate that it is at least partially responsible for the decline in native desert pupfish populations in and around the Salton Sea (Black 1980). Schoenherr (1988) referred to observations by other scientists that elucidated the behavioral interactions that allow Tilapia zilli populations to displace desert pupfish populations. The latter fish has been listed as "Endangered" by both the State and Federal governments. However, despite the continued presence of Tilapia zilli and the sailfin molly, another introduction implicated in the decline of the pupfish (Schoenherr 1988), the desert pupfish has experienced a resurgence and is now much more abundant in the drains and the shallow margins of the Sea (Lau and Boehm 1991). However, Schoenherr (1992, 1993, and 26 September 1994 pers. comm.) found that the recovery of desert pupfish in certain Salton Sea drains and shoreline pools in 1991 and 1992 was correlated with the virtual elimination of Tilapia zilli from these habitats during the long period of unusually cold weather in the winter of 1990–91. By 1994, *T. zilli* had recovered and the threat to the desert pupfish continued.

Referring to a personal communication from J.E. Williams, Courtenay et al. (1986) reported that Tilapia zilli was introduced in January 1983 into High Rock Spring in Lassen County. However, Department of Fish and Game personnel examined each fish in the approximate 1000-fish shipment to guard against the prohibited T. zilli. Only one was discovered and removed, the remainder were T. mossambica, which had been approved for aquaculture purposes. A second shipment in June 1983 may not have been similarly inspected, but probably again consisted almost entirely of T. mossambica.

The redbelly tilapia is unwelcome in California. It has potential in the control of nuisance aquatic weeds and insects (Hauser et al. 1976; Legner and Fisher 1980), but apparently is no longer used for these purposes.[125] The grass carp (sterile triploid variety) is the current weed eater of choice in southern California, but its use on an operational scale is limited to Imperial, Riverside, and San Bernardino counties. (It may be used elsewhere, but only for research purposes and only with approval from the Fish and Game Commission.) The potential contribution of the redbelly tilapia to sport fishing and aquaculture is limited and cannot be justified in light of its suggested impact on native fishes.

[125] Legner and Fisher (1980) said that the two principal aquatic weeds in California irrigation canals are sago pondweed (Potamogeton pectinatus) and Eurasian milfoil (Myriophyllum spicatum var. exalbescens)).

4.57. Yellowfin goby, Acanthogobius flavimanus (Temminck & Schlegel)

The euryhaline yellowfin goby is native to China, Japan, and Korea. The first specimen to appear in California was taken on 18 January 1963 by personnel of the Department of Fish and Game in a midwater trawl in the San Joaquin River off Prisoners Point. The second specimen was collected, again by personnel of the Department, in an otter trawl on 29 March 1963 in the Stockton Deepwater Channel just above the entrance of the Calaveras River (Brittan et al. 1963). The authors felt that it might have been introduced via a ship's seawater system partially clogged with fouling organisms. They also prophesied correctly that this goby might establish a substantial population throughout the Sacramento-San Joaquin Delta and San Francisco Bay region.

During the next few years, a few more specimens were taken in the Bay and Delta region including a collection in fresh water at a wasteway on the Delta-Mendota Canal. Then a truly explosive spread of this goby became apparent. By 1966 it had become common throughout all of San Francisco Bay and the Delta, had been found in the fresh water of San Luis Reservoir, Merced County, and by 1968 had progressed up the Sacramento River at least as far as the city of Sacramento. Meanwhile, a single specimen was found in Bolinas Lagoon (well separated from San Francisco Bay) in December 1967. Possibly it reached the lagoon through migration but more likely by transfer as a bait fish or in discharged coolant water (Brittan et al. 1970). After the preceding authors reported upon its spread, the goby was collected in Elkhorn Slough, Monterey County, on 17 July 1970, 13 July 1971, and 8 October 1971 (Kukowski 1972). Miller and Lea (1972) recorded it as far north as Tomales Bay.

Strangely enough, the yellowfin goby was also established in the Los Angeles-Long Beach Harbor and vicinity; Newport Bay, Orange County; and the San Gabriel River at least as early as 1978 (Haaker 1979). Swift et al. (1993) described collections from coastal lagoons and marshes in southern California. C.A. Usui (pers. comm.) reported this species at least as far south as San Diego and perhaps to Baja California Norte in 1980 (Courtenay et al. 1986).

Obviously, all theories as to its introduction are conjecture. Moyle (1976a), for example, stated quite conjecturally that both it and the chameleon goby originated in Japan. Its scattered occurrence in California hints at multiple introductions. We know only that the yellowfin goby can endure both pure fresh water and sea water, temperatures between 11° and 28.3° C, and is well established in estuarine and some freshwater areas of California. Its small size restricts its use to that of a bait fish.

4.58. Shimofuri goby, Tridentiger bifasciatus Steindachner Chameleon goby, Tridentiger trigonocephalus (Gill)[126]

As for the green sunfish and bluegill and the two crappies, these two gobies must be discussed together because the historical records of their introduction into California are confusing. Both species are native to Asian estuaries. For example, the chameleon goby is native to marine and brackish waters from Hong Kong to the Amur River Basin, Russia, and the Japanese Islands.

There is an overlap in the salinity ranges of these species and in Japanese estuaries they are sympatric. However, the chameleon goby is more marine, whereas the shimofuri goby is collected in fresh water and has not yet been collected in sea water.

It was generally believed that the chameleon goby was the only member of this genus which had been introduced into California, and until recently scientific authors have discussed all findings of Tridentiger in the state as being of that species.

According to Haaker (1979), the chameleon goby was first collected in American waters on 1 June 1960 by J. Wright of Marineland of the Pacific at Fish Harbor in Los Angeles Harbor. The one specimen collected was identified by C.L. Hubbs as T. bifasciatus, a synonym at the time of T. trigonocephalus. The specimen he examined is the basis of the report by Hubbs and Miller (1965, p. 51) of this goby (called Tridentiger trigonocephalus in our paper) being in Los Angeles Harbor.

Miller and Lea (1972, p. 186) listed the chameleon goby from shallow areas in Los Angeles Harbor and in San Francisco Bay, merely saying that it was inadvertently introduced from the Orient. Ruth (1964) has also pointed out that it is established in San Francisco Bay. Moyle (1976b) remarked that it "... has not yet been collected in fresh water in California but can be expected there since it occurs in brackish Lake Merritt in Oakland...."[127] Although not completely correct, this prophesy was fulfilled when this goby was collected in Pyramid Lake, Los Angeles County, in October 1990. It was also taken downstream in Piru Creek in June 1992, and it was suspected that these gobies came in with water imported from the Delta (Swift et al. 1993).

[126] Formerly known as the "trident goby," its present common name originated from the discovery of L.J. Dempster of the California Academy of Sciences that this species can change its color pattern within a few seconds. However, according to Matern and Fleming (1995) both Tridentiger species change color patterns rapidly.

[127] Hubbs and Miller (1965, p. 44) said that Lake Merritt is a freshwater lake even though it has an open connection with San Francisco Bay and was formerly a part of the Bay known as Peralta Slough.

According to Raquel (1988), P.B. Moyle and K. Hieb, in a personal communication to him, stated that this goby had been observed in Suisun Bay. Raquel (1988) definitely recorded its presence on 5 March 1987 at the John E. Skinner Delta Fish Protective Facility near Byron, Contra Costa County, about 130 km upstream from the Golden Gate Bridge. He stated that this was the first record of its occurrence this far upriver in the Sacramento-San Joaquin Delta, where the salinity at the time of the goby's collection was approximately [%].

C.L. Hubbs and J.H. Prescott (in MS) theorized that this goby might have reached San Francisco Bay in egg stages on the giant Pacific or Japanese oyster (Crassostrea gigas) , and Los Angeles Harbor among fouling organisms on a ship (Hubbs and Miller 1965, p. 51). Haaker (1979), who collected the chameleon goby in Los Angeles Harbor in May 1977, suggested that the introduction of this and the yellowfin goby might have involved the transport of eggs laid on fouling organisms of ship hulls, or from the contents of aquariums dumped from ships. Obviously, all of these theories are conjecture, as is that of Matern and Fleming (1995), who intimated that the introduction of gobies to California was through ballast water.

The chameleon goby was first noted in the southern portion of San Francisco Bay, an area of high salinity, in 1962, and for the next 25 years was recorded only from its marine environment. Then, in 1985, fish identified as chameleon gobies were collected in estuarial areas of lower salinity, and the population exploded in the Delta. Such a puzzling extension of the species to more freshwater areas has now been explained by Matern and Fleming (1995). All of the collections of Tridentiger from the freshwater and low salinity regions of the San Francisco Bay and Estuary appear to be T. bifasciatus or shimofuri goby. This paper will not attempt to explain in detail how this conclusion was reached.[128]

In summing up the matter, it would appear that all reported collections of Tridentiger from high salinity areas are the chameleon goby, and that collections from fresh water, including those listed by Swift et al. (1993), are of the shimofuri goby.

Matern and Fleming (1995) warn against the extension of the shimofuri goby to southern California (via diversion) where it may compete with the native endangered tidewater goby (Eucyclogobius newberryi) .

In any event, both of the Tridentiger gobies (called "striped gobies" in Japan) seem now to be permanent residents of California. They may offer competition to other fishes but, especially because of their small size (TL about 90 mm), are of no use to man either as food or game fish. They may have some use as bait fish.

[128] It is based primarily on a revision of the genus and studies on salinity distribution by the Emperor of Japan and a colleague (Akihito and Sakamoto 1989). Matern and Fleming (1995) can be consulted for details.

4.59. FISHES WHOSE STATUS IS UNCERTAIN

Paddlefish, Polyodon spathula (Walbaum)

The long-lived paddlefish, a ganoid, also known as the spoonbill, is a representative of an old group of fossil fishes; its nearest relative lives in China. In the United States, the paddlefish is native to lakes and streams in the Mississippi River drainage.

Although caught by anglers, it is also a food fish, and is particularly good when smoked. Consequently, it has been the subject of commercial aquaculture and at least one major producer, located in Missouri, has developed a domesticated broodstock. In California, the first inquiry known to us regarding paddlefish culture was received in 1982, but it was not pursued.

A more serious request from a California aquaculturist, desiring to sell paddlefish in the pet trade, was approved by the Fish and Game Commission at its January 1991 meeting. The proposal was supported by the Department and the Commission because the location of the facility (near La Grange, Stanislaus County) and the mode of operation essentially precluded escape into the wild. About 40,000 paddlefish fry were imported in April 1991; 25,000 eggs in April 1992; and 10,000 fry in May 1992. All emanated from an aquaculturist in Kentucky. These were reared to about 3 to 4 inches in length and sold (numbers unknown) to aquarium stores in the Fresno area.

Similar permission was granted by the Commission at its May 1992 meeting to an aquaculturist near Snelling, Merced County. Once again, the location and operation should prevent escape of the imported paddlefish. In this case, 300 paddlefish, weighing about 1,500 lb, were obtained from the University of Arizona. Reared as broodstock, the offspring were to be sold as aquarium fish with later production going to the fresh fish and roe trade.

Aquacultural activities regarding the paddlefish have been reduced to a very low level because it is a candidate for threatened species listing by the U.S. Fish and Wildlife Service. Listing is under review, and at the present time, the paddlefish is considered a species of special concern (Williams et al. 1989).

Although there is no proof that the paddlefish has ever been introduced into wild or open waters of California, its temperature tolerance, the propensity of fish to escape from confinement, and its use for aquaculture and as an ornamental species all indicate that it might become a part of the California fish fauna.

4.60. Deepbody thread herring, Opisthonema libertate (Günther)

Although the thread herring is not recorded either by Miller and Lea (1972) or by Hubbs et al. (1979) as being native to California, Radovich (1961) reported that it was found in southern California oceanic waters in 1947, 1948, 1949, and 1959.

Clark (1932) stated that during the summer of 1931, live-bait tuna boats returning to San Pedro after fishing for tuna off Mexico released several Mexican species of fish into Los Angeles Harbor or an area adjacent to it. She suggested that if the thread herring or any of the other species from Mexican waters which were released succeeded in being established, that new species of fish might be added to the California fishery.

4.61. Anchoveta, Cetengraulis mysticetus (Günther)

The established range of this oceanic fish is from Sechura Bay, Peru, north to Los Angeles Harbor, and it is included in the list of fishes of California by Hubbs et al. (1979) as native to the state.

However, Miller and Lea (1972) pointed out that the anchoveta was rare north of Magdalena Bay, Baja California, and suggested, "Its occurrence off California may be the result of inadvertent introduction by American tuna bait boats returning from tropical waters." In this respect, one is referred to Clark (1932) who stated that occasional specimens of the anchoveta have appeared in the fresh fish markets of San Pedro taken incidentally in round haul nets. She further stated that during the summer of 1931, boats fishing for tuna off Mexico returned to San Pedro with live fish taken in these waters and released them into Los Angeles Harbor or an area adjacent to it. One of the species released was the anchoveta. She suggested that if it (or any of the other species from Mexican waters which were released) succeeded in being established, new species might be added to the California fishery.

It may be noted that the anchoveta also was introduced unsuccessfully several times from Mexico into the Salton Sea (Table 2).

4.62. Smallmouth buffalo, Ictiobus bubalus (Rafinesque)

Like its close relatives, Ictiobus cyprinellus and I. niger, which are also used as food and are native to the central United States but have been introduced into Arizona, the smallmouth buffalo may, on occasion, find its way into the lower Colorado River and its connected waters.

On the basis of a photograph, C.L. Hubbs and J.A. St. Amant identified a specimen collected from a waterway in southern California in 1969 as the smallmouth buffalo (Shapovalov et al. 1981). None has been collected since then according to Swift et al. (1993).

4.63. Piranha

Certain members of the family Characidae, native to South America, are called piranhas, and the term is generally held by the layman to denote a particularly voracious flesh-eater belonging to this family.

The only published record of an occurrence of a piranha in open or public waters of what may be California that we have found is that of Sanchez (1974, p.

13) who, in the course of a paper on fish introductions into Latin America, merely said, illustratively, that there was an accidental liberation of "... 'piranhas' (Serrassalmo sp.) ..." into the Sacramento River. Sanchez provided no reference as to the exact place or time of the occurrence nor the source of his information. We have been unable to locate the author and inquiries in 1993 of the Food and Agriculture Organization (under whose auspices the symposium was held) elicited no information as to the source of this comment. We suspect that the "record" was anecdotal.

The presence of piranha in California waters was confirmed by the capture in August 1987 of a specimen from a small pond at the Swan Lake Mobile Home Park in Riverside County. Although not identified to species, the fish was identified with confidence as a piranha by Department of Fish and Game fishery biologists at the Chino Operations Base who were familiar with piranhas and pacus (Colossoma spp). The pond was partially drained and then chemically treated by the Riverside Department of Health in September 1987. No additional specimens were detected.[129]

There has never been a move to introduce piranhas into wild waters in California. There have, however, been importations of piranhas as ornamental aquarium fish, and to provide sadistic "amusement" to those Californians who delight in seeing a cold-blooded vertebrate tear a warm-blooded one to bits; e.g. piranhas on exhibit in public places such as bars where they are fed live mice. Fearing that if some of these voracious fish were introduced into Californian waters, they might not only harm other fish populations but be a danger to swimmers or bathers, water skiers, and boaters, there have been several moves to eliminate this potential menace.

In 1960, a bill was passed by the Congress of the United States to ban importations of piranhas throughout the country (OC 1960a). This was followed in 1961 by passage of a similar ban by the California legislature. In subsequent actions, the Fish and Game Commission added the following genera of piranhas to its list of prohibited species: Pygocentrus, Pygopristis, Rooseveltiella, Serrasalmo, Serrasalmus, and Taddyella (Section 671 of Title 14, California Code of Regulations). Species of Serrasalmus apparently are the most common piranhas in the aquarium trade (Lachner et al. 1970).

In a case that began in April 1965, a decision was handed down on 9 January 1969 by a Los Angeles Superior Court which upheld the State's constitutional power to prohibit tropical fish dealers from importing piranhas into California (OC 1969a).

An early attempt by the State to review the question of damage through the then widespread importation of piranhas culminated in a publication by St. Amant

[129] A 2-lb fish identified as a piranha, caught by an angler in August 1992, was said to be the first documented piranha catch in Nevada. It was suspected that it had been released by an aquarist (San Francisco Chronicle, 4 August 1992).

(1967). The classification of piranhas, their survival temperatures, and anecdotal history of their danger was reviewed, and he concluded with the possibility "... that piranhas could be established in southern California waters...." At a later date, St. Amant and Hoover (1971) published a bibliography of 168 references to piranhas and Mexican or banded tetra. (The tetra was included because it is the one member of the family Characidae which may be free-living in California.)

The morbid fascination with piranhas apparently stimulates illegal importations. For example, in a 1991 undercover operation, Federal and State agents broke up an international ring of exotic fish smugglers and seized 575 red-bellied piranhas (Sacramento Bee, 18 December 1991). It is likely that piranhas will continue to be introduced illegally into California from South America.[130]

Attention is called to the occurrence of a pacu, thought to be a piranha, and the possible occurrence of the Mexican tetra (Astyanax mexicanus) , another characid, in California.

4.64. Cutthroat trout, Oncorhynchus clarki ssp

The State has imported several shipments of cutthroat trout eggs (sometimes under the name of "blackspotted trout") from outside California. For example, circa 1924, "A quarter of a million cutthroat trout eggs from the Rocky Mountains were received, hatched, and planted in the streams of the northwest coast regions" (California Fish and Game Commission Report for 1922–24, p. 13). At least one shipment went to the Brookdale Hatchery in Santa Cruz County in 1909, and there appear to have been distributions of cutthroat to private individuals. Some of these trout have been planted in north coastal streams and may have also been stocked in other waters. Evans (1944), for example, pointed out that Montana (now Yellowstone) cutthroat, may have been shipped by the National Park Service from the Yellowstone Hatchery to Yosemite National Park. There is also a report in Ellis (1915) that an unknown variety of fish from Colorado was planted in about 1890 in Rock Creek on the east slope of the Sierra Nevada. This was probably a cutthroat trout.

California already possessed native cutthroat trouts and had propagated some of them. Probably the major reason why the State imported cutthroat eggs from the outside was because of temporary shortages of native eggs.

During a joint study of Lake Tahoe, the California and Nevada Departments of Fish and Game stocked large numbers of marked rainbow and cutthroat trout (Cordone and Frantz 1968). Among the latter were three groups of catchable-size Yellowstone cutthroat obtained from a Federal hatchery in Montana.[131] The estimated

[130] Piranhas were, at least at one time, commonly shipped from South America as species of Metynnis, Mylopus, or other tropical fish (letter of aquarist H.R. Axelrod to J.E. Deacon, 28 December 1970).

[131] We assume that the stocks of Yellowstone cutthroat trout eggs imported into California and Nevada came from Yellowstone Lake via the Bozeman National Fish Hatchery in Montana. Over a span of 50 years, huge numbers of eggs from these fish were exported to other western states (Varley and Gresswell 1988). According to Behnke (1992), the correct scientific name for this subspecies is now Oncorhyncus clarki bouvieri (Bendire).

returns were less than 1%, and in several years they disappeared completely. Cordone and Frantz (1968) concluded that lake trout predation was the primary cause of the failure of this subspecies.

Although one can find a few records of cutthroat egg shipments to California in published records, most of them are buried in discarded files. Present State planting records clearly indicate the source of the fish (i.e. of the eggs as well as the hatchery), but the old records do not show this. It would prove an impossible task to seek out and record just where and when alien cutthroat have been planted. Consequently, we have made no attempt to resurrect such records.

The possibility of finding and being able to differentiate an alien cutthroat trout from a native one appears slight indeed. Still, if anyone should wish to revise the California cutthroats, he/she must admit the possibility of admixtures.

4.65. Sheepshead minnow, Cyprinodon variegatus Lacepède

This small cyprinodont, very similar to the native desert pupfish, is native to the eastern United States from Cape Cod to Mexico in brackish and hypersaline waters. It is very hardy and can survive extreme changes in salinity and temperature. It is useful as a forage fish and because of its tenacity is also used as a bait fish.

As far as we know, it has never been introduced into the open waters of California, but in the late 1980s, the Department of Fish and Game became concerned about the use in California of the sheepshead minnow for bioassay tests. It was feared that continued widespread use for this purpose might eventually lead to its establishment following the accidental or deliberate release of test fish. Already stressed populations of native California estuarine fishes would be further jeopardized by the presence of the hardy and aggressive sheepshead minnow.

The use of the sheepshead minnow for bioassay tests in California was protested to the U.S. Environmental Protection Agency (EPA) by the Department (20 February 1987 letter from Director J.C. Parnell to J.E. Ayers, Regional Administrator of the EPA). The 27 April 1987 reply from Ayers to Parnell assured the Department that the Agency neither required nor recommended the use of sheepshead minnow for effluent toxicity testing in California.

In 1993 the Fish and Game Commission added the sheepshead minnow to its list of prohibited species (Section 671 of Title 14 of the California Code of Regulations).

4.66. Bluefin killifish, Lucania goodei Jordan

The bluefin killifish is largely confined to the fresh waters of the Florida Peninsula but penetrates into brackish water.

At least one *Lucania goodei* was in the first shipment in 1959 to California of Florida largemouth bass from the Holt State Fish Hatchery of the Florida Game and Fresh Water Fish Commission (Hubbs and Miller 1965, p. 48).[132] Swift et al. (1993) also said that in 1980 several urban aquatic sites in Los Angeles received introductions of Asian milfoil (Myriophyllum) from Florida which carried the eggs of bluefin killifish, and that the hatchlings survived for several months in an outside pond.

We know of no record of this fish in any public waters of California, and—it may be noted—Hubbs et al. (1979) did not include it in their list of introduced fishes not known to occur now in California.

4.67. Eastern mosquitofish, Gambusia holbrooki Girard

Gambusia holbrooki was formerly recognized as a subspecies, G. affinis holbrooki. Studies described by Smith et al. (1989) and Wooten et al. (1988) elevated the eastern and western mosquitofish to full species; i.e. G. holbrooki and G. affinis. These studies demonstrated that natural mosquitofish populations in drainages east of Mobile Bay in Alabama should be considered the former species, and those west of the Bay should be considered the latter. There may even be three distinct forms of G. holbrooki.

According to Rosen and Bailey (1963), the eastern mosquitofish originally ranged "... from southern Alabama and Florida northward on the coastal plain to southern New Jersey." Courtenay and Meffe (1989) stated that both species have been introduced worldwide, but the source of the stocks and thus the identity of the species was normally not mentioned. Most often the literature simply refers to "mosquitofish, Gambusia affinis. " In their detailed descriptions of the ecological impacts of mosquitofish introductions, Courtenay and Meffe (1989) referred to the two species as a unit, Gambusia affinis/holbrooki.

The situation in California is also unclear. Shapovalov et al. (1981), although recognizing that the eastern mosquitofish (then referred to as Gambusia affinis holbrooki) had been widely distributed in public waters, said that these fish hybridized with the western mosquitofish (then referred to as G.a. affinis) , and that pure eastern mosquitofish had yet to be collected from the wild. These views were based on two letters. The first was a 30 November 1978 letter from E.F. Legner of the University of California, Riverside, to A.J.C. which stated, "... G.a. holbrooki hybridizes with G.a. affinis to the point where it would be impossible to determine which subspecies occurred in a planting site now. They are very close to begin with, with *holbrooki* being slightly more low temperature tolerant."

[132] Incorrectly called Pensacola Fish Hatchery by the authors.

The second was a 13 March 1979 letter from K.J. Hiscox of the Butte County Mosquito Abatement District to A.J.C. which stated, "We have Gambusia affinis holbrooki here at the District headquarters in one pond. There has been, unfortunately, some mixing with G.a. affinis so it is not a pure stock anymore. They have been planted in sites over most of the county in recent years."

We do not know the details of the importations of G. holbrooki into California, but considering the importance and size of the mosquito control program in California, and the central role of mosquitofish in this endeavor, we suspect that pure Gambusia holbrooki may have been stocked on numerous occasions. Its ability to withstand lower temperatures is much in its favor. However, there is no real proof of its establishment in California. For example, Swift et al. (1993) referred to a personal communication from J.D. Lynch of the University of Nebraska who believed that only the western mosquitofish has been placed in California waters.

Whatever ichthyologists may say—and they do not always agree—concerning the specific status of the mosquitofish, we are dealing with a small (normally only about 5 cm or 2 inches long), aggressive fish, which has a large effect on mosquito control, but also may have a deleterious effect on other fish stocks, both native and introduced.

For further information on mosquitofish in California, see the section on Gambusia affinis.

4.68. Mexican molly, Poecilia sphenops Valenciennes[133]

One of the "mollies," a genus of viviparous fishes found in the southern United States, Mexico, and Central America, identified as Poecilia sphenops, was found in a portion of the Westminster flood control channel, Orange County, sometime between 12 April and 20 July 1968 along with other ornamental fishes (St. Amant and Hoover 1969). They believed that the place of origin was a goldfish farm in Westminster. Unpublished notes by C.L. Hubbs and W.I. Follett, however, indicate that the identification was incorrect and that these fish were probably Poecilia mexicana.

The next report of its occurrence was in 1977 by Schoenherr (1979) who pointed out that "An interesting assemblage of freshwater fishes inhabits waterways and canals draining into the Salton Sea in Riverside and Imperial counties.... Most of these drains carry irrigation runoff, and represent permanent aquatic habitats. The fish fauna of these waterways is a mixture of aquarium species, escaped bait fishes, introduced game fishes, introduced 'weed eaters,' and one native form ... the desert pupfish." In one of these waterways, the King Street Canal, 7 km north of the Riverside/Imperial County line on the northwest side of the Salton Sea, Schoenherr (1979) found Poecilia sphenops on 3 March 1977. It was most abundant near an outflow of water at 22° C. Schoenherr (1979) distinguished

[133] We follow Meffe (1989) in assigning the common name "Mexican molly" to Poecilia sphenops.

it by its dentition in accordance with Hubbs (1961) but said that in coloration it resembled a variety of *Poecilia mexicana* known in the aquarium trade as "liberty mollies." Some members of this genus are difficult to separate taxonomically, and P. sphenops is sometimes confused with P. latipinna. Each has a black phase.

Concerns about identification of P. sphenops persuaded Hubbs et al. (1979) and Shapovalov et al. (1981) not to list this species. More recently, neither Robins et al. (1991) nor Swift et al. (1993) listed Poecilia sphenops among established fishes. It is also absent from the list of introduced fishes collected but not known to be established (Courtenay et al. 1991). Courtenay et al. (1986) referred to an unpublished report by Courtenay and Hensley that "... treated *Poecilia mexicana* as part of a 'species complex'.... They recognized that records of other members of the complex in North America (P. latipunctata, P. petenensis and P. sphenops) could contain misidentifications."

The species can live only in warm water, so its distribution in California, if it is present, is obviously limited, and its small size precludes its use as a game fish.

4.69. Conodon serrifer Jordan & Gilbert

Conodon serrifer is native to Bahía de Ballenas, Baja California, Mexico, into lower Gulf of California to Ecuador (ichthyologist M.H. Wilson, 9 December 1994 pers. comm.). It was not listed either in Miller and Lea (1972) or by Hubbs et al. (1979) as being native to California.

Clark (1932) stated that during the summer of 1931, tuna boats with live bait taken in Mexican waters released several Mexican species of fish into Los Angeles Harbor or waters adjacent to it. She suggested that if Conodon serrifer or any of the other Mexican species which were released succeeded in being established, new species of fish might be added to California's marine fauna.

4.70. Micropogonias altipinnis (Günther)

The recorded range of the oceanic fish Micropogonias altipinnis is from Bahía de Magdalena, Mexico, into and throughout the Gulf of California to Mancora, Peru (ichthyologist M.H. Wilson, 9 December 1994 pers. comm.). Neither Miller and Lea (1972) nor Hubbs et al. (1979) record it as being a native of California.

Clark (1932), who called it Micropogon ectenes, stated that live-bait tuna boats, returning to San Pedro from fishing in Mexican waters during the summer of 1931, released a number of live Mexican fishes into the waters of Los Angeles harbor or waters adjacent to it. She suggested that if this species or any of the other fishes from Mexican waters which were released succeeded in being established, new species might be added to the California fishery.

5. FISHES WHICH HAVE ACHIEVED NO LASTING SUCCESS

This broad category of introductions includes: i) those known to have been introduced or known to have been found at one time in open or public waters, e.g. medaka, and ii) those found in bait tanks along the lower Colorado River from which they could have reached public waters.

The second category may appear to occupy a disproportionate amount of space in this paper, and obviously is of significance only in the Colorado River and its extensions. Still, such fish constitute potential introductions which are of more real importance than the finding of one specimen (again, for example, the medaka) in a small California-an stream.

5.1. Alligator gar, Lepisosteus spatula Lacepède

The native range of the alligator gar includes the lower reaches of the Ohio and Missouri rivers, the Econfina River of Florida, and extends west along the coastal plain of the Gulf of Mexico to Veracruz, Mexico. Possessing a modified gas bladder, it can exist in stagnant water and frequents quiet water. It reaches a large size (specimens over 3 m long have been reported), is covered with resistant ganoid scales, and is very voracious. It has some value as a game fish but rarely as a food fish. Small gars are sometimes used as aquarium fish.

The first positive record of its occurrence in California is that of Raquel (1992) who described the collection of a 145.5-cm male weighing 18.6 kg in the Clifton Court Forebay, an impoundment near Byron, Contra Costa County, which uses Sacramento-San Joaquin Delta water. The identification was confirmed by P.B. Moyle.

It was considered by Raquel and others that the gar may have been released by an aquarist. It was also considered that the species could establish a population in the Delta and be a piscatorial menace to the present fishery. An extended discussion in Scarnecchia (1992) points out that gars are not always to be considered detrimental to game fish populations, but the introduction of such a fish into California is not to be desired.

Although this is the only verifiable record of the alligator gar's presence in public waters of California, there is a possibility (unnoted in Raquel's report) that it has been reported before, in *Fish and Game Today*, 35(4): 10, a quarterly publication for Department of Fish and Game employees. During the latter part of 1983, an employee of the Kern County Parks and Recreation Department reported a 5- to 6-ft long alligator-like fish attempting to capture a coot or mudhen (Fulica americana) tangled in fish line near the shore of Buena Vista Lake in Kern County. A report, along with a drawing of the fish, was completed by the Parks Department and sent to the Department of Fish and Game. From the report and drawing, both agencies believed the fish could be an alligator gar. A depth sounder survey of the Lake made about "mid-month" showed nothing that would indicate the presence of a fish of that size. Obviously, this report indicated only that some large fish was reported from the lake and that it might have been an alligator gar.

5.2. Arawana, Osteoglossum bicirrhosum Vandelli

Two specimens of this large, popular aquarium fish have been recorded from the wild in California. The arawana is native to the rivers and clear water lakes of the Amazonas and Para states of Brazil. It may attain a length of 3 ft and is related to the pirarucú Arapaima gigas, one of the world's largest species (to 15 ft and 400 lb) of freshwater fish.

The first was a 22-inch specimen caught in 1972 by an angler in Lake Berryessa, Napa County (Shapovalov et al. 1981, p. 29). A second arawana was dipnetted by anglers from Lake Merced in San Francisco County on 10 August 1994. It measured about 24 inches TL and was identified by L. Breeler who owns an aquarium store in Pacifica, San Mateo County (Klinger 1994).

These records no doubt represent tropical fish which outgrew aquariums and were then consigned by their owners to an early demise in a nearby public water; an act both illegal and cruel. Such tropical fishes generally cannot withstand the cold winter water temperatures of northern California.

5.3. Freshwater eels (Anguillidae) in general

The history and status of freshwater eels (Anguillidae) in California have been so aptly summarized by McCosker (1989) that it may seem useless to repeat them here.[134] With respect to the first plants, we herein include additional primary references not included by him.[135] The known introductions and occurrences will be found under the species listed.[136]

The introductions of the American eel (during the last century) were made by the California Fish Commission solely because it was a good food fish on the eastern coast, and before it became known that it was a catadromous species

[134] His article is a summary of a report requested of the California Academy of Sciences by the Department of Fish and Game, which became aware of the presence of live eels in metropolitan retail outlets in 1985. New Zealand and Florida were the sources of these fish.

[135] The name of one of his secondary references was misspelled through an editorial error (i.e. it should be Shebley 1917, not "Shelby").

[136] In addition to those occurrences in which the organism has been identified to species, specimens of the genus Anguilla have been taken from the Los Angeles River, Legg Lake, and Puddingstone Reservoir (McCosker 1989), and from Cache Slough, Solano County, by angler E. Darling, on 20 September 1980 (pers. comm. from R.W. DeHaven of the U.S. Fish and Wildlife Service, 2 April 1981). One of us (A.J.C.) has a photograph of a large Anguilla specimen taken by an angler fishing in the Delta on 17 August 1982.

which spawned only in the Sargasso Sea in the Atlantic Ocean.[137] The later advent of eels in the waters of California stemmed not from deliberate introductions by the State or Federal Government, but apparently from escapement or unauthorized release into the wild. We can do no better than quote McCosker (1989) here: "Live anguillid eels have become popular in restaurants and markets [lately], particularly among the Asian-American communities and young urban professionals. The demand far outstrips the supply. Eel farms have been established with limited success in many southeastern states in order to supplement wild stocks of A. rostrata [the American eel].... Attempts have occurred in Colorado and Utah to raise eels in geothermal waters.... Recent proposals to the California Department of Fish and Game have involved the importation of adult anguillids and/or young eels ('elvers') which would be raised in growout facilities."

Although McCosker (1989) felt that it was most unlikely that any anguillid could leave California fresh waters, reproduce in the sea, and return, he felt "... that if released into California waterways, anguillids would survive and be competitive with and predatory upon the native ichthyofauna and introduced game-fishes." He pointed out that anguillids may live 30 or more years after escapement. He also felt that a variety of parasites and disease organisms, which might be harmful to native fishes and/or aquaculture and hatchery programs, accompanied anguillid introduction. Stating that total confinement is impossible for anguillids (i.e. that they could easily escape to the wild) and that they had remarkable mobility and were very hardy, it would be appropriate to prohibit any large-scale importation program of anguillids until the above risks are further studied.

On 4 December 1987, the California Fish and Game Commission added all species of Anguilla to the list of species prohibited from live entry into California.[138]

5.4. European eel, Anguilla anguilla (Linnaeus)

On 21 January 1969, a female European eel was collected at the State's Delta Fish Protective Facility near Byron, Contra Costa County, in the San Joaquin River drainage. The specimen was identified by W.I. Follett (Skinner 1971). This was the first authenticated record of this species in California. The California Department of Fish and Game's Newsletter No. 218, for February 1969, p. 9,

[137] It may be noted that with full knowledge of these requirements for reproduction, the American eel (Anguilla rostrata) has been stocked in Saskatchewan in order to create a food and game resource in saline lakes (Marshall and Johnson 1971).

[138] Eels are included in "... California Fish Showing ... Methods of Cooking Each Variety" issued by the Division of Fish and Game in 1935, which may have led some people to assume that they were established in the state (State Fish Exchange 1935).

first announced the finding of this eel, but incorrectly assumed that it was an American eel (Anguilla rostrata) . At least one other specimen of the European eel was taken in San Pablo Bay near Antioch Bridge in "1977 or before" (McCosker 1989).

Common in Europe, this species furnishes both sport and food and is extensively cultivated there (Deelder 1984; Dill 1990). It is obvious that it is not a reproducing resident of California.

Williamson and Tabeta (1991) surveyed the literature and consulted with experts regarding catches of eels from states of the United States and provinces of Canada that border the Pacific Ocean. Although no new California records were uncovered, they maintained that the two specimens described above as Anguilla anguilla could be A. japonica based on the number of vertebrae. They also related that "Starting in the 1960's many live Anguilla from various parts of the world have been imported into California and Oregon by Japanese and Chinese restaurants.... Since A. japonica is the eel species best known to Japanese and Chinese people, and is extensively cultured in Japan, Taiwan and mainland China, it is probable that many A. japonica have been imported into the USA." J.E. McCosker disagrees with this statement, saying that it is "possible" but not "probable" (pers. comm. 2 September 1994).

5.5. Shortfin eel, Anguilla australis Richardson

At least three shortfin eels (native to Australia, New Zealand, and some Pacific islands) have been taken from reservoirs (Puddingstone and Legg) in Los Angeles County during the 1983–85 period (McCosker 1989). Swift et al. (1993) reported, "Three specimens ... [Anguilla australis] of about three dozen noted by biologists between 1978 and 1986 came from Puddingstone Reservoir, Legg Lake, and lower Los Angeles River, Los Angeles County. The origin of these is not known, but many live eels were imported during this period...."

Again, as with the other species of Anguilla recorded from California, it is apparent that anguillids are either being released or have escaped from captivity.

5.6. American eel, Anguilla rostrata (Lesueur)

Importations of the American eel from the Atlantic Coast, native from Cape Cod to Colombia, were contemplated by the California Fish Commission as early as 1871, but were not made until 1874, 1879, and 1882. The total number of individuals planted appears to be about 2000. They were introduced under the name of Anguilla chrysypa. The California Fish Commission Report for 1878–79, p. 14, listed 4000 eels "obtained through Livingston Stone" as planted in 1879, also saying, "Without doubt, they will, in a few years, fill our streams." This numerical record is also found in California Fish Commission Report for 1893–94, p. 75; *Ibid.* 1897–98, table preceding p. 49. However, Stone (1882) claimed to have planted only "a few hundred" American eels in California in 1879.

Accounts also differ as to their place of deposition; some are reported to have been planted in the Sacramento River, Alameda Creek, and waters of San Francisco Bay (California Fish Commission Report for 1874–75, p. 5–6; *Ibid.* 1878–79, p. 14; *Ibid.* 1881–82, p. 6; Stone 1875, 1882). The exact planting sites are of no importance, but the differing records, which seem to have been detected only by Smith (1896, p. 438) and the present authors, do cast considerable doubt on the carefulness of writers on California fish introductions.

Apparently, the first plants of eels made in California were small silver eels from the Hudson River, New York, planted by Livingston Stone in a slough or lake near Sacramento on 12 June 1874, and small saltwater eels which he brought from New York Harbor, planted in San Francisco Bay or one of its inlets near Oakland (California Fish Commission Report for 1874–75, p. 5–6; Stone 1876a, p. 477).[139] The California Fish Commission Report said that 12 silver eels were planted; Stone (1875, 1876a) said that one can was planted. The California Fish Commission said that about 1500 saltwater eels were planted; Stone (1875, 1876a) said that one can was planted. Both the California Commission and Stone (1876a) said that these saltwater eels were planted in San Francisco Bay, but Stone (1875, p. 32) said they were planted in lakes near Suttersville (adjacent to Sacramento). The latter statement is completely illogical, and we think that they were planted in salt water.

The second shipment in compliance with a request from the California Fish Commission, according to Stone (1882), was of about 500 eels from the Navesink River, New Jersey. On 18 June 1879 some were planted in the Sacramento River, and some were put into Alameda Creek.

With respect to the third and last shipment to California, 10 adults from the Shrewsbury River in New Jersey were put into Suisun Bay by J.G. Woodbury of the California Fish Commission in 1882. According to Woodbury, "On being put into the water they immediately bored straight down into the soft mud, and in a moment they were all out of sight" (California Fish Commission Report for 1881–82, p. 6). This may well have been the last time American eels were seen in California for many years.

There were several reports of their capture in fresh water, in San Francisco Bay, and in the Pacific Ocean. For example, several were reported as taken in the Sacramento River between 1874 and 1879 (California Fish Commission Report for 1878–79, p. 14), and one report said, "Occasionally we hear of an eel being captured, but as yet they have not showed an increase in proportion to that of

[139] "Silver eels" (as opposed to "yellow eels," which they are sometimes called during their growth period) are freshwater eels which assume this color as they attain sexual maturity and descend to the ocean. Stone was quite cognizant of this distinction but did not understand their spawning habits. In fact, he (Stone 1877, p. 294) thought that the eel might be a hybrid since he had never seen eggs or young in one.

other imported fish" (California Fish Commission Report for 1880, p. 3). Although admitting that the eel plants had not been a success, the later Fish Commissioners continued to be optimistic for a time, saying, "It is probable that the place where they were deposited, and where they have made their home has not yet been discovered...." (California Fish Commission Report for 1883–84, p. 11).

The captures were summarized by Smith (1896). However, some of the supposed "eels" were found to be native Pacific lampreys (Lampetra tridentata) . Others, ones offered for sale in the San Francisco markets, may have been blennies (Stichaeidae, etc.) which are frequently called "eels" even today. No one can be sure of the identifications, and Shapovalov and Dill (1950) felt, "There are no authentic records of survival."

Then the American eel definitely appeared in California despite a lack of knowledge of any recent plants. During the week of 1–5 June 1964, angler D. Ivy caught an anguillid eel in the Sacramento-San Joaquin Delta about 15 miles north of Stockton. Unfortunately, only the skin and a photograph remained before it could be checked by scientists. C.L. Hubbs identified it as Anguilla rostrata (Skinner 1971). McCosker (1989) felt that it may have been either A. rostrata or A. anguilla, and discounted Skinner's (1971) theory that it had entered the Delta via foreign ship ballast. Under any circumstances, however, there are various other recent records of the American eel found in California. Detailed by McCosker (1989), 11 specimens have been found in waters of Golden Gate Park, San Francisco, during the 1978–79 period; one was taken on 13 October 1983 at Tracy; and one was taken on 27 April 1984 near Byron. (The two latter areas are in the Sacramento-San Joaquin Delta.)

One can only conclude that although the early plants failed, the occurrences above relate to more recent unauthorized introductions or escapes.

5.7. Milkfish, Chanos chanos (Forsskål)

It is, perhaps, a mistake to speak of the planting of milkfish as an "introduction" since the species does exist in California waters. Walford (1937) stated, "It has been found from San Francisco Bay to Panama, in Hawaii in the western Pacific, and in the Indian Ocean." He failed to provide any reference, however, to its presence in California. Similarly, de Sylva (1974) said that this species occurs in central California. He provided no reference for this statement and may have been following Walford (1937). Until recently, most other respected authors have not included its range along the California coast. A rather thorough discussion of this point was found in Duffy and Bernard (1985), although they did not mention either Walford (1937) or de Sylva (1974). They did, however, provide several records of milkfish actually taken in southern California in 1982 and 1983 and found dead in San Diego Bay as early as 1929.

It seems certain that this species is rarely, if ever, found along the California coast north of San Pedro. Even its presence within the state's boundaries was unknown to early California Fish Commissioners, for they are said to have made an attempt to introduce it in July 1877 when nearly 100, under the name of "awa," were received from the Hawaiian Islands in exchange for trout and salmon eggs. These were placed in a small stream near Cordelia in Solano County where they could have access to brackish and salt water (California Fish Commission Report for 1876–77, p. 25).[140] In this Report, the Commissioners stated hopefully, "We have reason to believe they will find congenial homes, and grow and multiply in the waters of this state." There are no authentic records of the survival of the planted fish, although Williams and Jennings (1991) listed it erroneously as an "exotic" collected in California.

Aside from the fact that the California Fish Commissioners wanted something in exchange for their own fish eggs, they may have been influenced by the fact that the "awa" was reputed to be a valuable food fish in Hawaii. As they said in their report of 1876–77, "They are said to be the most valuable food-fish of the Hawaiian Islands, of fine flavor, and thrive in fresh, brackish, and salt water. Where they have access to salt water they grow to weigh an average of 5 pounds...." However, the milkfish is largely a cultivated fish in the Indo-Pacific area where the fry, which are usually collected in salt water, are placed in fresh- or brackish-water ponds where they feed on microbenthic algae. Chanos ponds have long been common in Indonesia and the Philippines and good results have been attained in Taiwan.

In Hawaii itself, Chanos is now considered to be of low priority as a fish for pond culture. Milkfish are considered to be of limited value there because of their unpredictable dependence upon naturally spawned fingerlings (Hawaii Department of Planning and Economic Development 1978). Furthermore, they are definitely a fish of warmer waters. Solano County and its contiguous San Francisco Bay waters were not well-selected places to plant Chanos, nor was the traditional expertise to rear them available.

Despite the historical record of the milkfish's (awa's) introduction into the waters of California, and its adoption by later writers on the subject, our view is that this evidence is rather slender. It seems to us that a mullet (family Mugilidae) may have really been the species planted as "awa" in 1877. See "Hawaiian mullet" in the "Hypothetical Introductions" section.

5.8. Chinese carps in general

This group of fishes, all cyprinids, first attracted the attention of fish culturists because of the belief that an association of species could best utilize the available food resources in a pond. Chen (1934), Lin (1951), Hora and Pillay (1962), Bardach et al. (1972), Ling (1977), and others have described the culture of Chinese carps which has been practiced not only in China but also in Southeast

[140] The record says "Bridgeport," a town now known as "Cordelia." The stream is tributary to Suisun Bay.

Asian countries such as Cambodia and Vietnam. The procedures, developed over a period of 1000 years or more, have been extended to many other areas. Called "association culture" in the East, it has been termed "mixed fish culture" in Mediterranean countries such as Israel, and "polyculture" in Europe and the former USSR.

Polyculture with these species has been a major focus of fish farming in these regions. Extremely high yields from managed ponds are possible when fishes with discrete diets are reared together. The species most often involved are the grass carp (Ctenopharyngodon idella) , silver carp (Hypophthalmichthys molitrix) , bighead carp (Hypophthalmichthys nobilis) , and black carp (Mylopharyngodon piceus) . The grass carp feeds primarily on submerged aquatic plants, the silver carp prefers phytoplankton, the bighead carp utilizes mainly zooplankton, and the black carp feeds on macrobenthos.

The success of Chinese carp polyculture led to the spread of these species, especially the grass carp, to numerous countries around the world. The main attraction of grass carp is not polyculture but instead reflects the frustrations of water users seeking control of aquatic weeds. The grass carp was first introduced into the United States in 1963 for research purposes at the Fish Farming Experiment Station of the U.S. Fish and Wildlife Service at Stuttgart, Arkansas, and at Auburn University, Auburn, Alabama (Guillory and Gasaway 1978). The other Chinese carps followed in later years. Widespread distribution of the grass, silver, and bighead carps in ponds and lakes by the Arkansas Game and Fish Commission led to their escape into the Mississippi drainage.

Conservation organizations and state fish and game agencies are very concerned about the spread and establishment of Chinese carps in the United States. Conflicts between these groups and commercial fish farmers led to the development of a method of producing sterile fish. Polyploid animals are often sterile, and shocking newly fertilized fish eggs inhibits meiosis, causing retention of an extra set of chromosomes for a total of 72 rather than the normal 48 chromosomes. The techniques used to induce triploidy include heat shock, cold shock, and hydrostatic pressure shock. Pressure shock is the most effective, with yields approaching 100% triploid grass carp. Studies have shown that grass carp with 72 chromosomes are functionally sterile (Allen et al. 1986; Allen and Wattendorf 1987; California 1989; Van Eenennaam et al. 1990; Bain 1993).[141]

[141] A recent study, however, raised questions about the permanence of the triploid state (Anon. 1994b). Triploidy was induced chemically and then confirmed for each Japanese oyster stocked in the York River by the Virginia Institute of Marine Science. Follow-up inspection of the oysters revealed that many contained both diploid and triploid cells. They were reverting to pure diploids and thus capable of reproduction. Although an invertebrate is involved, the findings may have relevance to triploidy in fishes.

The development of triploid (sterile) grass carp has greatly expanded their use with many states, including California, now importing and stocking them on a limited operational basis, primarily to control noxious aquatic plants. The sterilization techniques are being applied to other species of Chinese carps.

We anticipate that triploids of bighead, silver, and black carp will be used more widely in the United States, and that they may eventually be introduced into California.

5.9. Grass Carp, Ctenopharyngodon idella (Valenciennes)

Long known by the name of grass carp and a leading member of the Chinese carps, this cyprinid was first popularized in the United States as the "White Amur," probably not to indicate its native home, but rather to disguise the fact that it is a "carp" or minnow. of course, the name "carp" is a hated one in America, and we admire the cleverness of this name selection.

Stanley (1976) stated, "The species is native to the low-gradient stretches of the large rivers of eastern China and Siberia, from latitude 50° to 23°...." More specifically, Guillory (1980) stated that the grass carp is "Native to the Pacific slope of Asia from Amur River of China and Siberia south to West River in southern China and Thailand, where it inhabits low gradient stretches of large rivers."

Its plant-eating proclivity was responsible for its worldwide introduction into over 50 countries, and its establishment in Japan, the former Soviet Union, and Mexico (Stanley 1976). In the United States, the grass carp has reproduced and is established in the Mississippi River and its tributaries (Pflieger 1978; Conner et al. 1980; Zimpfer et al. 1987; Brown and Coon 1991), and in the lower Trinity River below Lake Livingston in Texas (Anon. 1993, 1994a).

When appropriately managed, the herbivorous grass carp can control and even eliminate a variety of aquatic plants under a wide range of conditions. Even the exotic Hydrilla, a particularly noxious aquatic weed, which continues to spread in the United States, is susceptible to grazing by the grass carp. This strong plant-eating habit is the basis for widespread interest in the grass carp, which has elicited serious concerns from conservation agencies about its potential impact on important aquatic resources. Because of these concerns, the California Fish and Game Commission, in 1967, at the request of the Department, added the grass carp to the list of prohibited species (Section 671 of Title 14, California Code of Regulations). The Department's position on the grass carp was summarized by Pelzman (1971b). The policy remains in effect with only a few exceptions (described later) to that which allows grass carp to be used for research purposes. When illegally stocked grass carp are discovered, the Department attempts to eliminate them, usually with rotenone.

The first confirmed illegal importation of grass carp into California took place in late 1974 or early 1975 (24 March 1975 letter from State biologist J.B. Richard to R. Beland). A small farm pond in the foothills of El Dorado County was stocked with 48 grass carp, according to the owner. Treatment of the pond on 21 March 1975 with rotenone eliminated all 48 grass carp (7.4–9.5 inches FL). The pond owner maintained that the fish were received from an Arkansas fish grower, probably by air freight.

A 1-acre irrigation pond located in Padre Juan Canyon, Ventura County, was stocked in the fall of 1974 with 12 fingerling grass carp (20 November 1975 letter from State biologist K. Sasaki to the Fisheries Management Supervisor of Region 5). All fish were accounted for following a netting program in the autumn of 1975. By then, they averaged 18 inches TL (Swift et al. 1993). Another small pond near Fort Bragg, Mendocino County, was confirmed to have received 20 grass carp fingerlings from a Pennsylvania fish farm on 9 June 1978, but inspection of the pond by Department personnel in August 1978 showed no signs of the fish (15 September 1978 letter from State biologist K. Lal to A.J.C.).

One of the more ambitious illegal importations of grass carp into California was described by Baker (1977). In September 1975, a Napa County rancher imported 200 grass carp weighing 0.75 lb each together with 2800 fingerlings from Arkansas to control filamentous algae. Eleven ponds, totaling 61.2 surface acres, and 2.1 miles of tributaries were treated with rotenone on 21–23 April 1977. A total of 1204 grass carp was recovered from seven of the 11 chemically treated ponds. The larger grass carp cohort ranged from 26 to 30 inches FL, and the smaller grass carp ranged from 11 to 13 inches FL. All of the former were mature, and some of the males produced flowing milt. The ranch owner was aware that importation of the grass carp was illegal, since the fish had been smuggled past the California border check station in an aerated tank covered with hay. The grass carp had performed well; the ponds they occupied were devoid of aquatic weeds, whereas the ponds without them supported dense weed beds.

An Arkansas fish grower took advantage of golf course operators frustrated by aquatic weed beds in their ponds. An examination of his invoices by law enforcement agents of the U.S. Fish and Wildlife Service revealed that ponds on dozens of California golf courses were stocked illegally with grass carp transported by truck or air from Arkansas. Most of the fish were stocked in 1985. Sampling revealed that the fish were diploid. Acting on information in the invoices, the Department rotenoned ponds on 37 of 53 golf courses scattered throughout the state. About 1500 grass carp were killed in chemical treatments carried out throughout 1986–88. The absence of grass carp from some golf courses apparently was the result of losses from pond draining or poor water quality. It is likely that some grass carp were missed during this operation.

A small private pond near Mt. Shasta, Siskiyou County, was probably stocked during the period when the golf course ponds were stocked with grass carp. The fish were quite large when their presence was brought to the attention of the

Department in early 1993 (State biologist W.D. Weidlein, pers. comm.). Electrofishing yielded a single specimen as confirmation, and several large grass carp could be seen cruising. Several physical and legal constraints prevented the Department from rotenoning the pond. The large grass carp probably will not exit via the shallow ditch that leaves the pond, and they will eventually die from old age or other causes. No grass carp have been found in another small pond downstream on the ditch.

The most recent detection of grass carp included the bighead carp as well. Both species were illegally stocked in three ponds in a small drainage in Tehama County at an elevation of about 275 ft. The lower pond (the largest at 40 acres) is about a quarter of a mile from Brannin Creek, which at that point is only about 10 stream-miles from the Sacramento River. Using a combination of gillnetting, draining, and rotenoning, all fish were destroyed. Final counts were 139 grass carp (26–28 inches TL) and 26 bighead carp (32–33 inches TL). The removal operation took place over several days in August, September, and October 1992 (1 September 1992 letter from State biologist B.E. Curtis to T. Farley, and 1 December 1992 letter from State biologist T. Healey to A.J.C.). The grass and bighead carp, imported illegally by a commercial aquaculturist who leased the ponds from the landowner, were reportedly transported in a concealed compartment under a load of black bass in the fall of 1989 from a fish grower in Oklahoma or Arkansas. There is evidence that the ponds have spilled since 1989, and grass and bighead carp may have reached the Sacramento River.

Major legal introductions of plant-eating fish in open waterways of California have been confined to the canals and impoundments of the Coachella and Imperial valleys in Riverside and Imperial counties. The initial releases were experimental in nature and were prompted by the severity of the aquatic weed problem and the political influence of the local water and irrigation districts. The first studies tested the weed-consumption proclivities of Tilapia mossambica and T. zilli and were conducted by the local districts and the University of California, Riverside (see Swift et al. 1993 and the sections on these species for further detail). The tilapia were not as effective as desired and required annual stocking because they could not survive temperatures below 50° F. These shortcomings became more criticial with the discovery in 1977 of Hydrilla in the Imperial Irrigation District canal system. Opposition by the Department to grass carp, and its status as a Fish and Game Commission-designated prohibited species, precluded its use in these early field trials.

The search for a different plant-eating fish led to the work of researchers in Hungary (Bakos et al. 1978; Marian and Krasznai 1978) who developed a method of producing sterile hybrid grass carp by crossing female grass carp with male bighead carp. The hybrid progeny were termed "triploids" because they possessed three sets of chromosomes, compared with the normal "diploids" with two sets of chromosomes. Hybrid triploids of this type are considered sterile. At its August 1979 meeting, the Commission approved the importation of 5000 to 10,000 of these hybrids as part of a 3-year study of their plant-eating capabilities, sterility, and impacts on aquatic life. Local, state, and federal agencies cooperated in the study (California 1989). Hybrids were stocked in screened sections of two large canals in the Coachella and Imperial Irrigation districts. They not only did not control Hydrilla under field conditions, but consumed less vegetation than did pure grass carp under laboratory conditions. This led to a 2-year extension of the study to evaluate surgically sterilized pure (diploid) grass carp in the experimental canals (Anon. 1989). However, these fish were removed from the canals in late 1984 when it was discovered that their gonoducts regenerated and gametes could still be released.

The production of pure triploid grass carp in 1983 by a private fish breeder in Arkansas (J.M. Malone & Son Enterprises of Lonoke) led to a 5-year evaluation study of these fish in irrigation waterways in the Coachella and Imperial valleys. Large numbers were approved for stocking in unscreened waters by the Fish and Game Commission in March 1985, followed in May 1985 by Commission approval for operational use of these fish in the Imperial and Coachella valleys. Until 1995, this was the sole exception to the statewide prohibition by the Commission on the use of this species.[142] With Commission approval, a registered California aquaculturist, located in either of the two valleys, may possess diploid grass carp broodstock in order to produce triploid offspring. Each stocking requires a private stocking permit from the Department. Each fish must be certified triploid before release, and any load of imported grass carp requires an importation permit and disease and parasite clearance.

Serious aquatic weed problems continue to plague many pond owners on farms, golf courses, subdivisions, etc. The problem is so widespread and severe that continued illegal grass carp introductions can be anticipated. Publicity extolling the plant-eating prowess of the grass carp, particularly articles appearing in golf and aquaculture magazines, coupled with large-scale rearing of the species in Arkansas and other southeastern states and their ready purchase from these sources, have been behind the many introductions into California. The fish are relatively easy to obtain; shipped to California by air freight or smuggled past the border inspection stations. Some importations may be made in ignorance of the law, but others are known to be premeditated. Illegally imported grass carp will probably be the fertile diploid variety since they are considerably cheaper than the sterile triploid form. We anticipate that eventually some of these fish will escape and establish permanent populations in California rivers with suitable spawning and nursery habitats.

[142] Legislation passed in 1995 allows the stocking of triploid grass carp in waters of Imperial, Riverside, and San Bernardino counties, but only under strict conditions imposed by the Department of Fish and Game.

5.10. Bighead carp, Hypophthalmichthys nobilis (Richardson)

Like the grass carp, the bighead carp is native to low-gradient rivers of the Pacific slope in China and Siberia. It is the zooplankton-feeding species among the Chinese carps utilized in polyculture.

The bighead was first imported to the United States in 1972 by an Arkansas fish farmer (Anon. 1989). The Arkansas Game and Fish Commission began evaluating bigheads and other Chinese carps in 1974. Widespread stocking of the bighead in Arkansas ponds apparently led to escape into public waters and, ultimately, successful reproduction (Pflieger 1989).

Only a single instance of bighead carp in California has been recorded. Three ponds in a small drainage adjacent to Brannin Creek in Tehama County were illegally stocked, apparently with both grass carp and bighead carp. Bighead carp were recovered only from the middle of the three ponds located about one-half mile from Brannin Creek, which at that point is only about 10 stream-miles from the Sacramento River. A netting, draining, and rotenoning removal operation took place over several days in August, September, and October 1992 (1 September 1992 letter from State biologist B.E. Curtis to T. Farley, and 1 December 1992 letter from State biologist T. Healey to A.J.C.). The 26 bighead carp recovered were very similar in size, ranging from 32 to 33 inches TL. The grass and bighead carp, imported illegally by a commercial aquaculturist who leased the ponds from the landowner, were reportedly transported in a concealed compartment under a load of black bass in the fall of 1989 from a fish grower in Oklahoma or Arkansas. There is evidence that the ponds have spilled since 1989, and grass and bighead carp may have reached the Sacramento River.

Although of much less interest to commercial aquaculturists and pond owners than the grass carp, we expect that bighead carp will continue to enter California illegally and may eventually become established in some of our larger rivers. The desire among certain ethnic groups, such as the Chinese and other Asians, for live food fish is a potential source of illegal introduction. They especially prize large Chinese carps and will be tempted to release them into public waters to establish a local supply. This threat will grow with the continued increase of Asians in California.

5.11. Zebra danio, Danio rerio (Hamilton)

The zebra danio, native to India and Sri Lanka, has been a popular aquarium fish for many years. In fact, an old-time professional aquarist once told W.A.D. that the most beautiful aquarium of all was one populated by male guppies (Poecilia reticulata) with a few zebra danios to keep them stirred up.

Be that as it may, and discounting the fact that the restless movements of the zebra danio keep it from being used to keep aircraft spotters calm, or that it has become an experimental fish for geneticists, this fish was found in a portion of the Westminster flood control channel in Orange County sometime during the period of 12 April to 20 July 1968 (St. Amant and Hoover 1969). The reporters believed that the place of origin of the zebra danios was a goldfish farm in Westminster which handled them.

The temperature requirements of this small ornamental fish preclude its establishment in California waters.

5.12. Ide, Leuciscus idus (Linnaeus)

Although not known to have been introduced into wild waters of California, a domesticated variety, the "golden orfe," has been present in garden pools and commercial aquaculture facilities in California for a number of years. The natural habitat of the orfe or ide is in Eurasia in the running waters, lakes, and lagoons of northern and eastern Europe and Asia where it is used as a minor food fish. In its golden form, it is popular as an ornamental fish. It is also established in a few waters in the United States.

Feeling that it might be an undesirable addition to California's waters, Seeley (1962) prepared a report on the species and recommended against its addition to the fauna.

5.13. Emerald shiner, Notropis atherinoides Rafinesque

The emerald shiner, native to Canada and the eastern United States, is both a forage fish and a bait fish and feeds to a large extent on midges and other flying insects.

Although we do not know of its introduction into open or public California waters, in 1963 a stock of the emerald shiner was requested by S.F. Cook, Jr., for the Lake County Mosquito Abatement District at Lakeport, California, for experimental study (p. 3 of the *American Fisheries Society Newsletter* for April 1963). Furthermore, Swift et al. (1993, p. 146) reported, "A specimen of *Notropis atherinoides*, emerald shiner, was collected from a fish pond in Oak Glen [San Bernardino County] in the summer of 1975 (LACM 35569-1)."

See also the account of the inland silverside.

5.14. Bluntnose minnow, Pimephales notatus (Rafinesque)

The bluntnose minnow is widely distributed in the central and northeastern United States and the Great Lakes basin of southern Canada. One specimen of the bluntnose minnow was taken in Victorville, San Bernardino County, in a shipment of channel catfish from Arkansas in 1968 according to Swift et al. (1993, p. 146). The preserved specimen is held by the Scripps Institute of Oceanography.

The species has never been recorded as having been introduced into the state.

5.15. Tiger barb, Puntius tetrazona (Bleeker)

The common aquarium fish, the tiger barb, native to Sumatra, Borneo, and possibly Thailand, was collected in the small stream flowing from Warm Springs Sanctuary in Owens Valley, Inyo County, on 6 July 1973. Two mature specimens, a male and a female, both in breeding condition were taken. They were not known to have been present in the Sanctuary which contains, through previous introduction, the endangered native Owens pupfish. A barrier in the stream prevents ascension to the Sanctuary by other fish (Naiman and Pister 1974). It is presumed that the tiger barbs were introduced by an aquarist or fish dealer desirous of using the spring as a brood pond.

Repeated collecting efforts since 1974 have yielded no other tiger barbs either in the outlet stream or in the Sanctuary.

5.16. Bigmouth buffalo, Ictiobus cyprinellus (Valenciennes)

A member of the sucker family, the bigmouth buffalo is native to the Lake Erie and Mississippi River drainages. Common in these areas, it attains a large size and is a popular food fish. It is reared commercially in ponds and also harvested from the wild.

Evans (1950) reported the presence of bigmouth buffalo in reservoirs of the Los Angeles Aqueduct system. "Positive identification was made by Dr. Carl L. Hubbs from two specimens recently obtained from Chatsworth Reservoir near Los Angeles." How "recently" the fish were collected was not apparent, but most likely it was sometime during the winter of 1949–50. Evans (1950) stated that bigmouth buffalo were reportedly found in Upper and Lower Haiwee Reservoir in Inyo County, and Fairmount, Dry Canyon, Bouquet, Chatsworth, Upper and Lower San Fernando, Rowena, Silver, and Ivanhoe reservoirs in Los Angeles County. He also observed that this species was first seen seven or eight years before (circa 1942 or 1943) in the aqueduct system in Upper and Lower San Fernando Reservoir, located about 20 miles northwest of Los Angeles.

Evans (1950) noted that they might have come from any of several sources since commercial seiners traveled throughout nearby states to obtain them for the fresh fish markets of larger cities. Pointing out that Los Angeles fish markets commonly received bigmouth buffalo from Arizona and Utah, he suggested that some commercial operators might have brought the bigmouth buffalo to California to provide a local market supply, and that if this hypothesis were true, they were probably introduced from the Roosevelt Dam impoundment in Arizona where several local commercial seiners had operated.

In a paper on the commercial freshwater fisheries of California, Davis (1963) reported that small amounts of bigmouth buffalo were netted in some Los Angeles and Inyo County reservoirs. He relied heavily on information presented by Evans (1950). Kimsey and Fisk (1964) stated that the bigmouth buffalo was present in several reservoirs of the Los Angeles Aqueduct system in Los Angeles and Inyo counties, and Shapovalov (1965) listed it as an established species in California introduced in 1942. All of these authors were probably merely following Evans (1950) or Davis (1963) and had no personal knowledge of its presence.

The bigmouth buffalo occurs in Arizona only in four reservoirs on the Salt River. It was introduced into Arizona in 1918 along with the black buffalo (*Ictiobus niger*) and the smallmouth buffalo (Minckley 1973). According to Minckley, the three species remained very close to where they were originally introduced, not moving into tributary streams nor to the canal systems below the dams.

Shapovalov et al. (1981) eliminated the bigmouth buffalo from their list of freshwater and anadromous fishes resident in California, since it had not been collected from California waters since the late 1960s and probably no longer existed in the state.

Grass carp studies conducted in the early 1980s in southern California, however, indicated that the bigmouth buffalo might still be found in California waters, particularly the Coachella Canal. As a major offshoot of the All American Canal, which originates at Imperial Reservoir on the Colorado River, it can be expected to support a fish assemblage similar to that of the mainstem Colorado River. Since the bigmouth buffalo is found in Arizona, its reported presence in the Coachella Canal was not surprising.

Intensive electrofishing of the Coachella Canal was one phase of a program evaluating the plant control efficacy of the grass carp, either in its triploid (sterile) form or as hybridized with the bighead carp. In Beaty et al. (1986) and in progress reports and the final environmental document describing the results of the study, the bigmouth buffalo was sometimes listed as occurring in the Canal. The lack of detail, however, prompted contacts with the former project leaders of the Coachella study. Neither P.R. Beaty nor R.G. Thiery could recall (pers. comm.) actually collecting a bigmouth buffalo during sampling operations.

Other studies were likewise negative for this species. In late 1974, St. Amant et al. (1974) sampled the Coachella Canal with an electroshocking boat, and ponds and seeps adjacent to the Canal with nets and traps. No bigmouth buffalo were collected, and this species was absent from their list of fishes known to be present in waters directly supplying the Coachella Canal. Using rotenone, Minckley et al. (1983) sampled three stretches of the Coachella Canal in Imperial County in 1980. No bigmouth buffalo were found among the 9100 fish recovered.

The bigmouth buffalo is unlikely to become permanently established in California. An occasional specimen, however, may work its way into the lower Colorado River and the major canals that emanate from it.

5.17. Pacu, Colossoma spp

Increasing numbers of pacu have been taken by anglers in recent years. Because of their sharp, prominent teeth and general appearance they are usually mistaken for the closely related piranha. The result is a media-generating event that abates only when the fish is identified as an inoffensive pacu. Because Colossoma are difficult to identify to the species level, those mentioned below should be considered provisional.

There is only one published record of the pacu, a freshwater tropical (Amazonian) fish, in open waters of California, that of Brittan and Grossman (1979) who described a fish taken in the Sacramento River, Yolo County, on 10 October 1977 by a boy fishing with worms for catfish. It was thought originally to be a piranha (another member of the Characidae) whose presence in the state, even as an aquarium fish, is illegal. Brittan tentatively identified it as Colossoma nigripinnis, but it may have been C. macropomum (M.R. Brittan, 30 November 1994 pers. comm.). The authors surmised that the fish (332 mm TL) had outgrown its desirability as an aquarium fish and had been released recently into the River which was warm enough to sustain it temporarily. They pointed out that water temperatures in the Sacramento River in this location were unusually high during the summer of 1977 being above 18° C between mid-May and mid-October. They considered that 18° C is approximately the minimum temperature at which most tropical lowland fishes can maintain themselves. They also stated that mid-winter temperatures in the Sacramento River here range from 6.5° C to 9.0° C and would be lethal to the pacu.

Another "pacu" was reportedly taken from the California Aqueduct in 1979 (California Department of Fish and Game, Region 5 monthly report for November 1979, and reported by Shapovalov et al. 1981, p. 29).

Since 1987, at least 16 additional specimens were collected from northern California waters; all but one harvested by anglers. Eleven of these were taken from Marin and Sonoma County waters: four from Stafford Lake in Marin County, four from Roberts Lake near Rohnert Park in Sonoma County, and one each from the Russian River at Healdsburg in Sonoma County, Alpine Lake in Marin County, and a Sebastopol city park pond in Sonoma County (State biologist W.H. Cox, 14 March 1994 pers. comm.). The Sebastopol fish was found dead. Remaining capture localities included the San Joaquin River in Fresno County, an irrigation canal in Butte County, Putah Creek in Yolo County, and Stevens Creek Reservoir in Santa Clara County. The Department delivered three specimens to the California Academy of Sciences for species identification. One Stafford Lake fish was identified as Colossoma bidens and the San Joaquin River fish were C. bidens and C. oculus (D. Catania pers. comm.). The specimen from Stevens Creek Reservoir was tentatively identified as C. brachypomum (State biologist R.N. Lea, 16 September 1996, pers. comm.).

Most of these fish ranged from about 10 to 16 inches TL and appeared to be in excellent health. Although held to be herbivorous, examination of some stomachs revealed crayfish, other invertebrates, and small fish, as well as tubers and acorns.

The pacu, a prized food fish in South America, is caught commercially and is cultured, at least in Brazil and Venezuela. Its aquaculture potential prompted a registered aquaculturist to request permission to rear and sell Colossoma bidens and C. macropomum at an isolated facility near Encinitas in San Diego County. The Department issued a special permit for experimental culture of these species, but only under very strict conditions to prevent escape. Permits were granted in 1979 and 1980 and fish were imported, but the study was terminated for unknown reasons. Additional requests by aquaculturists to rear pacus can be anticipated.

Aside from some year-round warm waters in southern California, it is considered unlikely that this fish or other species with the same temperature requirements, could overwinter in California or have reproductive success here. In view of the numbers of angler-caught pacu, however, some overwintering may be occurring, and perhaps it is a lack of successful reproduction that prevents establishment.

5.18. Walking catfish, Clarias batrachus (Linnaeus)

Clarias batrachus is the most important cultured catfish species in Southeast Asia. Its albino form, a species native to eastern India and Southeast Asia, is the usual "walking catfish." In possession of an accessory air-breathing organ, members of its family (Clariidae) are able to remain out of water for extended periods.

Three "walking catfish" have been recorded from California. Minckley (1973, p. 185) referred to "... a specimen taken in California, from the 'All American Canal, west of Yuma,' by an unknown fisherman, and deposited at Arizona State University." Shapovalov et al. (1981, p. 29) reported that a "... specimen was taken by an angler from Legg Lake, Los Angeles County (J.A. St. Amant, pers. commun.)." Finally, Courtenay et al. (1986, p. 681) referred to a specimen from "... the San Joaquin River, Sacramento County, California (M.R. Brittan, pers. comm.)."

The "walking catfish" has become established in certain Florida waters to the detriment of game fishes, and this same species has been sold by tropical fish dealers in California for some time. Because these fish could cause problems if released into California waters, the Fish and Game Commission included four genera of the family Clariidae on the restricted species list in Section 671 of Title 14 (California Code of Regulations). The Department also issued a leaflet to assist in the identification of these fishes (Fisk 1969b). The restricted genera of Clariidae are: Clarias, Heteropneustes, Heterobranchus, and Dinotopterus. Members of the family are native to most of Africa, India, southern China, and portions of Indonesia.

5.19. Grass pickerel, Esox americanus vermiculatus Lesueur

The California Acclimatization Society suggested the introduction of "pickerel" into California as early as 1871, and was promised the ova of this fish by S.R. Throckmorton of the California Fish Commission (Alta California, 13 February 1871). We do not know the identity of these "pickerel" but suspect that the Society was referring to northern pike, *Esox lucius*.[143] In any case, they were not introduced at the time.

In December 1891, however, the U.S. Fish Commission brought in a rather large shipment of eastern fishes from Quincy, Illinois. Included among these were yearling fish presumed to be northern pike (E. lucius) . Four hundred were planted in Lake Cuyamaca, San Diego County, and 100 were placed in the Feather River near Gridley (U.S. Fish Commission Report for 1892, p. LXVIII and LXXXVII). With respect to the Lake Cuyamaca plant, two San Diego newspapers reported "pike 800" as planted by the U.S. Fish Commission in 1891 (see "Striped bass" in the "Hypothetical Introductions" section).

Some of these fish survived for a time in Cuyamaca and may even have reproduced. A number of small ones were taken in January 1896, and David Starr Jordan identified one of them as "Lucius vermiculatus"; i.e. grass pickerel (Smith 1896). The California Fish Commission Report for 1895–96, p. 29, listed "500 pickerel (Lucius vermiculatus) " as planted in both Lake Cuyamaca and the Feather River in 1891.

It should be noted that the Report of the California Fish Commission (1895–96) probably listed these plants as Lucius vermiculatus (i.e. grass pickerel) simply because of the identification by Jordan. That is, all of the esocids planted in both Cuyamaca and the Feather river were termed grass pickerel by the State on the basis of identification of a single specimen. We are not completely sure that the California Fish Commissioner's Report (1895–96) on the subject should be followed.

First of all, there is some question as to whether Jordan's identification was correct. We do not question his competence as an ichthyologist, but—as pointed out elsewhere in this paper—he was not infallible. Secondly, not only do many fishermen believe that grass pickerel are the young of northern pike, but at early stages the two species appear very similar even to ichthyologists. Third, without saying where they were caught, Smith (1896, p. 438) said that a San Diego angler "... recently caught with rod and line 2 pike that weighed 2 pounds apiece." If these fish were caught in Cuyamaca (as we assume), and the angler was truthful, their size would indicate that they were true pike (Esox lucius) rather than E. americanus. It seems entirely possible, therefore, that either species was planted or that both grass pickerel and northern pike were included in the 1891 plants.

[143] In Smith (1896), "pike" and "pickerel" are synonymous.

In any event, esocids vanished from Lake Cuyamaca. Without providing any dates or the actual identity of the species, J.W. Sefton, Jr., wrote that the "pike" vanished first from the Lake followed by the "striped bass" (letter of 1 March 1943 to W.A.D.). See also the account of the northern pike and that of the "striped bass" under Hypothetical Introductions.

In 1896, the State took 21 adult "pickerel" from Lake Cuyamaca and distributed them as follows: Battle Creek (3); Clear Lake (3); Hanford Lake, Tulare County (6); Sacramento River near Corning (2); Sweetwater Reservoir, San Diego County (7). Six others were taken to ponds at Sisson (Mt. Shasta) Hatchery (California Fish Commission Report for 1895–96, p. 73). Shebley (1917) stated that six "pike" were delivered at Sisson in 1895 and were later exhibited at the Mechanic's Fair in San Francisco where they died. Apparently these were fish from Cuyamaca.

There appear to be no records of further capture of grass pickerel after 1896. Evermann and Clark (1931) listed a record for Lake Cuyamaca in 1926, but this is an evident misprint for 1896. CFG (1918) said that this Lake was "bone dry" in 1914. Captain L.T. Ward of the Division of Fish and Game said that all the fish were destroyed when Cuyamaca went dry, and that the only kind of fish then present were "black bass" (letter of 9 June 1941 to W.A.D.).

The grass or mud pickerel was considered to be an "obnoxious little predator" in the eastern United States by Hubbs and Eschmeyer (1938), and most anglers consider it to be a nuisance fish to be discarded. At a much earlier time, Mather (1909) was even more vehement: "Speaking as a fishculturist, I would, if I could, exterminate every pike, pickerel and muscalonge in the waters of the earth...."

Regardless of such opinions, the grass pickerel rarely reaches a length of over 30 cm, and California can consider itself fortunate that this fish did not survive.

If indeed true northern pike were planted, the reader is referred to that section.

5.20. Muskellunge, Esox masquinongy Mitchill

The largest of the pike family (Esocidae), the muskellunge is native to the United States east of the Rockies and central and eastern Canada (where it is called the maskinonge). It is a highly predacious fish and the respected quarry of specialized anglers.

An account of the use of sea lions (probably Zalophus californianus) to control carp in Lake Merced, San Francisco County, in the 1890s is found in the section on common carp. During the course of this "experiment," muskellunge were also stocked in the Lake as a means of biological control.[144] In May 1893,

[144] Attempts at biological control of carp using muskellunge are still continuing. The State of Washington recently planted a lake containing nuisance carp with "tiger muskies," which are hybrids of muskellunge and northern pike (Jackson 1994).

93,000 muskellunge fry were received from Chautauqua Lake, New York, and planted in Lake Merced (California Fish Commission Report for 1893–94, p. 29–30, 75; Smith 1896, p. 437–438).[145]

This planting was undertaken by the California Fish Commission at the solicitation of the owners of the Lake, the Spring Valley Water Company, who had heard of the voracity of this species. The New York Fish Commission provided the muskellunge fry, and the U.S. Fish Commission defrayed a portion of the costs of transportation as did the Company. The State of California was at liberty to take stock from the lake for plantings elsewhere.

Smith (1896) stated that carp control was probably the chief reason for the muskellunge's importation. However, the State Fish Commissioners made no allusion to this in first describing its introduction. They merely said that it was in pursuance of their efforts "... toward securing a continued increase of the food fishes of the State...." (California Fish Commission Report for 1893–94, p. 29). Whatever the reason may have been, the efforts were not successful. Two years after planting, the lake was dragged with seines. No carp were taken. The muskellunge had vanished. The sea lions had grown thin (Smith 1896, p. 396).

It is believed that the plant in Lake Merced was the only plant of muskellunge in California, although there are other reports of its presence in the state. The statement of CFG (1922b) that "experimental hatching" of muskellunge has been undertaken by the State is believed to be erroneous. Roush (1976, p. 112) stated that he had "... learned ... of the catch of a four foot muskellunge two hundred feet offshore at Zephr [sic] Cove [Lake Tahoe] ... in the summer of 1969 or 1970." We believe that this record is quite false: i) because competent observers at Lake Tahoe have never found muskellunge there, and ii) because of Roush's (1976) statement, p. 109, that "Some might speculate that sturgeons, gars, even muskellunge were introduced with the lake trout when large loads of small fish were brought out from the Great Lakes...." The lake trout were, of course, planted in the Lake as fry from eggs from the Great Lakes but were hatched in the West.

Fishing for muskellunge is a rather specialized endeavor, and successful introduction of this species would probably have brought few dividends to California anglers.

[145] Shebley (1922) listed 100,000 muskellunge fry as planted in 1893, but was apparently referring to the number of fry which were shipped. The U.S. Fish Commission Report for 1893 stated that 91,000 fry were deposited in California waters (p. 9); that only 60,000 were planted in Lake Merced; and that 31,000 were also placed in Lake Pilarcitos near Milbrae (p. 138). This latter lake (a reservoir in San Mateo County) was also a source of water for the Spring Valley Water Company, and Smith (1896) stated that carp existed in great abundance there. (Smith said "Palisadas Lake," but this obviously refers to Pilarcitos.) All other authors known to us mention only the planting of Lake Merced.

5.21. Ayu, Plecoglossus altivelis Temminck & Schlegel

With respect to the ayu, sweetfish, or Japanese dwarf salmon, as early as 1901 Jordan and Evermann (1902) stated, "Perhaps more than any other foreign fish whatsoever it merits introduction into the waters of the United States, especially into those of California." Later, David Starr Jordan (1905, 1925) advised that this small salmon-like fish of Japan "... should be introduced into clear short streams throughout the temperate zones." He ranked it as one of the noted food fishes of the world, saying, "... it is ... so very delicate in its taste and odor that one who tastes it crisply fried or broiled feels that he has never tasted real fish before." Given praise like this and sponsors like these, it is not surprising that a state as prone to make introductions as has been California has attempted to acclimatize this fish.

Through efforts of Jordan, the State received a small shipment of ayu eggs from Japan in 1919 (E.D. 1920b), and subsequent shipments in 1920 (Bryant 1921b) and 1926 (Shebley 1927a; Bennett 1929). All of these eggs arrived in very poor condition. A few were hatched according to CFG (1921) but none of the fry survived to be planted.[146]

More than 30 years later, the Fish and Game Commission granted approval to again import ayu eggs into California at the request of A. Calhoun, Chief of the State's Inland Fisheries Branch. This time, the eggs were made available by a Japanese philanthropist, and sent to J.W. DeWitt, Professor of Fisheries at Humboldt State University, who supervised their hatching and planting, and carried on this work in connection with the International Friendship Charitable Foundation of Gardena, a number of scientists and governmental agencies in Japan, and the Department of Fish and Game (OC 1961, 1967a). DeWitt had previously observed its habitat, fishing for ayu, and its culture in Japan, and corroborated Jordan's impression of its taste. Ishida (1979) said that the ayu has been relished as a food since ancient times. The rationale for its introduction was that it is a plant-eating fish which was expected to thrive in coastal trout streams in sections of only marginal suitability with respect to temperature for salmonoid fishes.

Plants of ayu were made annually from 1961 through 1965. About 3,845,000 eggs and fry were stocked during this period: 200,000 eggs and fry in Morris Lake, Mendocino County; 395,000 eggs in Ruth Reservoir, Trinity County; and 3,250,000 eggs and fry in the Eel River below Fortuna, Humboldt County. No survivors were reported (Shapovalov et al. 1981, based on pers. comm. from J.W. DeWitt). Courtenay et al. (1991) and Williams and Jennings (1991) included this

[146] Crawford (1926) stated that probably the first successful attempt to hatch the eggs of the ayu in the United States occurred at the University of Washington's College of Fisheries on 14 December 1922 following receipt of eggs from Japan, but since none of the fry lived for more than a few days, his account of introduction is as academic as that of CFG (1921).

fish in a list of exotic fish collected in California, but the source of their information is unknown and is considered dubious.

The ayu is a small salmon-like fish native to the clear streams of Japan and Taiwan. It attains a length of from 8 to 15 inches and dies after spawning. It is fished for there using cormorants or by anglers using decoys (wooden plugs that look like adults) or very small artificial lures or natural baits such as live fish (ayu flies are about size No. 20). In Japan, its catch usually tops that of all other fish in inland waters. It is also farmed commercially in Japan, and some of the commercial ponds are open to fishing.

The last introductions of ayu were apparently made because the fish was both a noncompetitive food and game fish suitable for somewhat warm coastal streams. We, however, do not know why it should be considered an addition to waters which already contain small (young) native rainbow or steelhead trout.

5.22. Lake whitefish, Coregonus clupeaformis (Mitchill)

As early as 1871, the California Acclimatization Society had suggested that the whitefish be introduced into California, and in the 1870s and 1880s a determined effort was made by the State to establish the lake whitefish of the Great Lakes in California as a food fish (Alta California, 13 February 1871). The species is distributed largely in cold, deep lakes in North America from the Atlantic west across Canada and the northern United States.

The first introduction of the lake whitefish (under the scientific name of Coregonus albus) was made by J.G. Woodbury in Clear Lake, Lake County. Then assistant to Livingston Stone, he and Stone selected a site on Kelsey Creek near Clear Lake where whitefish eggs, furnished to the California Fish Commission by S.F. Baird of the U.S. Fish Commission, were hatched. An article in California Academy of Sciences (1875, p. 86) indicated that these eggs came from northern lakes of New York. The Kelsey Creek site, one of the first State fish hatcheries, the Clear Lake Experimental Hatchery, was selected for this specific purpose (Stone 1874c, 1876b; Leitritz 1970).

Tabulation of the individual shipment records of the U.S. Fish Commission indicated that over 3,000,000 whitefish eggs were sent to California from 1872 through 1883 (see the various U.S. Fish Commission Reports for this period, especially the Report for 1873 of the initial plant). On the other hand, published summaries of egg distribution indicated that a much smaller number of whitefish eggs were shipped to California during these years. See, for example, U.S. Fish Commission Report for 1875–76, p. 27; *Ibid.* 1885, p. CXI. Shebley (1917) stated that less than 1,500,000 whitefish eggs were furnished the State during the period of 1872–83, but this figure is difficult to reconcile with the figure of 1,640,500 whitefish which he listed as having been "distributed" in California during the same period (Shebley 1922). (We do not believe that the eggs of whitefish augment themselves.) Previous tables of the California Fish Commission show that 1,640,500 lake whitefish were "planted."

Neither the number of eggs received nor the number of fry planted is of real importance, however. The shipment of whitefish eggs was attended with difficulty, and it is certain that many of the eggs arrived dead or in poor condition. For example, the first lot of eggs was packed in sponges, and all of the eggs were dead upon arrival at Clear Lake (Stone 1876b). Another account (U.S. Fish Commission Report for 1872 and 1873, p. xxvi) said the eggs were smothered by sawdust and killed by excessive cold. Conversely, one allotment of 300,000 eggs in January 1878 "... had been so kindly cared for by the agents of the express company that they were placed near the stove in the car, and were killed by the heat on the journey" (California Fish Commission Report for 1878–79, p. 9). One can find similar references in other State and Federal reports.

As with the published history of many other introduced fishes, there is little agreement as to the number of fish or the dates when they were planted. The year 1883 is the last date that Shebley (1922) gave for the stocking of this species. The U.S. Fish Commission Report for 1895, p. 67, listed a shipment of 25,000 whitefish eggs to the California Fish Commission in 1894 or 1895, but there seems to be no record of its fate.

The fry of the lake whitefish were planted in lakes and in at least one stream in the Central Valley, the Sierra Nevada, and near the coast. Waters as markedly different as Lake Tahoe (high, deep, and oligotrophic), Clear Lake (low-lying, shallow, and even at that time probably mesotrophic), and Tulare Lake (low, very shallow, and very warm) were among those planted. Not all of the specific localities which were stocked are listed here because the species failed to establish itself. Detailed lists of plants will be found in: U.S. Fish Commission Report for 1881, p. 1048; Clark 1883, p. 582–583; Smiley 1884a, p. 912; Smith 1896, p. 428.

There were reports of their capture in all three of the lakes named above (California Fish Commission Report for 1874–75, p. 7; *Ibid.* 1875–76, p. 23; *Ibid.* 1876–77, p. 23; *Ibid.* 1878–79, p. 9; *Ibid.* 1880, p. 9; U.S. Fish Commission Report for 1873–74 and 1874–75, p. XXXII). None of these reports can be considered to be reliable, however, and some were quite misleading. For example, no less an authority than S.F. Baird (1874b) told members of the American Fish Culturists' Association that California had successfully planted whitefish (sent, of course, by his U.S. Fish Commission) in the waters of Clear Lake. That Clear Lake was "planted" is true, but the implication that the whitefish survived is untrue.

Native mountain whitefish (Prosopium williamsoni) were then abundant in the Tahoe region; they may have been mistaken for the lake whitefish. The Sacramento squawfish, which is native to lowland waters such as Clear and Tulare lakes, is commonly called "whitefish." This misleading name (common to many cyprinids and used both in Europe and the United States) was also in vogue during the 19th century and reports of "whitefish" may well have alluded to cyprinids. See, for example, p. 19 of the California Fish Commission Report for 1874–75.

The California Fish Commissioners (probably still flushed with the successful introduction of the shad) prophesied in their Report for 1878–79, that Tahoe, Tulare, and Clear lakes "... will, without doubt, within a few years, be stocked with this valuable fish."[147] At a later date, however, they evidenced strong doubts, saying, "... not one has been taken, as far as the Commissioners have any knowledge," and in their Report for 1893–94, p. 73, they admitted to complete failure. Meanwhile, at least up to 1890, some Californians were a bit dubious of the success of the whitefish, but contented themselves by saying that it "... is not yet profitably abundant" (Bancroft 1890).

The character of many of the waters planted makes it extremely unlikely that lake whitefish could have survived for any length of time. No further attempts were ever made to acclimatize this species.

5.23. Bonneville cisco, Prosopium gemmifer (Snyder)

The Bonneville cisco is one of three species of whitefish endemic to Bear Lake, Utah-Idaho (Sigler and Sigler 1987). It provides a short-lived (about 16 days) but very popular winter dip-net sport fishery. The most numerous fish in the Lake, it is a significant component in the diet of both cutthroat and lake trout. Attempts were made, all apparently unsuccessful, to establish cisco in Lake Tahoe, California-Nevada; Twin Lakes, Colorado; high mountain lakes in South Dakota; and Flaming Gorge Reservoir, Utah-Wyoming (Sigler and Sigler 1987).

A serious attempt was made during the 1964–66 period to establish Prosopium gemmifer in Lake Tahoe, an oligotrophic lake of 499 km^2 and maximum depth of 501 m on the border of California and Nevada at an altitude of 1897 m. The Lake once swarmed with Lahontan cutthroat trout, but this native species has disappeared from the Lake, and the sport fishery replaced largely by the introduced lake trout and rainbow trout. These efforts were chronicled by Frantz and Cordone (1965, 1967). The Nevada Fish and Game Commission (now the Nevada Division of Wildlife) and the California Department of Fish and Game collected spawning Bonneville ciscos in January of 1964, 1965, and 1966 and transported them to Lake Tahoe. of the 21,506 adults collected, 15,888 were released alive. Improved handling in the third year saw only four fish lost in transit and 5096 were released in excellent condition.

In addition, 250,000 fertilized eggs from ciscos spawned at Bear Lake were transported to Lake Tahoe where 205,000 were scattered in shallow rocky areas

[147] The Fish Commissioners' lack of knowledge concerning the species is well illustrated in their Report of 1883–84, p. 9, in which they speak of it as "... a land-locked shad."

in the Lake. "The remainder were held at Nevada's Verdi Fish Hatchery, and those that survived were released later [in Tahoe] as eyed eggs (25,000) and alevins (3,000)" (Frantz and Cordone 1967).

The primary purpose of the cisco introduction into Lake Tahoe was to improve the forage supply for lake trout, particularly during the summer months when both species would be confined to deeper, colder waters. During the remainder of the year, the presence of ciscos in the pelagic zone was expected to provide enhanced forage for rainbow trout. The Bonneville cisco, did not, however, become established in Lake Tahoe and, except for rumored sightings by anglers, no confirmed specimens were ever recorded.

5.24. Atlantic salmon, Salmo salar Linnaeus

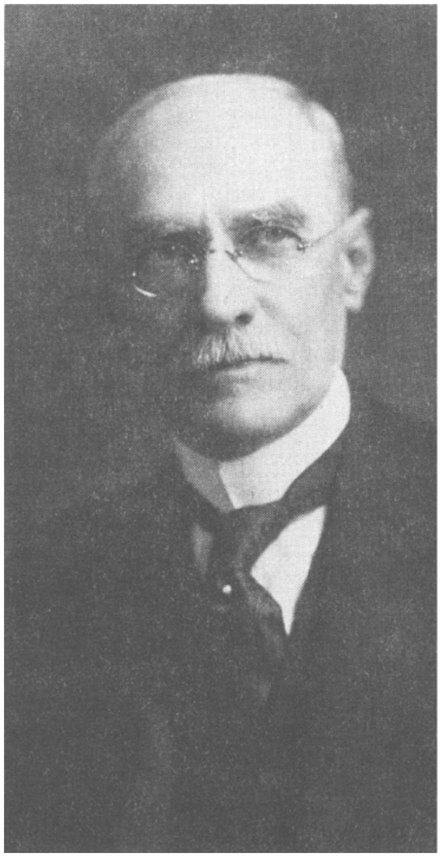
Some systematists have considered the anadromous form and the landlocked form of the Atlantic salmon to be different species or at least subspecies. Thus, in Europe, landlocked forms have been reported from lakes in Finland, Sweden, and Norway, and in the United States and Canada from several waters. In the United States the freshwater form has generally been termed "landlocked salmon." In Canada it is often called "ouananiche." Today, ichthyologists generally agree (Behnke 1988 is an example) that the anadromous and the freshwater forms are one and the same species. We accept this opinion, but since the two forms have been introduced into the waters of California as different species or subspecies, their history will be related separately.[148]

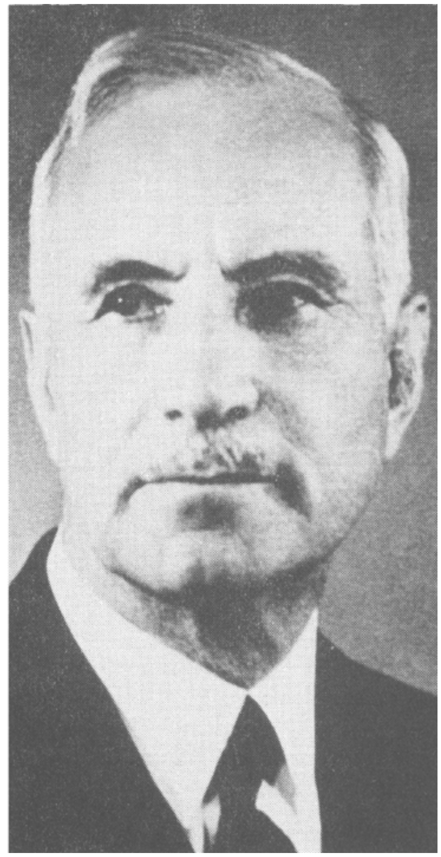
5.24.1. Anadromous form

The first attempt to establish the anadromous or sea-run form of this famous game and food fish in California was in 1874. At the request of the California Fish Commission, Livingston Stone brought 305 small Atlantic salmon from the Penobscot River, Maine, to California where they were planted in the Sacramento River near Redding in June 1874 (California Fish Commission Report for 1874–75, p. 5; U.S. Fish Commission Report for 1875–76, p. 45; Stone 1875, 1876a).

The quick success of the American shad was, no doubt, responsible for such sanguine remarks as, "None of the Eastern Salmon have been seen ... without doubt they have gone to the ocean, not to return until the Spring of eighteen hundred and seventy-six, when we hope to hear of some of them being caught on

[148] Many of the early fishery people placed great dependence upon the United States manual of fish culture in which the "Atlantic salmon" and the "landlocked salmon" were accorded different treatment. Although saying that the sea-going and landlocked forms were generally considered to be the same species, it also said that from the fish culturist's point of view the two forms were as widely separated in their habits and growth as any two species of the same family (Atkins 1898, p. 67).





their return for the purpose of spawning. It will be interesting to learn, in after years, if they will cross with the Sacramento Salmon and produce a new variety" (California Fish Commission Report for 1874–75, p. 6). This optimism was unrewarded; the spring of 1876 came and passed but no "Eastern Salmon" were taken.

The U.S. Fish Commission made the next attempt at the introduction of Atlantic salmon in July 1891 when about 194,000 fish, hatched at its Fort Gaston Station, were liberated into the Trinity River. The superintendent of the hatchery stated that the salmon did well and that some of them reached full size and were caught by Indians. No other reports of their survival are known (Smith 1896, p. 430).

Smith (1896) felt that the plant in the Sacramento River was too small to warrant the expectation of success, and we feel that in a stream like the Trinity—at that time swarming with native Pacific salmon and steelhead rainbow trout (Oncorhynchus mykiss irideus) —reports of the survival of Atlantic salmon were very dubious.

This was, surprisingly enough, the last planting until 1929 when efforts were resumed to establish the species by "experimental plantings." Plants by the State totalling about 146,000 Atlantic salmon were recorded for 1929, 1930, 1931, and 1932 by the California Division of Fish and Game. Eggs, received from the U.S. Bureau of Fisheries and from Canada, were hatched at several State hatcheries and the fish planted in coastal streams. These streams included branches of the Smith River, Redwood Creek, Cold Creek, Russian River, and waters in Santa Cruz County. Beaver Creek, a tributary of the Klamath River, was also stocked. Some of these fish were about 5 to 6 inches in length.[149]

Although the earlier plants of Atlantic salmon were made to provide another food fish for our waters, the last plants were an attempt to establish it as a game fish. "It has been claimed by some that if the fish succeeds ... it will prove more of a sporting fish than the native steelhead" (CFG 1929a).

No opportunity for the substantiation of this claim, sometimes a source of spirited argument between eastern and western anglers, ever arose. Snyder (1934a, p. 25) said, "Nothing of a positive nature has been learned relating to the results of recent introductions of Atlantic salmon in Klamath and Smith rivers. In the few cases where fish purported to be of that species were subjected to examination, they proved to be rainbow steelhead, cutthroat steelhead and humpback

[149] Complete records of the 1929–32 stocking are to be found only in the unpublished records of the then California Division of Fish and Game. Major published accounts of the attempt are as follows: CFG 1929a; CFG 1930c, p. 159; CFG 1930b, p. 181; CFG 1932a, p. 58; CFG 1932b, p. 267; Shebley 1931, p. 59; Snyder 1932, p. 24; California Division of Fish and Game Report for 1928–30, p. 163; Ibid. 1930–32, p. 107, 110, 112; Ibid. 1932–34, p. 82–83-A, 82–83-C.

salmon." For some years one heard of Atlantic salmon being taken in the Klamath River, but no specimens were seen by competent workers.[150]

These were the last plants made in California public waters of the anadromous form of the Atlantic salmon. Late in 1969, however, the California Department of Fish and Game received an offer from the Iceland Ministry of Fisheries to supply eggs of Salmo salar for introduction into California (Menchen 1970; OC 1970a). Before accepting the offer—as the State undoubtedly once would—it commissioned a report on the species primarily as an aid in determining the feasibility of introducing the species into California. The report, by Menchen (1970), concluded, "... California cannot provide the type of habitat to which the Atlantic salmon is adapted. Past attempts at introducing it into California have been unsuccessful and the expectation of a successful introduction is so remote that it does not warrant the effort and expense of an attempt." As a result, the State expressed gratitude for the offer but turned it down. We agree with the conclusion, although we do not agree entirely with Menchen (1970) that the Atlantic salmon always requires water as cold as that indicated nor that it closely resembles California's native steelhead rainbow trout.

Atlantic salmon were also raised successfully in the mid-1960s at Humboldt State College Hatchery from eggs obtained from Maine, but none of these fish were introduced into California streams (Menchen 1970).

The anadromous form of the Atlantic salmon is important in commercial aquaculture, but apparently only when reared in ocean net pens. At one time or another, it has been so cultured in Maine, Washington, British Columbia, the Maritime Provinces of Canada, Scotland, Chile, and the Scandinavian countries. Such operations are usually successful and tend to be increasing in number, but not in California where only pond culture of Atlantic salmon is authorized.

In 1984 and 1986, the California Fish and Game Commission granted two aquaculturists the authority to import Atlantic salmon for commercial purposes and gave the Department permission to authorize additional such operations. Among other attendant conditions, the ponds and other facilities had to be designed and situated to prevent escape of fish into public waters. Since then, on an almost annual basis, many thousands of Atlantic salmon eggs have been imported from Finland, New Brunswick, or the State of Washington by private aquaculturists located near Red Bluff, Bodega Bay, Susanville, and Santa Cruz. Although such operations can be expected to continue, financial success has yet to be demonstrated.

The commercial salmon fishing industry is a strong impediment to the development of Atlantic salmon culture in California. A proposal to establish a large

[150] Clemens and Wilby (1949) listed Atlantic salmon as ranging from northern California to Vancouver Island, Canada, apparently as a result of its introduction into British Columbia, but its presence on the Pacific Coast at that time is very doubtful.

aquaculture facility to rear this species in Del Norte County in the mid-1980s led to the passage of industry-sponsored legislation in 1988 rendering the activity illegal. Section 2118(j) and Sections 15600–15605, added to the Fish and Game Code in 1988, prohibit the possession of live Atlantic salmon or its roe in the Smith River watershed. The industry is also behind the law (Fish and Game Code Sections 15900–15908) which restricts ocean ranching to a single operation in Santa Cruz County, even though only native anadromous salmonids are involved. The industry is concerned about competition from domesticated stocks with their wild-caught salmon. Fears about new diseases and parasites are also expressed.

The threat from net pen rearing of Atlantic salmon has been expressed in the literature. Black (1994) summarized literature reporting the presence of cultured Atlantic salmon in British Columbia and adjacent natural waters. The identification of a female Atlantic salmon caught by a commercial troller off southeastern Alaska on 20 July 1990 was confirmed by morphology, meristics, and protein electrophoresis (Wing et al. 1992). In August 1991, identification was confirmed for another five Atlantic salmon harvested by commercial fishermen off southeastern Alaska. These fish were believed to be escapees from commercial aquaculture net pens located in Puget Sound and off southern British Columbia. Wing et al. (1992) were concerned that, despite the historical lack of success of attempts to establish Atlantic salmon in western North America, the repeated escape of large numbers from net pens might succeed in their establishment. Black (1994) suggested, however, that "biotic resistance" may preclude the establishment of the Atlantic salmon outside of its native range.

5.24.2. *Landlocked form*

As explained above, the freshwater (nonanadromous) form of the Atlantic salmon has been classified as a separate species or subspecies; e.g. Salmo sebago, S. salar sebago, or S. salar ouananiche. Its introduction into California was quite different than that of the anadromous form.

Young of this form, a notable Maine game fish, but also resident in other northeastern states and in the Maritime Provinces of Canada, have been planted in California lakes at both high and low altitudes and in some streams; e.g. Lake Tahoe and Tulare Lake. These plants began in 1978 and were continued at intervals until the early part of the next century often under the name of "Schoodic salmon".[151] The date of the last plant made has not been determined.

[151] The Grand or Schoodic lakes are at the headwaters of the St. Croix River which is in both Maine and New Brunswick. The U.S. Fish Commission Report for 1875–76, p. 919, lists 5000 eggs of the "Schoodic" or "Landlocked" salmon as being distributed to California in 1876. This record was not listed by Smith (1896) or other authors, and it seems probable to us that the first plant of this form was not made until two years later.

The last record of "distribution" of landlocked salmon as given by Shebley (1922) was in 1913. However, the California Fish Commission Report for 1912–14, p. 86, showed that this record applied to fish retained in the ponds at Sisson (Mt. Shasta) Hatchery and not to planted ones. Four hundred fifty yearling landlocked salmon were still present at Sisson as late as 1 July 1916 (Shebley 1916c, p. 56). Their disposal is unknown, and with but one exception there seems to be no record of their presence in California fish hatcheries after that date. On page 63 of the April 1923 issue of California Fish and Game, there is an undated photograph of a landlocked salmon in an aquarium at Mt. Shasta Hatchery. The caption states, "This is the last individual of the species left at any state [California] hatchery."

According to U.S. Fish Commission Reports covering the period from 1876 through 1906, 245,000 landlocked salmon eggs were sent to California. All of these eggs, with the exception of 10,000 allotted to the Country Club of San Francisco in 1895 and 5000 allotted to California only in 1876, were sent to the State's Fish Commission. The latter seems to have had no other source of landlocked salmon eggs nor to have received any after 1906. The maximum number of landlocked salmon reported by any one author (Shebley 1922) to have been planted by California during the entire period of 1871–1913 was 138,885. As has been indicated before, and since Shebley seems to have listed some entire shipments of eggs as "fish" distributed, this figure is undoubtedly too high. It seems futile to try to state with any degree of accuracy just how many landlocked salmon were ever planted in the state as the records are at such variance. (Persistent students may pursue this inquiry by referring to the reports of the U.S. and California Fish Commissions which cover the 1876–1916 period.)

of more real interest is the original introduction by the California Fish Commission which exhibits some of the thinking that prompted this entire history. The first known plants made of this form in California by the State were in 1878. In January 1878, the California Fish Commission received 50,000 eggs of the landlocked salmon from the hatching house of the U.S. Fish Commission on Grand Lake Stream in Maine. The California Commission said (p. 12), "As they are natives of the cold lakes of Maine we have thought the most appropriate places for the distribution of the young fish would be in our mountain lakes; but, for purposes of testing their fitness to thrive in warmer waters, a portion were also distributed to lakes in the valley and on the coast...." The Commission also spoke of these fish furnishing a large amount of food and yielding sport to anglers (California Fish Commission Report for 1878–79). The records of this Report and those of the U.S. Fish Commission (Atkins 1879, p. 832) do not agree exactly, but it is obvious that about one-third of the fry were planted in coldwater lakes such as Donner and Echo, while the rest of the fry were planted in waters where today no one would expect them to survive. For example, about 15,000 were planted in Tulare Lake in the San Joaquin Valley; others in small waters at low altitudes.

Because of the many discrepancies in figures, both between the two agencies, or within the same agency in different reports, or even within the same report on different pages, it seems futile to detail further plants of landlocked salmon in California.

Plants of landlocked Atlantic salmon were also made by the Nevada Fish Commission during the last century in Lake Tahoe and some Sierran streams which originate in California (Smith 1896). Possibly the U.S. Fish Commission also planted this fish in California waters.[152]

Smith (1896), who summarized the reports of the landlocked salmon's success through 1895, said that catches of landlocked salmon were reported from Independence Lake in 1891, and from lakes on the preserve of the Country Club of San Francisco in Marin County in 1895. The only other published record of landlocked salmon being taken in Marin County known to us is that of Whitney (1906) who said (p. 235): "I was a member of a California club which was the first, and I think as yet the only one to introduce this fish [landlocked salmon] in that state, in Crescent Lake, on the Shafter ranch at Point Reyes, where they grew with unparalleled rapidity in less than three years, from six inches to four and five pounds in weight..." On p. 458, he said, "In California, near Point Reyes, in Crystal Lake, controlled by the Country Club, and where I aided some years ago in introducing the landlocked salmon, they gained most incredibly in weight in less than four years...." On p. 458–459, he described the "red salamander lizard" known as the "water devil" and thought that the eating of these accounted for the inferior flavor of the landlocked salmon. A cattle herder told him that the "water devils" had been diminished since the landlocked salmon had been put in. Whitney's book is a most rambling account. Despite his remarks on "water devils," which were probably California newts (Taricha torosa) , he had previously ascribed a disagreeable flavor of the landlocked salmon at the Country Club to their subsistence on caddis larvae. Unfortunately, he provided no dates of capture, but his account of the survival and capture of landlocked salmon does tally with that of Smith (1896). Furthermore, landlocked salmon (as well as whitefish) are recorded as being sent to "Shafter" in Marin County in 1881 (California Fish Commission Report for 1881–82, p. 18).

[152] Smith (1896) stated that the Federal station at Fort Gaston received 20,000 eggs from Maine in 1890, but that he did not know of the disposition of the fry. According to the U.S. Fish Commission Report for 1895, p. 62, landlocked salmon were distributed by the U.S. Commission in California in extremely large numbers during the fiscal year 1894–95. Fry totalling 852,500 in number and 332,000 adults or yearlings were listed as planted in the Trinity River, Mad River, and Redwood Creek. These numbers may be in error, since the same report, p. 9, states that the entire national distribution of landlocked salmon during this period amounted to only 144,680 eggs and fish.

There was indeed a Country Club of San Francisco (also known as the Bear Valley Country Club) founded in 1890 by a group of San Francisco "gentlemen" or "elite" citizens (and helped by P. Shafter) who built a large establishment or "retreat" on the ridge separating Bear Valley Creek from Coast Creek in what is now part of the Point Reyes National Seashore. These men (according to Mason 1972) were "... the moneyed and the famous of the Bay Area of their time." Some of the nonnative plants introduced by the members still remain, and the Club was also responsible for other introductions, notably "English" pheasant (Grinnell et al. 1918). They made some of the early introductions of fish into the five natural lakes that exist nearby as part of the Shafter Ranch property. Theodore Roosevelt and Ignaz Paderewski were among the Club's guests. Crescent Lake is now called Crystal Lake (pers. comm. by D. Livingston of the National Park Service via State biologist W.A. Evans, 1992; Mason 1972, 1976).

Despite these reports of the presence and capture of landlocked salmon, there are also known to have been plants of Salmo trutta (under the names of "Von Behr trout," "Loch Leven," and "Brown trout") at the Country Club by the U.S. Fish Commission during the 1894–96 period. Since brown trout can be confused with Atlantic salmon, the record of landlocked salmon taken here is somewhat dubious.

Other reports of their survival in California are also dubious. C.A. Vogelsang of the California Fish Commission, reporting circa 1903 on a consignment of 1899, said, "... occasional specimens [of landlocked salmon] are taken ..." in Lake Tahoe and "... two or three specimens ... the largest weighing about 4 pounds ..." were taken circa 1902 from a lake in Placer County near Cisco (Titcomb 1904). Apparently, these fish were assumed to be the results of plants made in 1899. The California Fish Commission Report for 1903–04, p. 48, stated that a few specimens from plants made in 1895 were taken from a lake near Cisco and/or from a small lake in the Tahoe region. Local resident W. Terrill has also informed W.A.D. (pers. comm. of 24 May 1941) that he once took several fish purported to be landlocked salmon from a lake near Cisco. Possibly there was survival of landlocked salmon in some of these mountain waters. However, it is known that the term was sometimes applied to large salmonids caught in the high montane Lahontan lakes of California even before they were stocked with Salmo salar. It is possible that this mistake persisted for many years after Seth Green (circa 1872) pronounced "large brown and silver trout of Lake Tahoe and the Truckee River not to be trout but species of the sebago or land-locked salmon" (California Fish Commission Report for 1870–71, p. 45).[153] It is also known that the so-called "landlocked salmon" reported caught in Clear Lake were found to be "steelhead" by David Starr Jordan (California Fish Commission Report for 1903–04, p. 56–57).

[153] These fish were Lahontan cutthroat trout.

No reports of the capture of landlocked Atlantic salmon in California have been reported for many years, and even the anglers responsible for the reports detailed above may have confused this form with some other large salmonid. It is known, however, that Salmo salar will survive when transplanted to the Pacific Coast. For example, it furnishes a "different" type of angling in Hosmer Lake, Oregon. However, very little success with the stocking of this fish has been obtained either in the eastern United States or Canada (Needham 1938d, p. 17; Dymond 1955, p. 549).

The Department of Fish and Game nearly stocked landlocked Atlantic salmon in Gold Lake, Sierra County, in the late 1960s. This species was selected as a test species for the Department's Trophy Trout Program, and stocking was approved by the Deputy Director on 23 May 1968. The purpose of the program was to improve fishing in large lakes and reservoirs for a variety of species, subspecies, and strains of trout and salmon.

The creation of a California version of Hosmer Lake was envisioned. However, a review of the Oregon situation revealed that the Hosmer Lake Atlantic salmon fishery is hatchery supported and represents the only success out of eight or 10 lakes stocked with this species. In its hatchery phase, the Atlantic salmon requires special care, space, and constant observation. The Department was fearful that a successful Atlantic salmon program would create a demand among anglers that would be difficult to meet and would create costly operational problems for already overburdened trout hatcheries. The Trophy Trout Program concentrated instead on different subspecies and strains of rainbow trout, as well as brown trout, coho salmon, and chinook salmon.

The landlocked Atlantic salmon was dropped from consideration under the Trophy Trout Program and would appear to have no future in California.

5.25. Japanese medaka, Oryzias latipes (Temminck & Schlegel)

The statement by Snyder (1935), "It has been found in San Francisquito Creek," and Coates (1942), "... this fish has been turned loose in ... parts of California, where it is reported to be thriving," are the sole bases for admission of the Japanese medaka to this report.[154] In a conversation with Snyder on 21 March 1943, he told W.A.D. that some of his students at Stanford University had collected one specimen in San Francisquito Creek, Santa Clara County. He did not recall the date or other circumstances. A letter of 3 November 1943 by W.A.D. to Coates of the Department of Tropical Fish at the New York Aquarium, inquiring into his reference to the medaka, received no reply. It is our belief that Coates' knowledge of the introduction was based solely upon Snyder (1935).

[154] These papers are cited in Shapovalov and Dill (1950), Shapovalov et al. (1959), and Shapovalov et al. (1981). The statement concerning the extirpated California population appearing in Courtenay et al. (1991, p. 186) is completely discounted in view of our knowledge.

The medaka is native to mainland China, Taiwan, Japan, and Korea. It has been widely used in Japan as a laboratory animal in various fields of biology, especially developmental biology and genetics. It is also available at goldfish farms and is used as an aquarium fish. It could have been turned loose in San Francisquito Creek very easily as it was once found in local fish farms. Hensley and Courtenay (1980) said that it is apparently established in some ponds in New York.

Small, hardy, oviparous, omnivorous, and prolific, it tolerates water temperatures as low as 1° C and as high as 37–38° C according to Yamamoto (1975) or from above freezing to about 32° C (Axelrod and Schultz 1955). Consequently, it could have survived easily enough in the waters of California, but apparently did not.

5.26. Argentine pearlfish, Cynolebias bellottii Steindachner

The Argentine pearlfish is among the "annual" or "instant" fishes native to Brazil, Argentina, Colombia, Venezuela, and Uruguay (Myers 1952). It usually survives from year to year as eggs buried in the mud or silt of pond-forming depressions, ditches, swamps, etc. The eggs are dependent on a period of dryness for their development, and normally the adults live for less than one year.

Boschi (1957) stated that Cynolebias bellottii is native to "Pools and small rivulets of the Buenos Aires Province, as far as Mar del Plata, south of Entre Rios and Santa Fe. It also occurs in the southern part of Uruguay." In addition, he referred to an A. Bachmann, who reported this species from the Province of Salta and Paraguay. Other than Uruguay and Paraguay, these locations are all in northern Argentina.

In a paper calling attention to insect resistance to pesticides, the toxic hazards of such chemicals to man, and the increasing need for biological control of pests, Hildemann and Walford (1963) described a group of "annual" fishes which they felt held unusual promise for the control of mosquitoes and other aquatic invertebrates. The special merit of these fish lay in their capacity to survive and multiply in impermanent waters where other species of fish would perish. Furthermore, "annual" fishes occupy a wide range of temperate and tropic habitats, the young are voracious, the eggs are easily transportable, and the adults constitute no known hazard to man. Emphasis was placed on the use of Cynolebias bellottii and C. elongatus for trials in temperate climates where seasonal temperature extremes occur.

Two years later, Bay (1965) also suggested that this group of fishes could be a tool for mosquito control. Bay (1966) proposed that "annual" or "instant" fish might be particularly useful in helping to control California's rice-field mosquito problem and conducted studies to determine whether introduction of the Argentine pearlfish would be useful.

Bay (1965, 1966, and 8 December 1978 letter to A.J.C.) described field trials with the Argentine pearlfish. (At different meetings, Fish and Game Commission approval was obtained for the various releases of annual fishes.) During the period 1964–67, small numbers of adult Argentine pearlfish were stocked in study plots at the Riverside campus of the University of California (U.C.) in Riverside County, at the Biggs Rice Experiment Station in Butte County, and at two duck clubs in Kern County. The results were generally unfavorable; eggs were few in number or were in poor condition. Bay (8 December 1978 letter to A.J.C.) concluded, "In my estimation, it is extremely unlikely that any C. bellottii became established in California as a result of efforts in which I was directly involved. I might add that by the time we made these final releases in Kern County, I was no longer very optimistic about the probability of these fish effecting satisfactory mosquito control in the sites under consideration. While we did find them quite effective in some confined experimental situations, in larger ponds the fish concentrated too much on benthos and not enough on mosquito larvae. In most situations where they might have been used, I believe that better control could be effected by periodic replacement of Gambusia affinis. " However, the Argentine pearlfish in one of the study plots at U.C. Riverside sustained itself for six years before dying out (Legner and Medved 1972).

Additional releases of the Argentine pearlfish may have been made at sites in Orange and/or Los Angeles counties, but no details are available, and there is no evidence of survival and establishment. Courtenay et al. (1991) listed this species as formerly established in California and then extirpated, and Williams and Jennings (1991) listed it as collected in California, but we do not consider that it was an inhabitant of open waters.

Although the Argentine pearlfish or one of its relatives might appear to be a promising addition to some waters in California as a means of mosquito control, it seems to have no other use for man. Present indications are that it has no use here, although Coykendall (1980) stated that the pearlfishes may find a niche in California mosquito control, possibly in ricefields or vernal pools.

5.27. Blackfin pearlfish, Cynolebias nigripinnis Regan

The blackfin pearlfish is another species of "annual" fish from the coastal plain of South America, especially Uruguay. Myers (1952) referred to C. nigripinnis, "From 'La Plata,' which probably means Buenos Aires Province." Like other "annual" fishes, it occurs in mud-bottomed puddles, ponds, ditches, and swamps. Following Fish and Game Commission approval, it was introduced into California to assess its ability to control mosquitoes, especially in the ricefields of northern California.

E.C. Bay (8 December 1978 letter to A.J.C.) conducted either laboratory studies or outdoor plot studies with blackfin pearlfish at the Agricultural Experiment

Station at the University of California at Riverside. The experiments, which lasted only one year (1964–65), were terminated because the species failed to reproduce adequately, was too subject to diseases, and was intolerant of cold temperatures.

Despite the negative results from the Riverside experiments, the Butte County Mosquito Abatement District conducted several tests with the blackfin pearlfish at the Biggs Rice Experiment Station in Butte County (Hiscox et al. 1974; 13 March 1979 letter from K.J. Hiscox to A.J.C.). In 1973 and 1974, fry were stocked in ponds and rice paddies at the Station and in an adjacent vernal pool. The results were negative; no fish survived, and the tests were terminated. Coykendall (1980) corroborated this information, adding that the blackfin survived through the summer in California ricefields and was able to overwinter outside. Despite the statements concerning its former establishment in California by Courtenay et al. (1991) and Williams and Jennings (1991), we do not consider that it was an inhabitant of open waters.

Aside from use in the aquarium trade, this species has no future in California.

5.28. Rio pearlfish, Cynolebias whitei Myers

The Rio pearlfish is another species of "annual" fish from the coastal plain of South America. Myers (1952) reported it from Brazil from the "State of Rio de Janeiro and Federal District ... swamps 10 or 12 miles north of Cabo Frio, and ponds closer to Rio." Like other "annual" fishes, it occurs in mud-bottomed puddles, ponds, ditches, and swamps. Following Fish and Game Commission approval, it was introduced into California to assess its ability to control mosquitoes, especially in ricefields.

E.C. Bay (8 December 1978 letter to A.J.C.) conducted either laboratory studies or outdoor plot studies with the Rio pearlfish at the Agricultural Experiment Station at the University of California at Riverside. The experiments, which lasted only one year (1964–65), were terminated because the species failed to reproduce adequately, was too subject to diseases, and was intolerant of cold temperatures.

Despite the negative results from the Riverside experiments, the Butte County Mosquito Abatement District conducted several tests with the Rio pearlfish at the Biggs Rice Experiment Station in Butte County (Hiscox et al. 1974; 13 March 1979 letter from K.J. Hiscox to A.J.C). In 1973 and 1974, fry were stocked in ponds and rice paddies at the Station and in an adjacent vernal pool. The results were negative; no fish survived, and the tests were terminated. Coykendall (1980) furnished essentially the same information. Despite the statements concerning its former establishment in California by Courtenay et al. (1991) and Williams and Jennings (1991), we do not consider that it was an inhabitant of open waters.

Aside from use in the aquarium trade, this species has no future in California.

5.29. Nothobranchius guentheri (Pfeffer)

Members of the genus Nothobranchius are closely related to South American "annual" fishes, with most species found in the drier regions of eastern Africa from Uganda to southern Mozambique according to Myers (1952). However, Greenwood (1966, p. 96) maintained, "This genus is widely distributed in Africa; its range extends from Somaliland to Natal and from the Great Lakes to northern Nigeria, with species in the Seychelles and Zanzibar." Bailey (1972) stated, "Nothobranchius guentheri is found in seasonal pools and streams in the coastal region of Tanzania."

E.C. Bay (8 December 1978 letter to A.J.C.), following Fish and Game Commission approval, released N. guentheri into study plots at the Agricultural Experiment Station at the University of California at Riverside. The experiment lasted only one year (1964–65) and was terminated, apparently because N. guentheri was intolerant of the low water temperatures encountered.

As far as we know, no further releases of N. guentheri were made in California, and it has no future in this state except perhaps as an aquarium species.

5.30. Guppy, Poecilia reticulata Peters

The guppy is native to coastal streams from Venezuela east to the Caribbean waters. This live-bearing "topminnow" is so prolific that it has been termed the "millions fish." Rarely exceeding 5 cm in length, named after the Rev. R.J. Lechmere Guppy, President of the Scientific Association of Trinidad, this is a popular aquarium fish which has been domesticated for about 100 years and was known for many years as Lebistes reticulatus.

It has been introduced into many subtropical and tropical countries for mosquito control, and has been considered for annual replacement in mild climates of California for the same purpose. At Riverside, it has been found that it can be stocked as early as 1 April and in some years will survive until late December, particularly in polluted sites (Mallars and Fowler 1970).

Because of its widespread use and popularity as an aquarium fish, the guppy has no doubt been released in public waters on numerous occasions. Its inability to withstand cold temperatures (below about 52°F.) is surely responsible for the lack of established populations in California. Here it was first found in a portion of the Westminster flood control channel in Orange County sometime between the period of 12 April and 20 July 1968 along with other ornamental fishes (St. Amant and Hoover 1969). The reporters believed that the place of origin of the guppy was a goldfish farm in Westminster.

The California Fish and Game Commission approved the importation of the guppy twice in 1968 to control mosquitoes. Since then numerous releases have been made for this purpose. Information on file in the Department's Inland Fisheries Division in Sacramento, as well as Coykendall (1980), refer to releases of guppies: in dairy and poultry waste lagoons in San Bernardino County; mosquito abatement district ponds in Orange, Riverside, Tulare, and Kings counties; and in sewage treatment facilities in the cities of Chico, Oroville, Davis, Lodi, and Burbank. Guppies are able to survive in sewage ponds with high levels of organic wastes and other pollutants, but they seldom overwinter there.

Moyle (1976b, p. 52) attributed the presence of guppies in sewage treatment plants to releases by pet-fish owners. This may have occurred, but most likely their presence is the result of official stocking for mosquito control.

Like other poeciliids introduced outside their native ranges, the guppy has had a negative impact on endemic fishes. In generally unsuccessful efforts to control mosquitoes, the guppy has established populations in many tropical areas.[155] The impacts on native fishes are summarized by Courtenay and Meffe (1989). An example of the problem is expressed by Arthington and Lloyd (1989) who predicted, "... the widely distributed carnivorous guppy, Poecilia reticulata, may prove just as troublesome [to the endemic fish communities of Australia and New Zealand] as G. affinis. "

The tiny guppy will not live on a permanent basis except in the warmest waters of California and these are very limited.

5.31. Green swordtail, Xiphophorus helleri Heckel

The green swordtail, native to the Atlantic slope of Middle America, is an ornamental fish used in aquariums.

It is recorded as having been found in a portion of the Westminster flood control channel during the period of 12 April–20 July 1968 by St. Amant and Hoover (1969), who believed that its place of origin was a goldfish farm in Westminster, Orange County. Courtenay et al. (1986, p. 691) said, "It has also been collected in a drainage canal near Oasis, Mono County, and near Mecca, Riverside County, but that neither population appears to be established (Mearns 1975)." They were mistaken in saying "Mono County" when Riverside County was meant. The Mearns (1975) collection consisted of a single specimen taken from an irrigation canal 1 mile south of Mecca. The Oasis location is based on a personal communication from J.A. St. Amant, who maintained that X. helleri had been released at Avenue 82 near Highway 86 in the Coachella Valley, a site about 4 miles east of Oasis.

Hubbs et al. (1979) listed this species among the "Introduced Fishes not Known to Occur at Present in California," and Shapovalov et al. (1981), following the combined advice of all the California authors mentioned above, did not list it as an established species in California

[155] However, in a comparison of guppies, mosquitofish, and Amargosa pupfish, Castleberry and Cech (1990) declared, "Guppies appear to be the best choice for mosquito control in wastewater marshes ... guppies established higher population densities than mosquitofish and pupfish, and this seemed to result in better mosquito control."

5.32. Southern platyfish, Xiphophorus maculatus (Günther)

The southern platyfish, native to Mexico and Central America, and often kept as an ornamental fish, was collected from a portion of the Westminster flood control channel in Orange County during the period of 12 April–20 July 1968 (St. Amant and Hoover 1969). The collectors believed that the place of origin of this fish was a goldfish farm in Westminster. It was not found there in collections made in December 1980 (pers. comm. by M.H. Horn) according to Courtenay et al. (1986) and is believed to have disappeared.

This platy or moonfish, formerly known as Platypoecilius maculatus, will live in moderately warm water, say 18° C, but generally requires water of about 27° C. Establishment in California waters is not likely.

5.33. Variable platyfish, Xiphophorus variatus (Meek)

St. Amant and Sharp (1971) collected about 200 adult and juvenile variable platyfish, a native of Mexico, on 24 December 1969 in the Avenue 82 Drain Ditch, 4 miles north of Oasis, Riverside County. Additional specimens of this fish were collected from the same location by J.A. and M. St. Amant on 7 January 1970.[156] These two collections were the first verified record that X. variatus was established in California, although St. Amant and Hoover (1969) had collected this same species in the Westminster flood control channel (Orange County) in 1968, and J.A. St. Amant had collected it in the same area in 1970. The owner of a tropical fish farm adjacent to the Avenue 82 Drain Ditch said that the platys had escaped from one of his ponds about 1956. A different tropical fish farm was the source of the Westminster platys.

According to Shapovalov et al. (1981), the California population of the variable platyfish has since died out, and Courtenay et al. (1986) also thought so. However, during a spring 1991 survey to assess the status of the desert pupfish, Lau and Boehm (1991) collected 17 variable platyfish from the Johnson Street drain (tributary to the Salton Sea in Riverside County). Despite intensive sampling with baited minnow traps in numerous drains and tributaries to the Salton Sea, as well as in shoreline pools of the Sea, X. variatus were taken in only this one locality. Subsequent intensive sampling of Salton Sea drains, including surveys as recent as 1994, uncovered only a single specimen taken from Buchanan Avenue drain south of Avenue 64 in a 1992 survey (A.A. Schoenherr of Fullerton College, 26 September 1994 pers. comm.).

This relative of the common swordtail of aquarists demands warm water, and owing to its small size would never enter into the California fauna as either a food or game fish.

[156] However, none was collected by Mearns (1975) at this site in 1974.

5.34. Brook silverside, Labidesthes sicculus (Cope)

The brook silverside, a resident of the central and southern United States, is both a forage fish and a bait fish. It has basically a one-year life cycle.

Concerns about nuisance midge concentrations and blooms of bluegreen algae at Clear Lake in Lake County led to the establishment of the inland silverside in this highly productive and popular body of water. Not widely known, however, is the fact that another atherinid, the brook silverside, was also brought into California for these purposes.

The Fish and Game Commission, at its January 1963 meeting, granted authority to the Lake County Mosquito Abatement District to import the brook silverside into California. The program was described by Cook (1968). The fish were obtained from Ohio, apparently in 1964, and were released in isolated, experimental ponds in the vicinity of Lakeport. The experiments were considered successful, and at its August 1967 meeting, the Commission approved the District's request to release brook silverside into Upper and Lower Blue Lakes in Lake County. However, although they reproduced and did well in one experimental pond for three years, they died from unknown causes and none were released into the Lakes.

Given the abundance and rapid spread of the inland silverside in California and controversies surrounding its impact on sport and nongame fishes, it is not surprising that the brook silverside received no further consideration.

5.35. Rock bass, Ambloplites rupestris (Rafinesque)

The rock bass, a panfish, is native to southeastern Canada and central and eastern United States.

On 12 June 1874, four adult rock bass brought by Livingston Stone from the Missisquoi River, Vermont, were planted in Napa Creek (California Fish Commission Report for 1874–75, p. 5; Stone 1875; Stone 1876a, p. 477). Smith (1896), Shebley (1917), and Evermann and Clark (1931) all concurred in saying that there were no known results from this plant and list no other reports of this species.

However, both the U.S. Fish Commission Report for 1892, p. LXVIII and LXXXVI, and the California Fish Commission Report for 1895–96, p. 29, listed a further distribution of this species in California in 1891. Yearlings from Quincy, Illinois, were said to have been brought out by the U.S. Commission and planted as follows: 100 in the Feather River near Gridley; and 400 in Lake Cuyamaca, San Diego County. In 1896, a representative of the State reported that he had found large numbers of all the fish planted in Cuyamaca in 1891 (the others reported planted by the U.S. Commission were black bass, catfish, yellow perch, and pike) except rock bass and crappies (California Fish Commission Report for 1895–96, p. 29). There are no further reports of the rock bass in Cuyamaca. Moreover, San Diegan newspaper accounts of the U.S. Fish Commission's plant of 1891 in Lake Cuyamaca did not list rock bass among those species planted. (See "Striped bass" in the section titled "Hypothetical Introductions.")

One other record of a plant of rock bass in California is known to us. W. Toms (then a warden for the Division of Fish and Game) planted eight "rock bass" on 6 January 1917 in a pond on upper Cottonwood Creek, San Diego County, near Lake Morena. These fish had been secured from an exhibit of the U.S. Bureau of Fisheries at the San Diego Exposition. As far as is known, the plant was not successful (letter of State game warden E.H. Glidden to W.A.D. 16 February 1943 and Glidden's notes).

Neale (1931a) also said that rock bass were introduced into California in 1891 from Illinois. His further statement, "The rock bass have not thrived so abundantly as other members of the family [Centrarchidae] and but very few are found in waters where there are no other bass," indicated that the species survived. (Both this sentence and Neale's somewhat similar one with respect to the presence of the yellow perch seem rather ambiguous. We interpret them, in part, as meaning that these two fishes are usually—if not always—to be found in waters which contain black bass.)

The *Aquarium Journal* (1934), after referring to the introduction into California of the rock bass in 1891, said, "It has not ... increased to any great extent. Occasionally, one is captured in some of our streams and specimens have been sent to the Aquarium [Steinhart in San Francisco] for identification." Finally, in a footnote to a table showing the number of fish rescued in California during 1936–41, Woodhull (1943) said that the record of about half a million warmouth bass might include a very few rock bass.

The statements by Neale (1931a), the *Aquarium Journal* (1934), and possibly by Woodhull (1943)—for those who read footnotes—appear to be the only major published bases for the assumption by other authors that rock bass are (or have been) present in California waters. We believe that the *Aquarium Journal* (1934) report was based on misidentification, and inquiries at the Steinhart Aquarium as to its validity proved fruitless.

It is true that members of the State fish rescue crews (of which Neale was a strong advocate) have reported the occurrence of the rock bass in the Central Valley, and one can find it listed in published records of rescued fish. For example, 113,902 "Rock Bass" are listed as having been rescued from six counties in 1937 (California Division of Fish and Game Report for 1936–38, p. 96–97-F). However, it is known that some of the California rescue workers have confused it with the warmouth, and the last time the term "Rock Bass" was used in the State fish rescue records was 1938.[157] Furthermore, in a personal communication, A. Woodard, who conducted fish rescue work and acted as Foreman of the State teams for many years, told W.A.D. that the old rescue workers were "ordered" to record "rock bass" even if they were warmouth. Nevertheless, he also told him

[157] See also the account of the warmouth.

that the true rock bass used to be found in the Central Valley, but—like the yellow perch—it vanished before 1930, especially as the waters became more turbid. Questioning after 1930 of State workers familiar with fish rescue operations (M.W. Brown, C.H. Freyschlag, and C.A. Woodhull) always elicited the same reply; i.e. that they had never seen a rock bass.

In some parts of the State, the so-called "rock bass" of fishermen has proved to be the green sunfish (Lepomis cyanellus) which often hangs around rocky places. It may also be of some interest to note that the white bass (Morone chrysops) has, under a formerly used scientific name, *Roccus chrysops*, been known in some early U.S. Fish Bulletins as "Rock Bass"; that in the southeastern United States, the warmouth is sometimes called the "rock bass" (Cloutman and Olmsted 1983); and that early issues of the U.S. Fish Commission Reports called it the "red-eye perch."

We conclude by saying that we have been unable to find a single verifiable record of the present occurrence of this species in California.

5.36. Walleye, Stizostedion vitreum (Mitchill)

The walleye, primarily native to the northern states and well east of California in the United States and Canada, is an excellent food and game fish, and the largest member of the perch family.

As early as 1871, under the name of "worklike pike," later to be corrected to "walleye pike," the California Acclimatization Society planned to introduce it to California (Alta California, 13 February 1871, 14 February 1871) but did not bring it in.

Under the name of "wall-eyed pike," "glass-eyed pike," "glass-eyed perch," or "yellow pikeperch," Livingston Stone did plant 16 adults from the Missiquoi River, Vermont, in the Sacramento River near Sacramento in June 1874. One was reported to have been taken by an angler in a slough of the River shortly thereafter, but this is the only report on the outcome of the original plant (California Fish Commission Report for 1874–75, p. 5; Stone 1875; Stone 1876a, p. 447). The State Fish Commission later evidenced a desire to make more plants of the walleye to reduce carp in Clear and Blue lakes, and applied to the U.S. Fish Commission for shipments (California Fish Commission Reports for 1895–96, p. 31; *Ibid* 1897–98, p. 33).[158] However, no walleye were imported at the time.

In 1959, the State did, however, import the walleye again. In exchange for rainbow trout and steelhead eggs, 1,080,000 walleye eggs were imported from Minnesota to control bluegill and support other game fish in southern California reservoirs. The eggs were placed in deep, temperature-controlled jars at the mouth

[158] More sophisticated attempts to use walleyes for biological control are now in vogue. The State of Washington has recently planted a lake with sterile walleyes in hopes that they will control panfish populations rather than use the chemical agent, rotenone (Jackson 1994).

of the Santa Ana River northeast of Redlands, some were placed in Casitas Reservoir, Ventura County, and others taken to the State's rearing facility at Chino to grow to a larger size (California Department of Fish and Game, Press Release 7 [20] of 15 May 1959).

The recent history of walleye introduction into California was summarized by Miller (1967c) and further summarized by Shapovalov et al. (1981, p. 34) as follows: "The second attempt spanned the years 1959 to 1963, when the California Department of Fish and Game, through the cooperation of the Minnesota Conservation Department, secured large numbers of eggs from walleye captured in the Detroit River, Minnesota. About 5,350,000 fry and 34,590 fingerlings were stocked in five southern California warmwater reservoirs in 1959, 1960, 1962, and 1963. These plants were successful in that good survival and growth were experienced, but anticipated angling benefits did not accrue and the program was abandoned. Natural spawning did not take place and the original plants gradually died out." The reservoirs stocked were: Cachuma, Santa Barbara County; Casitas, Ventura County; Puddingstone, Los Angeles County; and San Vicente and El Capitan, San Diego County. Shapovalov (1965) recorded the walleye as an established form in California, but dropped it from his later (1970) list of introduced forms as in the list by Shapovalov et al. 1981.

In view of its history of introduction and subsequent fate, there appears to be no good reason for further attempts with this species.

5.37. Green guapote, Cichlasoma beani (Jordan)

The green guapote is native to tropical Latin America. It is a lesser known member of the same genus to which the Jack Dempsey (C. octofasciatum) belongs and which has also been found in wild waters of California.

A well-established population of this species was found on 16 August 1974 in a pond above Putah Creek (a tributary of the Sacramento River) in Solano County by A.D. Castro, an aquarist with the California Academy of Sciences. A seine haul netted both adults and young from several spawnings as well as a large number of fathead minnows. Castro felt that the guapote had been introduced illegally with a plan to attempt aquaculture with a potential food fish. He also felt that the green guapote was a tough, hardy fish that was aggressive enough to out-compete native species, and might eventually work down Putah Creek and thence to the Delta. However, a representative of the Department of Fish and Game who visited the pond (the date is uncertain but appeared to be 1975) could not find any live fish in it, and it was assumed that a low water level and cold weather (there was ice around the edges of the pond) had killed the population (Castro 1984).

Information provided by Shapovalov et al. (1981) on the occurrence of this fish differs somewhat from the article by Castro (who was the collector). They say that the population was discovered in 1975, refer to "ponds," say that identification of the green guapote was made by W.I. Follett, that sampling in 1979 did not uncover any specimens, that some of the "ponds" were dry, and that their statements are based on personal communications with A.D. Castro and State biologist R.L. Reavis.

5.38. Jack Dempsey, Cichlasoma octofasciatum (Regan)

The Jack Dempsey is native to the Atlantic slope drainages of Mexico and Honduras. Three specimens of this popular Latin American aquarium fish (sometimes called C. biocellatum) were taken from Lafayette Creek, Contra Costa County, in April 1986 by State biologist F. Gray. The fish were identified by C.C. Swift, Associate Curator, Ichthyology, of the Los Angeles Museum of Natural History. Subsequent collecting by Gray did not turn up more of this species. It is presumed that the fish had been turned loose by an aquarist.

This is a hardy and pugnacious fish which is carnivorous and, in aquaria, an uprooter of plants. Although it can tolerate some salinity and, therefore, might spread to the Delta, it usually requires a water temperature of 24–26° C to breed. It is unlikely that it could establish itself in northern California.

5.39. Angelfish, Pterophyllum sp

Angelfish, South American fish of the genus Pterophyllum, have long been popular with aquarists. There are at least three species and they have been confused by hobbyists. The "scalare" Pterophyllum scalare, P. eimeki, and P. altum are among the species kept in aquariums.

St. Amant (1966a) found a single angelfish (Pterophyllum eimeki) in a small pond 5 miles north of the Salton Sea, Imperial County, in January 1964. A tropical fish farm was located directly below the pond. Members of this genus were also collected from a portion of the Westminster flood control channel, Orange County, during the period of 12 April–20 July 1968 (St. Amant and Hoover 1969). The reporters believed that the place of origin of Pterophyllum sp. was a goldfish farm in Westminster which handled angelfish.

While angelfish survive well in captivity, they require heated water for continued life and reproduction. They would not become established in California.

5.40. Tautog, Tautoga onitis (Linnaeus)

Only one marine fish has ever been purposefully introduced into California's oceanic waters, although the introduction of a good many has been contemplated. The tautog, a food fish of the Atlantic Coast of the United States, was one of the earliest fish introductions into California.[159]

Twenty-three small tautog were placed in San Francisco Bay or an inlet of the Bay near Oakland in June 1874 by Livingston Stone who had obtained them

[159] Brown (1850) erroneously stated that the tautog was found in San Francisco Bay. His assumption was that it was native to the area.

from Woods Hole, Massachusetts (California Fish Commission Report for 1874–75, p. 5; Stone 1875, 1876a). Shebley (1922) listed 300 tautog as "distributed" in California in that year, but as the previous reports and that of Smith (1896) say that only 23 were planted, he is probably incorrect. These somewhat confusing statements are compounded by a report by Dunn (1889), written in 1887, who suggested that tautog be introduced to the Pacific Coast, and said that the late Mr. Throckmorton (one of the three first Fish Commissioners for California) had told him that some tautog were sent probably 10 years ago, and that he had put them in the waters of San Antonio Creek near Oakland. The tautog is an estuarial-dependent fish but certainly not a freshwater fish.

The California Fish Commission's Report for 1876–77 said that some tautog had been reported as seen in the San Francisco market, but the report seems dubious.

Plants of four more tautog in 1896 and 525 in 1897 were recorded in the California Fish Commission Report for 1897–98 (table preceding p. 49), and on p. 8 it said, "... the National [Fish] Commission ... has ... since our last report made ... plants of ... Tautog—Monterey Bay and Farallones—570." The latter report was, except for the plant in Monterey Bay, corroborated by the U.S. Fish Commission which stated that in July 1897, 566 tautog, 4 to 10 inches long, were planted in the Pacific Ocean near the Farallon Islands (Ravenel 1899, p. XXXIII).

There have been no reports of survival since the first dubious ones, and it seems certain that the tautog has never been established in either California or other Pacific coastal waters. Furthermore, it is very doubtful if this coastal bottomfish would have added anything to the already rich Californian marine fauna.

6. HYPOTHETICAL INTRODUCTIONS

6.1. Mexican tetra, Astyanax mexicanus (Filippi)

The Mexican tetra is an aggressive little fish belonging to a family (Characidae) primarily native to the southern hemisphere; i.e. Latin America and Africa. The species extends from Mexico into southern Texas and New Mexico. It has a reputation as being very destructive to other fishes.

Recorded by Evans and Douglas (1950) from bait tanks along the lower Colorado River, Miller (1952) also discussed its presence there. Minckley (1973) stated that it appeared to have reproduced in the lower Colorado River but his locale seemed to be Arizona and not California.

At least as late as 1970, St. Amant and Hoover (1971, p. 1) considered that this species was "... the one member of the Characidae family found free living in California." Evidence for this belief was provided by St. Amant (1967, p. 13) who based his opinion on a personal communication with C.L. Hubbs, who in turn based his opinion on a letter of 1966 from W.I. Follett of the California Academy of Sciences, who at that time believed that the species was established in California. Hubbs et al. (1979) did not, however, list this species in their list of native and introduced fishes which were established in California, listing it only as one of the fishes introduced into California but not known to exist there now. Furthermore, in 1980, both Follett and L.J. Dempster agreed with us that even this inference was so slight that this tetra should be dropped from any list of fishes actually introduced into the public waters of California (Shapovalov et al. 1981).

We conclude that the Mexican tetra was never actually known to have been introduced into California waters, but that its establishment might have been harmful to resident stocks.

6.2. Flat bullhead, Ameiurus platycephalus (Girard)

In a list of the fishes of Clear Lake, Lake County, based on a short survey in 1925, Coleman (1930) recorded "The Brown spotted Cat—Ameiurus platycephalus, Girard. A variety known to fishermen which is becoming quite common." Since he also listed Ameiurus nebulosus, it is evident that he believed this to be a different species. However, he gave no details of its introduction, and the many years of study of Clear Lake by more competent fishery biologists have never revealed the presence of this species. We consider that it was never a resident of California.

6.3. "Striped bass"

In 1891, the U.S. Fish Commission sent out a shipment of fish from Illinois to California. Most of the fish from the shipment were planted in Lake Cuyamaca, San Diego County, one of the first storage reservoirs in the state.[160] Although two reports of the U.S. Fish Commission and that of the California Fish Commission (1895–96) differ somewhat, at least the following species appear in all governmental lists of the 1891 Cuyamaca plants: catfish, black bass, crappie, yellow perch, and pike. (Plants of individual species are discussed elsewhere.)

However, accounts which appeared in San Diego newspapers of 7 December 1891, not only differed from the governmental reports as to the species and number of fish of each species said to have been stocked in Lake Cuyamaca, but added another form, the "striped bass," and did not mention the "rock bass" (recorded in the U.S. Fish Commission Report for 1892) nor the "warmouth bass" (Smith 1896). Both the *San Diegan* and the *San Diego Union* of 7 December 1891 provided identical information as to the species and numbers stocked: "black bass 1500, croppie 200, pike 800, catfish 200, sunfish 300, ringed [yellow] perch 7000, striped bass 200."

[160] Skinner (1962, p. 207) erroneously stated that Lake Cuyamaca was in Santa Barbara County. There is a Lake Cuyama in this County; apparently Skinner confused the two.

Regardless of the differences in the numbers given above with those provided in the Reports of the United States or California Fish Commissions, nor the absence of either rock bass or warmouth bass from the newspaper accounts, the question remains—to what species did the fish termed "striped bass" belong? We have several theories on the subject. First of all, it is highly doubtful that any shipment of fish from Illinois (Mississippi drainage) would include the striped bass, *Morone saxatilis*. The true striped bass is an anadromous fish which was already present in California, and at the time was shipped in brackish or salt water. Secondly, in at least one area of the United States, namely the Lake Champlain, Vermont, area, it was reported that the largemouth bass was sometimes known locally as the "striped bass." This theory, like the first, is discounted because this term is not used in Illinois, and because "black bass" were also recorded for the Cuyamaca plant. Third, since newspaper accounts usually place dependence upon what was told their reporters, in this case either by the recipient or by the Federal employee in charge of the shipment (who in turn had informed the recipient), we believe it likely that the "striped bass" was either believed to be a "rock bass" or that it was a freshwater *Morone* such as the white bass (M. chrysops) or yellow bass (M. mississippiensis) . Our reasoning follows. The striped bass (M. saxatilis) is often called the rockfish in the east, and the term "rock bass" may well have been turned into "striped bass." Or, equally plausible to us, the "striped bass" of the newspapers may have been one of the other *Morone*. At early stages they all bear stripes and are sometimes even termed "striped bass." We shall probably never know what they were, since they are supposed to have disappeared from the Lake.[161]

Incidentally, we are indebted to J.W. Sefton, Jr., who not only sent us copies of the newspaper accounts, but provided us with additional information on Lake Cuyamaca and the plant of 1891, which casts light on the reasons behind some fish introductions into California. He has informed us that his father, then President of the San Diego Flume Company, which brought water from Lake Cuyamaca to San Diego, applied to the U.S. Fish Commission for the shipment of fishes. The shipment arrived on 6 December 1891 accompanied by R. Johnson and six assistants, and it was probably Johnson who was the source of the information concerning the shipment. (The reports of the U.S. Fish Commission did not necessarily reflect the statements of Johnson to Sefton or to the newspapers.) According to the newspaper accounts following the plant, Lake Cuyamaca would

[161] Most if not all of the fish distributed from Illinois at that time originated from the Quincy Station which started in 1877–78 using fish rescued from the Mississippi drainage. Among the fish rescued were the young of "crappie," "basses," "pike-perch," "yellow perch," and "spotted catfish." According to the U.S. Fish Commission Report for the year ending 30 June 1892, Quincy did distribute 2115 "white bass" and 9884 "sunfish" to the United States, but none of these were listed for California.

serve as a center of distribution for other applicants in southern California, supply the markets of San Diego with freshwater fish in abundance, and afford Sefton many hours of sport with rod and reel.

After the train was unloaded, the cans were taken by wagon to Lake Cuyamaca where the fish were released. According to J.W. Sefton, Jr., only "largemouth bass" and "sun fish or bluegill" were left in Cuyamaca in 1943, and these may have been fish rescued from the lake. The lake which has a small watershed has gone dry on several occasions as has been noted elsewhere. In fact, an early name for the Lake was La Laguna Que Se Seca (the lake which dries up).

6.4. Bluespotted sunfish, Enneacanthus gloriosus (Holbrook)

"This species is listed in the accession list for Steinhart Aquarium [in San Francisco] as having been collected on March 1931, in the vicinity of Willows, California. The identification was made by A. Seale, but the specimens were not saved. We believe this to be a misidentification" (Shapovalov and Dill 1950).

There is no specific record of this eastern sunfish ever having been introduced into California. There is no other record, published or unpublished, of its occurrence in California. There is no evidence that it has ever been seen in the state by any of the State fish rescue workers, who have seen literally thousands of sunfish, nor by anyone except Seale.

6.5. Longear sunfish, Lepomis megalotis (Rafinesque)

The longear sunfish is found from the Dakotas east to the St. Lawrence River and south to Florida and Texas.

We have only one example of its possible occurrence in California and even that is highly dubious. The record rests upon two specimens found in the collections of the California Academy of Sciences accompanied by a label reading "9556. Lepomis humilis, Camp Taylor, Cal., Aug. 2, 1890, Eigenmann." The name Allotis humilis appears on a printed California Academy of Sciences label on which 9556 is entered as "Indiana University Coll. No." The specimens themselves were identified by C.L. Hubbs in 1943 and reidentified by W.I. Follett of the California Academy of Sciences in 1948 as the longear sunfish, Lepomis megalotis megalotis.

Inquiries of Miss Thora Eigenmann, daughter of C.H. Eigenmann, in 1943 elicited the reply that inquiries of her mother indicated that Eigenmann was, indeed, in Camp Taylor, Marin County, in 1890 (pers. comm.). However, careful examination of the labels and the Indiana University catalog led Follett to believe that the "record" of Lepomis megalotis in California should be added to a doubtful list (letter of 14 December 1948 to C.L. Hubbs). We agree with Follett's reasoning, but, since the collection does exist, we have included the name of the longear sunfish here.

We know of no other record of its occurrence and, because of its generally small size, this sunfish would not have been much of an addition to the Californian angling fauna.

6.6. Sheepshead, Archosargus probatocephalus (Walbaum)

In 1947 W.A.D. was presented with the head of a fish said to have been found in a canal 15 miles south of Bakersfield in Kern County by K. Robinson, a resident of Buttonwillow. The specimen was delivered by Warden L. Arnold of the California Division of Fish and Game, and a request for identification was made. It was recognized as the head of a sheepshead; the identification was verified by G.S. Myers of Stanford University. We believe that this was a hoax since Archosargus is a marine fish native to the Atlantic and Gulf coasts.

6.7. "Hawaiian mullet"

Although California already possessed a supply of native striped mullet (Mugil cephalus Linnaeus), her early Fish Commissioners once anticipated a promised "... consignment of the Hawaiian Islands mullet, said to be a superior food fish, which also lives equally well in fresh or salt water" (California Fish Commission Report for 1876–77, p. 25). There seems to be no further mention of this consignment in any periodical unless a statement by W.N. Lockington (1879), which he attributed to one of the first Fish Commissioners, B.B. Redding, refers to it (see below).

The importation of another species of mullet (if it were one) to California seems ill-advised, especially since mullet have never been popular here. Furthermore, the possibility exists that the California Fish Commissioners were really alluding to the milkfish (Chanos chanos) which is said to have been introduced in 1877 as the "awa." The milkfish has a superficial resemblance to a mullet. In 1775, Forsskål even listed Chanos chanos as Mugil chanos, and in more recent times a specimen of Chanos from Baja California found in the San Pedro fish market in 1929 was referred to as a "Mexican mullet" by the fish dealer (Clark 1929).

On the other side of the coin, however, are several observations which indicate that not only were "Hawaiian mullet" introduced into California, but that the oftrepeated report of the milkfish's introduction may be erroneous. They follow: i) In speaking of the milkfish (or awa) the California Fish Commissioners said in their Report of 1876–77, "They are said to be the most valuable food-fish of the Hawaiian Islands, of fine flavor, and thrive in fresh, brackish, and salt water. Where they have access to salt water, they grow to weigh an average of 5 pounds." ii) Such a remark applies generally either to milkfish or mullet, but the statement concerning the market value of this fish is the most important one. We have no figures on fish value in the Hawaiian Islands in 1877, but we do have figures from the first thorough survey of the commercial fisheries of the Islands (made by J.N. Cobb in 1901). In 1900, on the island of Oahu, mullet was ranked first in value in fish catch or about three times the value of milkfish. iii) Cobb (1905) also pointed out that the Hawaiian name for milkfish was "awa" and the name for mullet was "ama-ama." The vernacular name could have been easily confused. iv) A letter from Senator J.F. Miller to S.F. Baird (U.S. Commissioner of Fisheries) suggested the introduction of the "Hawaiian mullet" which "... inhabits the salt water in the harbor of Honolulu, and is propagated and reared in artificial ponds which have been made in the salt marsh lands near that city." He felt that the mullet was a very hardy fish which could be easily transported by steamer to San Francisco and "... no one at Honolulu seemed to doubt that it would do well in California" (Miller 1884). In a footnote to this article, T.H. Bean said, "This is said to be Mugil Chapalii Eyd. & Soul. voy. Bonite, Zool. I, p. 171, pl. 4, fig. 1."[162] v) Further, in discussing some fisheries of Hawaii, Moser (1898, p. CLXIX) stated, "The mullet is the principal marketable fish, and those supplied are largely taken along the reefs; but another source of this species is from the ponds.... The fish-ponds are nearly as old as the peopling of the islands.... There are about a dozen of these ponds in the vicinity of Honolulu ... the fry are driven or transported to these artificial ponds and there raised." There is no mention of what species was meant. vi) Finally, previous to this time, Lockington (1879) discussed some fish termed "Mugil mexicanus (?) Steindacher" taken in the Pacific Ocean near Santa Cruz, California, saying, "... I should not hesitate to pronounce them to be of that species were it not that Mr. B.B. Redding, one of the Fish Commissioners for the State of California, has informed me that about three years ago he placed several (I believe about forty) individuals of a Mugil from the Sandwich Islands, in the Sacramento River, and it is, therefore, possible that the specimens obtained may be some of these or their young." Lockington (1879) also said that the specimens taken agreed "tolerably well" with Mugil cephalus.

The U.S. Fish Commission Report for 1883, p. LXXVI, in discussing "The Mullets (Mugil)," also said, "The experiment has been made by the California fish commissioners of transporting a Sandwich Island [Hawaii] species into that State, although I have no report as to the general result."[163]

It is indeed difficult, therefore, to know whether the California Commissioner's Report of 1876–77 referred to a true mullet (family Mugilidae) or to the milkfish (family Chanidae). Both mullet and milkfish have been cultured traditionally in ancient Hawaiian fish ponds and have sometimes been reared together.

[162] Gosline and Brock (1965) listed "Mugil chaptalii Eydoux and Souleyet as a synonym of Neomyxus chaptalii," but said that it is the mullet of open sandy shores and tide pools and that Mugil cephalus is the form found in mullet ponds.

[163] As has been noted in the Introduction, a certain amount of information on introductions appears to have been passed back and forth either verbally or in unpublished letters. S.F. Baird, who ostensibly wrote this report, was a correspondent with and an admirer of B.B. Redding.

Secondly, none of the writers quoted, except Cobb and Lockington, really knew anything about the characters distinguishing the two. Third, Redding may have used the term "Sacramento River" as a general term for any plants made in the drainage.

We believe that some fish from Hawaii were planted in the waters of California by the California Fish Commissioners, circa 1877. Whether they were "Hawaiian mullet" (probably Mugil cephalus) or milkfish (Chanos chanos) is not clear. In either case, they were native to California, but were planted well north of their usual range. Furthermore, even if they had been mullet, their establishment would have been of no continued value to California. Today, mullet (Mugil) cultured in Hawaii constitute only a small percentage of Hawaii's annual fish consumption, and about 95% of its total consumption of mullet is imported.

6.8. "Gulf butterfish," Peprilus ovatus Horn

Whether or not the gulf butterfish should be listed as "introduced" is open to question.

Under this common and scientific name, Hubbs et al. (1979, p. 31) listed it as one of their "Introduced Fishes Not Known to Occur at Present in California" without further explanation. One assumes that they referred to a Salton Sea introduction, but Walker et al. (1961, p. 78–79) did not list this fish in their table "Known Fish Introductions into the Salton Sea."

However, in a letter to W.A.D. dated 5 October 1962, State biologist P.A. Douglas (one of the principals in obtaining fishes for the Salton Sea) wrote: "... Palometa simillium. About one dozen small specimens of the pompano were mixed with the anchovetta at the time of their introduction in the Salton Sea. The pompano had entered the tuna bait tanks through circulation of the San Diego Bay water, and therefore were undoubtedly local specimens. Condition of these fish at time of release is unknown since they merely flushed in with the other fish."

At this point, one would merely assume that the fish of which Douglas writes was the one now known as the Pacific pompano or Pacific butterfish, Peprilus simillimus, native to California and introduced together with anchoveta (Cetengraulis mysticetus) from San Diego on 23 December 1948 (see Table 2). Since this "butterfish" or "pompano" is native to the coastal waters of California it need not be mentioned here.

However, it is also reported that in a letter titled "Identification of Fishes Collected at the Salton Sea" by State biologist J. Calaprice, dated 5 October 1962, a fish found on the shore of the Sea was identified by C.L. Hubbs and B.W. Walker as "Palometa sp." (letter of J.A. St. Amant to Fisheries Management, Region 5, Department of Fish and Game, 29 October 1963). Copies of St. Amant's letter were sent to both Hubbs and Walker.

Obviously, if the "Palometa sp." identified by Hubbs and Walker, were found after 1961—there is no indication in St. Amant's letter as to when this occurred—it would have been impossible for it to have been included in the list presented by Walker et al. (1961). We believe, however, that Hubbs, despite Douglas's letter of 5 October 1962 (which was in part repeated in St. Amant's letter of 29 October 1963), still assumed that the fish he and Walker identified originated in Mexico and thus was included in the list of 1979 which he compiled together with Follett and Dempster.

Neither Hubbs, Walker, Follett, nor Dempster can be contacted for verification. We believe, however, that the inclusion of the "gulf butterfish" in this list of introduced fishes is highly hypothetical, and Douglas has reiterated that the butterfish of which he wrote was indeed from San Diego (pers. comm. 14 September 1992).

7. FISH WHOSE INTRODUCTION WAS NEVER COMPLETED

7.1. "Nelson's trout," Oncorhynchus mykiss ssp

The rainbow trout, now known as Oncorhynchus mykiss instead of Salmo gairdneri, is, of course, native to California. The so-called "Nelson's trout," "Lower California trout," or "Baja trout," called Salmo nelsoni Evermann when described in 1908, is now considered to be a form of the rainbow living in Baja California, Mexico, one of the southern-most native coastal trouts known from the west coast of North America. Neither Hubbs (1946) nor Follett (1961), who reviewed its affinities and distribution, considered that it had even subspecific status. On the other hand, W.J. Berg, on the basis of genetic studies, said that it contains a unique allele and that it should be called O. m. nelsoni (Berg 1987 and pers. comm.). However, Behnke (1992, p. 195) questioned the taxonomic validity of the subspecific designation.

Regardless of ichthyological opinion, the "Nelson's trout" was at one time considered to be a separate species (Evermann 1908), and was intended for introduction into California as a separate species. For this reason, and because its attempted introduction is an interesting part of California's fishery history, it is included in this paper.

In the hopes of establishing a nonmigratory trout, one which had been prevented by barriers from migration to the sea, which would have purity of strain in the wild state and adaptability to high water temperatures, "Salmo nelsoni" was brought into California by a U.S. Bureau of Fisheries team headed by P.R. Needham. Fifty fish (yearlings and two-year olds) taken from branches of the Santo Domingo River (its mouth about 400 km south of the Mexico/ United States border) in May 1937 were brought to the State's Forest Home Hatchery on Mill Creek, San Bernardino County, on 26 May 1937. The fish apparently did well and some of them were spawned on 17 February 1938 (Needham 1938b, 1938c). Less than a month afterwards, 2–3 March 1938, however, a flood destroyed the Hatchery and probably all of the fish and their eggs were killed or lost (Needham 1938a).

Arrangements were made between the U.S. Bureau of Fisheries and the U.S. Forest Service for another trip to the Santo Domingo River to secure and again acclimatize this Mexican trout in California. On 14 May 1938, a total of 325 "Salmo nelsoni" were taken out by a team headed by Needham. The trout were held temporarily at the Convict Creek Experimental Stream, Mono County, California, by the U.S. Bureau of Fisheries (pers. comm. by State biologist E.P. Pister), and were then taken to Clackamas Hatchery in Oregon, where two years later (1940) they all perished. According to Anon. (1939), the fish taken to Convict Creek were captured in 1939. However, Needham (1955) and Ruiz-Campos and Pister (1995) say that the year was 1938.

The introduction of "Salmo nelsoni" to the United States met with repeated failure. Nevertheless, it did give P.R. Needham the opportunity of some interesting trips (some are related in Needham 1955) and resulted in the issue of at least five papers on the subject. Needham did advance the science of inland fishery biology, especially in California (see Wales 1965). He was, however, a bit of a showman, and the senior author recalls seeing him discomfited only once. This was when H.J. Rayner, who accompanied Needham on the 1937 trip, announced publicly (at a meeting of the Western Society of Naturalists at Stanford University) that he had deliberately produced a nuchal hump on specimens taken from the Santo Domingo drainage in Mexico. See the description of this "hump" on p. 142 of Needham (1938c).

Hubbs (1946) has suggested that the establishment of a rainbow trout in tributaries of Río Santo Domingo may well have resulted from its southward migration during cold periods. He also found nothing in published accounts to justify the separation of "Salmo nelsoni" even as a subspecies from the rainbow trout of California coastal streams. It may be noted that the trout of the Santo Domingo River were first made known by specimens collected in 1902 and recorded by Meek (1904, p. 96) as Salmo irideus, or rainbow trout, now known as Oncorhynchus mykiss. Hubbs (1946) also pointed out that both the expected nonmigratory habits and resistance to warm water of the Mexican trout remained to be thoroughly tested. Despite such statements, Needham persisted in calling the trout of the Río Santo Domingo "Nelson's trout" (although he did lower it to subspecific rank, "Salmo gairdneri nelsoni Evermann") and proposed its introduction to streams in Hawaii (Needham and Welsh 1953). Ruiz-Campos and Pister (1995) have also awarded it subspecific rank, calling it "Oncorhynchus mykiss nelsoni (Evermann)," and giving it the common name "San Pedro Mártir rainbow trout." Nevertheless, as has been said before, regardless of its taxonomic status, an attempt was made to introduce this fish into California as a new species.

It seems probable to us that some of the other rainbow trout now used by the State fulfill all the criteria originally desired when "Salmo nelsoni" was selected for introduction.

7.2. Río Truchas trout, Oncorhynchus mykiss ssp

According to Behnke (1991), the Río Truchas trout, resident in a tributary of the Río San Lorenzo in mainland Mexico, has not yet been classified. He thinks, however, that it may have resulted from hybridization between Mexican golden trout (Oncorhynchus chrysogaster) and the form of rainbow trout (O. mykiss) found in the Río del Presidio drainage of Mexico.

Regardless of its systematic position, an attempt was made to bring trout from the Río Truchas to California in 1957. Two hundred trout from that river, about 240 km southwest of Durango, were flown to California's Fillmore Hatchery, Ventura County, from McNary Hatchery in Arizona as a gift from the U.S. Fish and Wildlife Service. The purpose of this import was to try out a stock adapted to warm water (26.6° C). The fish were about two years away from maturity, and it was considered that it would be four or five years before the experiment could be evaluated (OC 1957b). of 194 received by a California hatchery, the Director of the Department of Fish and Game stated in October 1957 that there were some difficulties in rearing them (Anon. 1958). Needham and Gard (1959, p. 10) generally corroborate this. We do not know the fate of these fish, but believe that they were never planted (see Needham and Gard 1959, p. 16).

7.3. Mountain whitefish, Prosopium williamsoni (Girard)

This whitefish or coregonid is native to Lake Tahoe and Californian streams flowing eastward to the Great Basin and is also native to other western states. It is mentioned here, however, because part of its history is a good example of how the words of a prominent ichthyologist may influence the action of someone who can be instrumental in fish introductions.

In 1908, A.C. Bassett of Menlo Park sent David Starr Jordan, President of Stanford University, a specimen of a fish which he had often caught in the McKenzie River in Lane County, Oregon, and which he called the "Chiselmouth Jack." Jordan, who often "found" new species, thought that it represented a fish new to science. In a letter of 5 September 1908 to C.A. Vogelsang, Chief Deputy of the California Fish Commission, he explained that "... it is undoubtedly a valuable game fish for such streams as the McCloud and the Feather. I would suggest that if possible you send someone up there to get the eggs and hatch them out in the hatchery, and stock some of our streams with it...." In a letter of 11 September 1908, Vogelsang replied, saying in part, "I shall make inquiry of our mutual friend, Mr. A.C. Bassett and if possible get details regarding the country, with a view of sending some one there to see if we can get some of the spawn." In another letter to Vogelsang (14 September 1908), Jordan explained that the chisel-mouth jack "... is clearly not one of the lake species [of coregonids], and should be planted in a swift stream, as for example, the Truckee or the Feather or the McCloud."

The fish was later described by Jordan and Snyder (1909) as Coregonus oregonius from the type collected by Bassett, referring to it by the common name of "Chisel-mouth Jack" or "Chisel Bill." Although noting that it was related to the mountain whitefish, they considered that it was a new species. Snyder, like Jordan, believed that if a form looked different it should probably be given specific status. At a later date, Jordan (1919) even assigned it to a new genus, *Irillion*. He stated that his choice of names for the new genus was from "the merry wild Irillion rejoicing from fields of snow" of Lord Dunsany's dream world.[164] However, Jordan had created his own dream world. Today, the "Chisel-mouth Jack" is considered merely a valid mountain whitefish with a strange "ski-jump" snout on the older specimens, mainly from the McKenzie River (pers. comm. from C.E. Bond of Oregon State University).

Although no action was ever taken to introduce it into California, this is an example of the influence which Jordan and other members of the Stanford school had upon the State agency dealing with fishery matters.

7.4. Weakfish, Cynoscion regalis (Bloch & Schneider)

The weakfish or squeteague is a popular game fish on the east coast, found in the surf, sounds, bays, and estuaries. It can be taken both by bait and on artificial lures.

Livingston Stone had intended to introduce the weakfish to California in 1873 and had secured a consignment from the Atlantic coast of the United States. However, his "aquarium car" was wrecked near Omaha, Nebraska, and another intended introduction by him in 1874 was not made (Stone 1875, 1876a).

In 1951, its entry into California was again recommended, but the Fish and Game Commission turned down its introduction into central California waters. The principal reasons given were that water temperatures in California were too low, insufficient brackish estuarine areas existed here, and it would be in competition with two native sciaenids, the queenfish (Seriphus politus) and white seabass (Atractoscion nobilis) (OC 1951b).

Nebraska is the closest the weakfish has ever come to reaching this state.

7.5. Northern kingfish, Menticirrhus saxatilis (Bloch & Schneider)

"Kingfish" were in the "aquarium car" of Livingston Stone which was wrecked near Omaha, Nebraska, in 1873. It had been intended that they be introduced into Californian waters, but obviously never reached their destination. Another attempt to bring "kingfish" to California was made by Stone in 1874, but this stock died en route (Stone 1875, 1876a, 1876b). It is assumed that these "kingfish"

[164] Lord Dunsany's true name was Edward John Moreton Drax Plunkett.

were Menticirrhus saxatilis as most of Stone's cargo of fish in 1873 had been obtained from the Atlantic coast.

The kingfish belongs to a group commonly called the "whitings." All are small marine shore fishes and have some angling and food value. The kingfish of 1873 was probably sent to California as part of a "Duke's mixture" of fishes and has not been asked for again.

8. FISHES WHOSE INTRODUCTION WAS RECORDED BUT NOT MADE

8.1. Sea lamprey, Petromyzon marinus Linnaeus

Although there is no indication in the article that the sea lamprey was ever introduced into California, the ammocoetes larvae of Petromyzon were recorded from the Russian River, near Healdsburg, by Hartman (1938) in a reputable scientific publication.

The sea lamprey, Petromyzon marinus, occurs in salt water from Greenland to Florida and from Norway to the Mediterranean Sea, ascending fresh water to breed. It invaded the upper Great Lakes, presumably through ship canals or ships, and has been the subject of much research and a vigorous eradication program.

It has never been a resident of California, nor has it ever been introduced into this State. Hartman (1938) recorded it erroneously, and it is suspected that she merely gave this name to the native Pacific lamprey, Lampetra tridentata. [165]

8.2. "Smelt, Leucichthys orcutti"

In 1922–23, J.G. Needham of Cornell University and his son, P.R. Needham, made a biological survey of Lake Elsinore, Riverside County. Their report, primarily a limnological survey based on observations during a residency at Pomona College, was published in the *Journal of Entomology and Zoology* issued by the Pomona College Department of Zoology.

Aside from carp, bluegill, and bass (Micropterus) recorded as present, and "bullheads" (probably Ameiurus) reported, it was said that "A single smelt (Leucichthys orcutti) less than three inches long was picked up at the drift line." In a footnote on p. 35 of their paper, the authors said that identification of the fish species was made by B.W. Evermann of the California Academy of Sciences (Needham and Needham 1925). A summary of their results was published in *California Fish and Game* by CFG (1929b) who compounded (what we shall see to be) an error by terming the smelt "Leurichthys. " To the best of our knowledge,

[165] Unfortunately, O. Hartman, although an outstanding expert on nereid annelids, was not careful in her choice of allied subjects. Thus, for example, she described the introduced Neanthes succinea, a common marine form, as N. saltoni (Hartman 1936) from the Salton Sea, thinking that the Salton Sea was a relict sea. This fact was not recorded by Walker (1961) nor corrected by Hartman, although the error was called to her attention by W.A.D. in 1948.

these are the only references to the presence of either "Leucichthys" or "*Leurichthys*" in California.

We do not know with certainty to what species the Needhams referred. However, we surmise that they referred to a native cyprinid now known as the arroyo chub, Gila orcutti (Eigenmann and Eigenmann). Our reasoning is as follows. This cyprinid is resident in the San Jacinto River, a tributary of Lake Elsinore. It has also been assigned to the genus Tigoma, but appeared in Jordan and Evermann (1896) as Leuciscus orcutti. (Leuciscus is an old genus, dating back to Linnaeus, which has been divided many times.) It is believed that Evermann either told or wrote to the Needhams that their small fish found at the drift line was "Leuciscus orcutti. " It is also believed that the Needhams (neither of whom was an ichthyologist) confused "Leuciscus" with another genus, Leucichthys, which at that time was a name used for some of the coregonids.[166] The common name "smelt" was applied to one of the coregonids in the Finger Lakes in New York State where Cornell University is situated (see Jordan et al. 1930).

We conclude by saying that no "Leucichthys" was ever found in California.

8.3. Chevron snakehead, Channa striata (Bloch)

We have no record of the occurrence of the piscivorous tropical fish, the chevron snakehead, in any of the open or public waters of California nor of any attempts to introduce it.

Jordan (1925) said of this family, Channidae or snakeheads: "They are extremely tenacious of life, and are carried alive by the Chinese to San Francisco and to Hawaii, where they are now naturalized, being known as 'China-fishes.'" It is probably because of this statement that in his "A History of Fishes" Norman (1931, 1936, 1948, etc.) spoke of "Ophiocephalus" (now Channa) being "naturalized" in San Francisco. Jordan did not mean that it was "naturalized" in San Francisco, but only in Hawaii. With respect to San Francisco, he meant only that the species had appeared in the Chinese markets. Norman's statement was erroneous, but the popularity of his book and his fame as an ichthyological author gave such a misstatement wide circulation. Subsequent edited editions of "A History of Fishes," such as Greenwood (1963), have corrected this error.

Oddly enough, although Dobie (1936) had a long description of Chinese foods in San Francisco's old Chinatown, he did not mention the live snakehead.

The snakeheads have accessory pharyngeal air cavities, and like the walking catfish are capable of moving across land from one freshwater pool to another. In some areas of Hawaii, the snakehead is also a game fish (Morita 1963).

It is highly doubtful that it would ever be accepted either as a food fish or game fish in California or that any of the group could long survive in open waters here.

[166] The elder Needham was a famed aquatic entomologist; his son Paul was at most only 21 years of age, still an undergraduate student at Cornell University, and had not yet undertaken fishery work.

In addition, all members of the family are prohibited in California (Section 671, Title 14, California Code of Regulations).

9. FISHES WHOSE INTRODUCTION HAS BEEN CONSIDERED

During the period from 1871 through 1996, many species of fish were suggested or at least considered for introduction into California. In early years, the fish were considered primarily for food to be taken from open or public waters or for sport. More recently, the aquaculture industry has requested the importation of various nonnative species including some which have already been stocked in public waters; e.g. the Atlantic salmon. We have not recorded every suggestion here, but have given special attention to certain species, namely:

i) Those brought formally to the attention of the California Fish and Game Commission or Division/Department of Fish and Game; e.g. snook.

ii) Those brought to the attention of or requested from the U.S. Fish Commission or its successors by the State of California; e.g. alewife.

iii) Those brought to the attention of or requested from some other agency, such as a state fish and game department by the State of California; e.g. Arctic char under the name of "Sunapee trout."

iv) Those suggested for introduction by prominent fishery scientists or ichthyologists; e.g. tarpon.

v) Those suggested by employees of the Division/Department of Fish and Game; e.g. orangespotted sunfish.

vi) Those whose introduction has been considered of enough importance to warrant a State study of their desirability; e.g. Nile perch.

A number of marine fish have been suggested for introduction to California, but most of these have not been the suggestion of present-day marine scientists, and most of these proposals belong to the "Phase 1" described in our section "Discussion."[167]

In fact, about the only comment on the introduction of marine fish species into California which we have found is that in Frey (1971, p. 132), a fairly recent recommendation: "... the California Department of Fish and Game will have authority to prohibit cultivation of any marine species that it considers potentially injurious to any native species.... With the increased volume of thermal wastes along the coast, it may be possible to cultivate a number of exotic (non-native) crustaceans, mollusks, and fishes in the future. Development of this potential should be an intricate [sic] part of any plan for utilizing the marine resources of California."

[167] The general subject of the introduction of marine and anadromous organisms on a worldwide basis was covered by Walford and Wicklund (1973). The subject was also discussed by Baltz (1991) who seems to have overlooked the 1973 publication.

9.1. Tarpon, Megalops atlanticus Valenciennes

The tarpon, magnificent game fish of the Atlantic, has frequently been suggested as an introduction for California. Davis (1949), for example, claimed that he had advocated stocking the Salton Sea with tarpon as far back as 1932. Tarpon were not among the fish actually stocked in the Sea, however, and Davis really knew little about the demands of this fish. It was also considered for introduction into the Salton Sea circa 1948 by the State's Bureau of Fish Conservation (pers. comm. from State biologist W.A. Evans), but the idea was given up. One esteemed ichthyologist, C.L. Hubbs, even suggested that it would be a desirable fish in the Sacramento-San Joaquin Delta (pers. comm. to State biologist J.H. Wales).

It has never been introduced into California and, if introduced, it would be solely for its value as a game fish since tarpon are rarely eaten in the United States.

9.2. Alewife, Alosa pseudoharengus (Wilson)

The alewife, native to the Atlantic coast from Labrador to Florida, attains a length of about 30 cm. It also has a landlocked or freshwater form about 7 to 15 cm in length.

Livingston Stone had intended to introduce the alewife from the Mystic River, Massachusetts, to California in 1874, but all of his stock expired en route so they were not planted.

On 10 May 1895, the California Fish Commissioners wrote to the U.S. Commissioner of Fish and Fisheries concerning the alewife of the Atlantic slope and asked for his opinion as to its desirability for Californian waters. On 16 May 1895, the U.S. Commissioner replied: "... there is little doubt that the waters of your State are adapted to the alewife, and there is every reason to believe that the introduction of these fish would prove as successful as that of the shad. At the same time this commission is not satisfied that the acclimatization of the fish is necessary or even desirable." The Commissioner pointed out that alewives (both Alosa pseudoharengus and A. aestivalis) were inferior to the shad as food fish which—despite its success as an introduction—was not met with high esteem in San Francisco. Furthermore, in his mind, the presence of carp eliminated the usefulness of introducing alewives as forage for striped bass and other piscivorous fish (Smith 1896, p. 471). Applications for the alewife's import were still on file, however, with the U.S. Fish Commission according to the California Fish Commission Report for 1895–96.

The alewife was never introduced into California—a move which would appear to be accepted both by "acclimators" and by those who disparage introductions. It is doubtful (as the U.S. Fish Commissioner pointed out) if the alewife would ever have been accepted as a desirable food item. Although the small landlocked form is a useful planktonic feeder, and thus a good forage fish in some waters, the later introduction of the threadfin shad made its introduction unnecessary. Furthermore, the alewife has received such unfavorable publicity, following its takeover of much of the commercial fishery and its die-offs in Lake Huron, that there would be strong opposition to its introduction into California.

9.3. Gizzard shad, Dorosoma cepedianum (Lesueur)

There have been various suggestions to introduce the gizzard shad of the Mississippi and other Atlantic drainages as a forage fish into California. Hubbs (1934) considered it "... the most efficient biologically of all the forage fishes." In fact, this was the initial choice of one of his students, R.W. Eschmeyer, Special Consultant to the Wildlife Conservation Board, but he hesitated to recommend it, fearing that it might invade the Sacramento-San Joaquin Delta (pers. comm. to W.A.D. and others). The gizzard shad is particularly valuable in fluctuating impoundments of the United States which resemble many California reservoirs in that they have little littoral vegetation and a paucity of benthic organisms.

Inquiries concerning the usefulness of importing the gizzard shad to California were pursued, especially during the 1948–50 period, by the State. However, since that time, and since Eschmeyer's stay in California, the State has found a forage fish for its reservoirs, a smaller relative of the gizzard shad, the threadfin shad. The latter is actually better for California than the gizzard shad which grows to a larger size and in shallow waters with mud bottoms is apt to get out of control (Miller 1960).

Owing to the presence of the introduced threadfin, there seems to be no place in California for the gizzard shad.

9.4. Samlai or Chinese shad

The "Samlai or Chinese Shad," said to be indigenous in the Yangtze Kiang of China, was an early candidate for introduction into Californian waters. It is probable that under the name of "samli" it was brought to American attention by G.H.C. Salter, ex-U.S. Consul to the Treaty Ports of the Yangtze-Kiang, China, in the 1870s, who felt that it could ascend very muddy rivers and therefore would prosper in the United States.

This fish was considered for acclimatization by the U.S. Fish Commission, who stated: "By many persons it is considered to be even superior to the American shad ... when first taken shad [i.e. the samlai] command fabulous prices ... and ... it is only the Emperor and the very highest officals who can procure them on their first arrival." The Commission also mentioned that the samlai and its oil were considered very efficacious in the treatment of tuberculosis (U.S. Fish Commission Report for 1872–73, p. lv–lvi). Perhaps the California Fish Commissioners, who also believed that the samlai was larger and of better flavor than the American shad which they had imported, were susceptible to this suggestion (California Fish Commission Report for 1874–75, p. 15).

There had been an early correspondence between the California Fish Commissioners and "gentlemen in China" on the subject of Chinese food fish which could be procured for California (California Fish Commission Report for 1870–71). No fish, including the "samlai", ever seems to have been imported from there, however, and the correspondence lapsed.

Baird (1876, p. XXIX) identified the "Samlai or Chinese shad" as Alosa reevesi and it is believed that it is indeed the "Hilsa herring," now Hilsa reevesi (Richardson), a clupeid indigenous to the area between Hainan Island and Manchuria. Although it spends most of its time in the sea, it ascends rivers to spawn. The Yangtze Kiang is one of these rivers (Lin 1938).

As its relative, the American shad, had already been introduced to California, there appears to have been no reason—despite the glowing accounts—to introduce the "Samlai."

9.5. Silver dollar fish, Metynnis roosevelti Eigenmann

The silver dollar fish, native to Brazil's Amazon River, was among six tropical fishes tested for aquatic plant-eating potential at the Davis campus of the University of California (Yeo 1967). Experiments were conducted in aquariums, plastic pools, and a one-half-acre concrete-lined irrigation reservoir. Only the reservoir experiment is relevant to this paper, because of the possibility of escape, however remote, of test fish into public waters.

The reservoir was stocked with 200 Metynnis roosevelti on 22 May 1965, and 10 fish were retrieved on 12 October 1965 when the reservoir was drained. They had grown about 2 inches in length and had grazed effectively on aquatic plants. However, interest in this and the other species waned with the arrival of the grass carp, a species of proved plant-eating prowess. To our knowledge, no further trials with the silver dollar fish were conducted.

9.6. Bagre branco, Arias barba (Lacepède)

One of the sea catfishes (family Ariidae), known vernacularly as the "bagre," was once proposed as an introduction from Brazil to the Salton Sea. At that time, the Sea supported a substantial sport fishery of introduced forms.

McClendon (1968) made an evaluation of the proposed introduction, but discouraged the bagre's importation for the following reasons: i) insufficient information on life history, ecology, and salinity tolerance, ii) lack of knowledge of venom pharmacology and action, and iii) probability of competition with the top carnivore in the Sea, the orangemouth corvina (Cynoscion xanthulus) .

Prior to that time, however, W.E. Ripley, then a marine fishery biologist with the California Division/Department of Fish and Game, who had spent a year in Brazil circa 1955 on a Technical Assistance assignment in fisheries for the United Nation's Food and Agriculture Organization, had suggested the introduction of a "bagre" from the southern coast of Brazil to California's marine waters.

Indeed, an experimental shipment of bagre was to be arranged in the autumn of 1962. Arrangements were made with B.N. Barcellos of the State of Rio Grande do Sul for the collection of bagre eggs and fish, and A. da Faria of the Federal Division of Hunting and Fishing for governmental cooperation and clearance. A. Reese, pilot for the California Department of Fish and Game, working with Ripley, was conducting the California participation. At the last moment, however, the United States Government, which was to supply the air transportation of the shipment, requested an additional commitment. This, plus the departure of Ripley for an appointment with the U.S. Bureau of Commercial Fisheries caused a collapse of the project to obtain bagre. Nevertheless, trout eggs from California—an integral part of the exchange—were sent to southern Brazil.

With respect to the bagre itself, of which there are many species in Brazil, the one suggested for California is known locally as "Bagre-branco." The primary habitat of this fish, one of the tastiest marine catfishes, is the Lagoa dos Patos where it migrates to spawn, but it is thought to range from south of the Rio Grande do Sul north to Sao Paulo.

Shannon (1963) implied that it would be an excellent ocean sport fish, and a Department of Fish and Game news release of 1962 stated that the Brazilian bagre reached a weight of 70 lb and that the waters it frequented were similar to some southern California coastal waters now populated primarily by such "undesirable" elasmobranchs as skates, rays, guitarfish, and angel sharks.

Most of the above information has been secured from W.E. Ripley as personal communications. The article by McClendon (1968) does not mention any of this information—an example of the need for more unpublished information to be stored for ready access by the Department of Fish and Game, or for the need of "institutional memory" (Hilborn 1992).

It may be noted that most, if not all, of the sea catfishes have venom glands at the bases of the spines of the pectoral and dorsal fins which can produce very painful wounds. They do not have much commercial value in the United States, but in the Brazilian State of Rio Grande do Sul are of major importance. Incidentally, the marine family to which "bagre" belongs was not represented in Californian waters until a specimen identified as Bagre panamensis (Gill) was caught off the Santa Ana River in 1965, a northern extension of its known range of about 1045 km (Fitch 1966).

Meanwhile, no bagre of any species has ever been introduced into California.

9.7. Rainbow smelt, Osmerus mordax (Mitchill)

There have been occasional requests to introduce the rainbow smelt (formerly called the American smelt), from the western and inland Atlantic drainages, into California to serve as a forage fish.

California already possesses several species of smelts (family Osmeridae), both native and introduced. There seems to be no good reason to introduce another one either as a forage fish or as a fish for food or sport. This is especially true since the rainbow smelt has been considered an undesirable addition to the fauna of the Great Lakes.

9.8. New Zealand common smelt, Retropinna retropinna (Richardson)

The New Zealand common smelt is the most important food of the famous rainbow trout populations of Lake Taupo and other lakes of the North Island. It is also native to riverine, estuarine, and marine habitats of this island nation. It was nearly introduced in 1961 into California for the benefit of our rainbow trout sport fisheries.

Characteristics of the smelt that attracted the attention of Department of Fish and Game fishery biologists included its small size (average of 2.0 and maximum of 2.5 inches TL), short life span (most are mature at 1 year of age and some may reach 2 years), and wide distribution in the pelagic zone where it feeds on planktonic crustacea.

Lakes and reservoirs were selected for "experimental" introductions, contacts were made with New Zealand fishery authorities, and transportation funds were located. However, at the "last hour" the proposal was dropped due to the following concerns: i) as smelt mature they concentrate in the littoral zone where they could compete with small trout, ii) the presence of smelt would add another link in the food chain which could result in larger trout but fewer pounds of trout per surface acre, iii) smelt might find their way into the lower courses of rivers to the detriment of their fishery resources, and iv) these smelt are afflicted with species of tapeworms and other parasites not found in California.

9.9. Ohrid trout, Salmo letnica (Karaman)

In the mid-1960s, the Ohrid trout was the subject of considerable interest among fishery biologists in the United States. It was stimulated by a book on Lake Ohrid by Stankovic (1960). A close relative of the brown trout, the Ohrid trout is endemic in this ancient lake on the border of Albania and Macedonia. (Macedonia was then part of Yugoslavia.)

Four reproductively isolated subspecies or races of the Ohrid trout inhabit the lake and three of them spawn in the lake itself and do not use the tributary streams (Behnke 1969). It was primarily the lake-spawning habit that sparked interest in this species, although its ability to coexist with and utilize cyprinids was also encouraging. The widespread construction of coldwater reservoirs in the early 1960s in California and elsewhere in the western United States prompted fishery managers to seek lake-spawning salmonids since such waters often lacked the suitable stream spawning grounds required by most salmonids. Kokanee salmon and lake trout were the only available lake-spawners, and thus the Ohrid trout appeared promising as a third choice.

The U.S. Bureau of Sport Fisheries and Wildlife (now the U.S. Fish and Wildlife Service) imported Ohrid trout eggs from Yugoslavia in 1965, reared them at different Federal and State hatcheries, and distributed the progeny to fish and game agencies in Colorado, Minnesota, Tennessee, and Wyoming. Results from stocking of Minnesota lakes were summarized by the Sport Fishing Institute (1969). The Ohrid trout showed only marginal recreational potential; i.e. poor survival, slow growth, and low catchability. Interest faded away.

The California Department of Fish and Game was initially caught up in the flurry of interest in the Ohrid trout, and in 1965 made direct contact with authorities in the former Yugoslavia to exchange 200,000 rainbow trout eggs for 200,000 Ohrid trout eggs. However, the proposed acquisition was cancelled following a more thorough investigation of its potential. The proposal was never resurrected, but the rainbow trout eggs were shipped successfully.

9.10. Arctic char, Salvelinus alpinus (Linnaeus) Sunapee trout form

Many ichthyologists consider the "Sunapee trout" to be a landlocked form of the Arctic char or part of the "Salvelinus alpinus complex"; others still consider it to be a distinct species, Salvelinus aureolus Bean, or at least a subspecies, e.g. S. alpinus oquassa. (See for example, Vladykov 1954; Behnke 1980; Kircheis 1980.) Regardless of its taxonomic identity, however, as with the landlocked form of the Atlantic salmon, it was once widely considered to be a distinct species, a char (commonly called trout) confined to a few lakes in New England.

In 1923, an attempt was made by California to obtain it, as the "Sunapee trout," from the Massachusetts Fish Commission. No reason was given as to why its acquisition was desired. However, CFG (1923a) mentioned its bright color, the rarity of its natural distribution, its gaminess, and its large size. It was also noted that "It is ... said to be especially hardy and easy to propagate." Perhaps these were the reasons why it was considered as a desirable addition to a stat already possessing a large number of salmonids, including the closely related introduced brook trout. Plans were still being laid in 1925 to introduce it through exchange, but were never carried through (CFG 1925c).

One of the lakes where it is native (Sunapee Lake in New Hampshire) has been subjected to the planting of no less than 14 nonnative species, including some native to the Pacific Coast (Kendall 1924). It is now believed that the only pure and naturally producing strain of this char is in Floods Pond, Maine.

Aside from its novelty—the Arctic grayling was apparently introduced into California for the same reason—there seems to be no good reason for ever considering the introduction of this char into California. In its native lakes, it is generally caught only by fishing in deep water and, although unique, provides but little angling.

9.11. Cusk, Brosme brosme (Ascanius)

Smith (1896, p. 470) felt that the cusk could be acclimatized on the Pacific coast of the United States as easily as the haddock but need not be considered further as it was less valuable.

The cusk, although large, is rather rare on both coasts of the Atlantic, and California already possessed several members of its family (Gadidae). It is doubtful that even its successful introduction would have accomplished anything in California.

9.12. Haddock, Melanogrammus aeglefinus (Linnaeus)

A.B. Alexander, "fishery expert" of the S.S. Albatross, a research vessel of the old U.S. Fish Commission, felt that the haddock, Atlantic mackerel, and bluefish were among the most desirable fishes to be introduced from the Atlantic to the Pacific Coast states (Smith 1896, p. 470). He felt that the haddock would be a more desirable food fish than the native "red rockfish" (Sebastes spp.) or lingcod (cultus) (Ophiodon elongatus) , then and now used for food in these waters.

An important food fish on both sides of the Atlantic, it is true that its family (Gadidae) has only two common species resident on the California coast. Californians are not very partial to this type of fish, however. The haddock has never been introduced into this state nor would it be a popular choice for introduction.

9.13. Pollock, Pollachius virens (Linnaeus)

As with the cusk and "hake," Smith (1896) felt that the pollock from the Atlantic could be acclimatized on the Pacific Coast as easily as could be the haddock, but need not be considered further as it was less valuable. Smith was, of course, considering it as a food fish, but the pollock, being found in shallower water than some of its family members, is also a game fish.

Members of its family (Gadidae) already exist on the California coast but have never been very popular. Introduction of the pollock has never been attempted, and it is doubtful that it would ever have achieved popularity here.

9.14. Red hake, Urophycis chuss (Walbaum)

Smith (1896, p. 470) felt that the "... hake (Phycis chuss) ..." could be acclimatized on the Pacific coast as easily as the haddock but need not be considered further as it was less valuable.

California already possessed two common members of the cod or hake family (Gadidae): the Pacific hake (Merluccius productus) and the smaller Pacific tomcod (Microgadus proximus) . In view of their relative unpopularity as food fish (and that of the Pacific hake as a game fish), it is doubtful that even a successful introduction of another closely related fish would have been welcomed in California.

9.15. Peixe rei, Odontesthes bonariensis (Valenciennes)

The piexe rei or pejerrey of the family Atherinidae is native to the fresh or brackish waters of Argentina, Brazil, and Uruguay. It has never been introduced into California, but was seriously considered by the Department of Fish and Game in the early 1960s for use as a pelagic sport fish in warmwater fluctuating reservoirs. Its zooplankton feeding habits and size (maximum of about 5 lb) attracted attention in California. However, in 1963 the Department decided against importation of the piexe rei because of findings that it is primarily a commercial species taken with nets, not well suited for angling, and, in fact, had been considered as an aquacultural pond fish in countries such as Israel.

9.16. Common snook, Centropomus undecimalis (Bloch)

The snook or robalo of the family Centropomidae is an important game fish normally found only in the coastal waters and lower reaches of streams in the American subtropics and tropics. It can be taken on live bait and on artificial lures, especially in chilly weather. However, its minimum temperature tolerance is about 15.5° C.

It has been suggested on several occasions that the snook be introduced into waters off the California coast, but as J.O. Snyder, once head of the former Division of Fish and Game's Bureau of Fish Conservation observed, "... it is sensitive to changes in temperatures and would not survive in our relative [sic] cold waters" (CC 1937a).

9.17. Nile perch, Lates niloticus (Linnaeus)

Circa 1970, there was a proposal to the California Department of Fish and Game to introduce the Nile perch, native to lakes and streams of Africa. As a result, the organization commissioned a report on the species which was prepared by Emig (1970) who recommended against it.

In its native waters, the Nile perch furnishes some exciting fishing, especially because of its large size (some may reach a weight of over 160 kg), and is also a good food fish. It has, however, caused devastation to some fisheries and indigenous fishes where it has been introduced; e.g. Lake Victoria, where an introduced aquatic plant, the water hyacinth, has also created problems.

The family to which it belongs (Centropomidae) is also represented in both marine (sometimes brackish) and fresh waters in other parts of the world. The closely related Lates calcarifer or barramundi is an excellent freshwater game fish of northern Australia, and the common snook (Centropomus undecimalis) is found in American waters.

Although its ecological requirements appear to be within the limits available in California, the likelihood that its predacious habits would harm already established species, both native and introduced, keeps it from being a candidate for introduction. It may be noted, however, that the flesh of imported Nile perch does appear in California food markets.

9.18. Murray cod, Maccullochella peeli (Mitchell)

The Murray cod, which is not a cod but a member of the temperate bass family, Percichthyidae, is a large food and game fish found in southeastern Australia in the Darling-Murray drainage. It attains a maximum weight of about 250 lb and a length of 6 ft.

In 1959 it was recommended by Region 5 of the Department of Fish and Game for introduction into California, undoubtedly because of its size and reputation as a game fish. Australian authorities were contacted regarding procurement and shipment of Murray cod fry. However, no introduction was ever made (pers. comm. of State biologist W.C. Johnson to W.A.D. May 1959).

9.19. Orangespotted sunfish, Lepomis humilis (Girard)

State fishery personnel have twice suggested the introduction of the orangespotted sunfish. W.H. Shebley suggested that it might be successful in the brackish waters of Lake Elsinore, Riverside County, according to CFG (1927). Coleman (1930) recommended it for Clear Lake, Lake County. We do not believe that either Shebley (a fish culturist) or Coleman (an early Californian State biologist) knew much about the fish they proposed for introduction.

The orangespotted sunfish is an attractive little sunfish which has no angling value since it rarely reaches a length of 10 cm, and its food habits would not make it a forage fish of consequence.

9.20. Bluefish, Pomatomus saltatrix (Linnaeus)

The bluefish, a food and game fish, was regarded, circa 1896 by A.B. Alexander of the U.S. Fish Commission, as one of the most desirable fishes that could be introduced in American Pacific oceanic waters (Smith 1896, p. 470). The bluefish has almost a worldwide distribution, although it is not native to the eastern coasts of the Pacific. It is the only member of its family (Pomatomidae), and although it does not reach the large size of some other game fishes, it is considered almost legendary to saltwater anglers. Alexander felt that its predacious habits might be a drawback, but nevertheless felt that it would be a desirable addition. The California Fish Commissioners had already anticipated such a desire. In 1873 and again in 1874, they had requested this fish from the eastern United States, but it was never sent to them (California Fish Commission Report for 1872–73, p. 5; *Ibid.* 1874–75, p. 23, 25–26).

One might assume that it would be a resident or visitor to the eastern coasts of the Pacific were conditions suitable for it here.[168]

[168] The bluefish is included in "... California Fish Showing ... Methods of Cooking Each Variety" issued by the Division of Fish and Game in 1935, which may have led some people to assume that it was established in the state (State Fish Exchange 1935).

9.21. Scup, Stenotomus chrysops (Linnaeus)

The scup or porgy is a common table fish in the Atlantic Ocean, one of the family Sparidae which provides sustenance in many parts of the world and has members which are sometimes cultivated.

Smith (1896, p. 470) thought that it "... would unquestionably find a congenial habitat in San Francisco Bay and in other shore waters of the coast, and it would also be a well-received addition to the fresh-fish supply of the region...." He felt that it was superior to the native viviparous perches (Embiotocidae) which were extensively consumed in San Francisco.

With about 18 saltwater embiotocids already present in California waters, there would appear to be no reason to attempt to introduce a somewhat similar, although quite unrelated, minor food and sport fish to the state.

9.22. Red drum, Sciaenops ocellatus (Linnaeus)

The red drum, also known as "redfish" and "channel bass," is resident along the Atlantic and Gulf coasts from Massachusetts to Texas. It is a favorite of surfcasters, especially along the southeast coast of the United States, and is also taken on fly, plug, and spinning tackle.

Under the name "channel bass," it was suggested for introduction into central California waters on 20 July 1951. The Fish and Game Commission denied the request for its introduction because, "... indications are the temperatures thereof are unsuitable and there is danger of competition with native species" (Transactions of the Commission, in California Department of Fish and Game Monthly Report of September 1951). A lack of suitable spawning areas for red drum was also cited as a reason for not introducing it (OC 1951b).

Circa 1974, the introduction of the red drum was again suggested, but the proposal was rejected by an advisory committee of marine scientists (from California universities, the National Marine Fisheries Service, and the California Academy of Sciences) because of lack of suitable habitat (Young 1974).

California already has eight native members of the family Sciaenidae to which the red drum belongs.

9.23. Oscar, Astronotus ocellatus (Agassiz)

The oscar is one of several cichlids native to South America which are commonly called "peacock bass" or "tucanare," and are considered excellent game fish, especially by angler-authors such as McClane (1974). The oscar is native to the Orinoco, Amazon, and La Plata river systems of South America (Courtenay et al. 1986). It is an excellent game and food fish, attaining weights up to 28 lb with an average of 5 to 6 lb in some Venezuelan streams (McClane 1974).

Aquarium releases are apparently responsible for the establishment of the oscar in Florida and Hawaii and for collections, but no established populations, in Massachusetts, Mississippi, Ontario, Pennsylvania, and Rhode Island (Courtenay et al. 1986, 1991). However, Davidson et al. (1992) stated that both Astronotus ocellatus and Cichla ocellaris (which they call the "tucanare") were introduced into Hawaii as candidates for freshwater fishing.

The sport fishing potential of the oscar led G. Wolfsheimer, an aquarist from Sherman Oaks, California, to recommend that it be introduced into California (14 July 1951 letter to A.C. Taft of the California Division of Fish and Game). The proposal was dropped, apparently because G.S. Myers of Stanford University reported that cold temperatures would preclude its natural reproduction in California.

A second request to rear oscars in California was submitted in 1963 by C.L. Moller of Los Angeles, who applied for a Domesticated Fish Breeder's License to culture this species for commercial purposes. He intended to stock them in a ¼-acre thermal pond near the Salton Sea in Riverside County and charge anglers to fish for them. The operation was to be supervised by J. Woods, who already held oscars at his nearby tropical fish farm. The Department supported the proposal because of the remote chance of survival should any fish escape the pond. The Fish and Game Commission, at its June 1963 meeting, authorized Moller to import and possess oscars for aquaculture purposes, but as far as we know the fish were never stocked.

9.24. Banded tilapia, Tilapia sparrmani (Smith)

Formerly called Sparrman's cichlid, the banded tilapia has several distinctions. It is one of the smallest and most widely distributed of the African tilapias and may be the hardiest of all the cichlids.

In response to suggestions that it be introduced into California waters, Pelzman (1972) evaluated the species. He concluded that if introduced for aquatic weed or insect control, it might survive in both southern and northern California waters and compete both directly and indirectly with game fish. He recommended that it not be introduced into the state and that its possession in California be prohibited except for display in public aquariums. It was officially listed as prohibited by the Fish and Game Commission.

We agree with this action.

9.25. Atlantic mackerel, Scomber scombrus Linnaeus

Although California already possessed one member of the family Scombridae (the Pacific or chub mackerel, Scomber japonicus) , it was recommended circa 1896 by A.B. Alexander, fishery expert on the S.S. Albatross, that the larger Atlantic mackerel was one of the most desirable fishes that could be introduced into California. Furthermore, he thought that the Pacific's chub mackerel and the

Atlantic's chub mackerel were the same species, and since the Atlantic (or true) mackerel coexisted with the chub in the Atlantic, that it would obviously coexist with the already resident Pacific form (Smith 1896, p. 470).[169]

It was never introduced and it is doubtful that its introduction would have been worthwhile. It is true that the Pacific mackerel is of smaller size, but it has provided a valuable marine fishery in California.

9.26. Gourami, Osphronemus goramy Lacepède

One of the most interesting introductions contemplated by the State of California was that of the gourami. This fish, a native of the intertropical belt (Java, Vietnam, etc.) where it is used as food and attains a length of about 60 cm, had been the subject of acclimatization experiments for many years by France. Acclimatization of the gourami, following its successful introduction into Mauritius, rivaled the acclimatization of the carp and later of "Tilapia."

As early as 22 January 1864, Colonel A.C. Hamlin of Washington, D.C., in a letter suggesting a "bureau of pisciculture" for the United States, asked T. Gill of the Smithsonian Institution if he deemed it possible to import the gourami (*Progressive Fish Culturist*, No. 45, May–June 1937). Gill, who must be considered an astute ichthyologist, thought that the gourami might be a very valuable acquisition by the United States, and suggested that it might be acclimatized by gradually introducing it northward from warmer country (Gill 1874).

The U.S. Fish Commission Report for 1872–73, p. lxxvii, stated that it was a good food fish adapted to both brackish and fresh water and hot sun, and largely a vegetable eater. It suggested that the gourami "... might be readily introduced from the region of China into the high-temperature 'tule' lakes of Southern California and Nevada and from there distributed farther east."[170] This suggestion for introduction was seconded by the California Fish Commission in its Report for 1874–75, p. 15, which suggested, "... it would thrive in the sloughs and stagnant waters in the southern portion of the State."

Plans were laid for its introduction into a warmwater lake near San Gabriel by B.B. Redding, one of the original California Fish Commissioners. However, he had difficulty securing the stock from China as he pointed out in a letter of 11 May 1875 to S.F. Baird. Despite the glowing praise for the gourami by the U.S. Fish Commission, it was unable to provide stock, and applied to the Société d' Acclimitation of Paris for information on where to secure the fish. The Society in turn wrote to its agent in Saigon to have some shipped via Hong Kong to San

[169] Alexander was apparently correct; a 1967 study synonymized the Atlantic's Scomber colias under S. japonicus (Matsui 1967).

[170] Although still hoping that the gourami would be sent to California, doubts of its success in most parts of the United States were voiced by the U.S. Fish Commission Report for 1880 (p. XXXVI) after finding that it did not appear to thrive in France.

Francisco.[171] Plans for its introduction into California evidently terminated with Redding's death in 1882 even though ponds had been prepared for it. (See U.S. Fish Commission Report for 1873–74 and 1874–75, p. 480–482; *Ibid.* 1880, p. XXXVI; *Ibid.* 1882, p. XXIII.)

At the time, many people (including Californians) visualized the state as a subtropical paradise. Consequently, many tropical species such as the gourami were considered entirely appropriate as introductions. Conversely, areas such as Tulare Lake, now considered completely inappropriate for such coldwater species as coregonids, were at that time believed to be quite suitable for that group.

The gourami was never introduced into California and its continued survival would have been highly dubious.[172] Nevertheless, its contemplated fate remains a part of our ichthyological history.

10. LIKELY CANDIDATES FOR INTRODUCTION

It is clear that almost any fish whose temperature requirements meet those current in some part of California could be successfully introduced into the state. And from the list of introduced fishes already found in our waters, it is obvious there may be inadvertent or unplanned introductions of very small fish which have little or no practical use to man in wild or public waters; e.g. the brook stickleback.

On the other hand, there are some species of fish which have either been considered as sport fish or food fish, or used as bait fish or for biological control, whose introduction to California's open or public waters is quite likely.

We have singled out for this section, three fishes which have not yet been found in California's wild or public waters, but whose ultimate presence would not be surprising. The subject is reviewed at greater length in the "Discussion" when the future of fish introductions into California is discussed. Any overlap between this or other sections is inadvertent.

10.1. Silver carp, Hypophthalmichthys molitrix (Valenciennes)

Like the other Chinese carps, the silver carp is indigenous to low-gradient rivers of the Pacific slope in China and Siberia. As a phytoplankton feeder, it assumes an important role in worldwide polyculture activities and is considered a good food fish in many countries.

Silver carp, along with other Chinese carps, were introduced into Arkansas in the early 1970s. Large numbers have been stocked by Arkansas fish farmers, and

[171] At that time, Saigon was the capital of the colony of Cochin-China, a part of French Indo-China.

[172] Trials of the gourami as a controller of aquatic weeds were made by Yeo (1967) in Davis, California, sometime during the period 1962–65, but it was not planted in public waters.

many have apparently escaped into the Mississippi River and its tributaries (Robison and Buchanan 1984; Pflieger 1989). Courtenay et al. (1991, p. 97) noted that Hypophthalmichthys molitrix "... is so widespread in the central United States that its establishment seems assured; only confirmation of a feral breeding population is needed before this species is added to the list of established exotics."

Although the pressure to import silver carp illegally into California is much less than that for grass carp, such an activity seems inevitable. The combination of its ready availability from fish farmers in southeastern states, the ease with which it can enter, and the interest in the species by amateur and professional aquaculturists almost guarantees that the silver carp will be illegally imported. Whether or not it escapes or is deliberately released into state waters and becomes a permanent resident is a function of human, climatic, and other factors. It is also possible that silver carp will be included, by accident, in legal shipments of grass carp.

10.2. Black carp, Mylopharyngodon piceus (Richardson)

of the four Chinese carps most commonly employed in polyculture, the black carp is perhaps the least known and utilized in the United States. Like its close relatives, it is native to low-gradient rivers in eastern China and Siberia.

Interest in the black carp (often called the "snail carp") in this country was awakened with the discovery of the zebra mussel (Dreissena polymorpha) in North America. This Eurasian bivalve was discovered in Lake St. Clair in 1988, has spread throughout the Great Lakes, and continues to expand its range with the expectation that it will invade hard-water habitats throughout much of the United States and southern Canada (Strayer 1991, French 1993).

French (1993) reviewed potential agents in the biological control of the zebra mussel. He recognized the mollusk-eating habits of the black carp, but recommended against its introduction in North America "... because research has shown repeatedly that an introduced biological controller usually does not forage for unwanted pests or reside only in preferred habitats of pests." Nevertheless, several short articles in the May and July 1993 issues of the *Water Farming Journal* refer to the black carp as a likely answer to the zebra mussel crisis. Aquaculturists in Missouri and Arkansas are seeking to develop triploid black carp to overcome objections by conservation agencies. They also observe that the black carp is the most popular food fish in China, and that this species can help in parasite control by eliminating snails that are part of the parasite's life cycle.

In a letter responding to French (1993), J.V. Huner (*Fisheries* 18[11]:36–37) maintained that the black carp has been in the United States for some time and may already be established in the Mississippi River drainage. He inferred that if it becomes established in natural waters, fisheries managers should be able to use it for beneficial purposes.

A different approach has been shown by the North Central Division of the American Fisheries Society which, in a meeting of December 1993, urged "... all state, provincial, and federal governments ... to take immediate steps to eliminate all existing populations of black carp now in North America and prohibit any additional importation" (*Fisheries Action News*, Fall 1994, p. 5).

For the reasons related for the other Chinese carps, we, nevertheless, anticipate that the black carp may eventually become a permanent member of the California fish fauna.

10.3. Rudd, Scardinius erythrophthalmus (Linnaeus)

The rudd is a common cyprinid native to most countries of Europe, where it is a minor market fish and one of the coarse fish utilized in that type of fishing.

Courtenay et al. (1986) described the native distribution of this cyprinid, and also its distribution in the eastern United States. They listed it among the species with declining populations. However, Courtenay et al. (1991) maintained, "During the past 5 years, the rudd has been cultured extensively in Arkansas and widely distributed in the central and eastern United States as a baitfish and, to a lesser degree, as an outdoor ornamental fish. It has been reported from bait shops in 16 states and from open waters in 11 states. It is probably more widespread than current reports indicate and probably will become established in states from which it has not yet been reported." Burkhead and Williams (1991) gave more details regarding its spread in the United States, and the Sport Fishing Institute (1992a) reported the occurrence of the rudd in Lake Ontario.

There is no evidence that the rudd is established within or has ever been introduced into California. It is, however, being reared for sale as bait by the same Arkansas aquaculturists who rear golden shiners, large numbers of which are shipped annually to California for use as bait. The two species are superficially quite similar, and it is not inconceivable that occasional rudd find their way into loads of golden shiners shipped to California. During the late 1980s, the Department alerted field biologists to the possible presence of rudd in bait outlets, but none were reported. The Department also expressed its concerns to the Arkansas Game and Fish Commission and five major aquaculturists involved in the rearing of rudd and golden shiners. They all contended that the species are reared separately and that no mixing occurs. Nevertheless, the human element, floods, and other factors lead to some healthy skepticism. Furthermore, the rudd is known to hybridize with the golden shiner (Burkhead and Williams 1991).

Anon. (1988) summarized the status of the rudd in the United States and the reasons for widespread concerns about its introduction.

11. BAIT FISHES OF THE LOWER COLORADO RIVER

Evans and Douglas (1950) first reported the presence of five species of fish not native to California in bait tanks along the lower Colorado River and suggested that they might already be established in natural waters of the state. Two years later, Miller (1952) discussed 32 species of fish, including the five mentioned above,[173] found in bait shops along the lower Colorado River during the 1948–51 period. Fifteen of these were species not yet known to be established in Californian waters (i.e. the Colorado River and its derivatives); the others were natives or introductions which were already established in California.

The introduced species already established were the common carp, goldfish, golden shiner, red shiner, fathead minnow, western mosquitofish, bluegill, green sunfish, and yellow perch. The native species included the mountain sucker (Catostomus platyrhynchus) , speckled dace (Rhinichthys osculus) , hitch (Lavinia exilicauda) , California killifish (Fundulus parvipinnis) , and longjaw mudsucker (Gillichthys mirabilis) .

The common and scientific names used here are those adopted by the American Fisheries Society (Robins et al. 1991) and often differ from those listed by Evans and Douglas (1950) and Miller (1952). We have excluded subspecific names because subsequent studies have shown many of them to be invalid.

Since none of the 15 "aliens" had been established in Californian waters and since they were apparently no longer being used as bait in the Colorado River area, they were dropped from the 1981 list by Shapovalov et al. (1981). The names of the non-autochthonous fishes listed by both Evans and Douglas (1950) and Miller (1952) are given in Table 1. Although they have never been found in Californian waters, the possibility still exists that in time they may be found here.

Miller (1952) voiced recommendations against the use of three of these forms as bait fish on the Colorado River because of lack of knowledge concerning them, or because they were of particular interest to science: dusky mountain sucker (now recognized as the native mountain sucker), Rio Grande chub (now designated as the Chihuahua chub), and White River spinedace. He voiced stronger recommendations, especially because of their potential harm if introduced, against the Mexican tetra, white sucker, redside shiner, and Utah chub. We agree generally.

[173] Miller (1952) described reasons for excluding Gillichthys detrusus. Its inclusion by Evans and Douglas (1950) was based on an initial identification by C.L. Hubbs, who, at a later date, reidentified the Colorado River specimens as the native Gillichthys mirabilis. Subsequently, Barlow (1963, p. 47) concluded "... that detrusus should be regarded as a synonym of mirabilis."

TABLE 1. Fishes found in bait tanks along the lower Colorado River and considered to be alien to California by Evans and Douglas (1950) and Miller (1952). Common and scientific names have been updated to conform with those of the American Fisheries Society (Robins et al. 1991).

Carp and minnow family (Cyprinidae)[1]
- Longfin dace, *Agosia chrysogaster* Girard
- Utah chub, *Gila atraria* (Girard)
- Leatherside chub, *Gila copei* (Jordan & Gilbert)[2]
- Chihuahua chub, *Gila nigrescens* (Girard)
- White River spinedace, *Lepidomeda albivallis* Miller & Hubbs[3]
- Virgin spinedace, *Lepidomeda mollispinis* Miller & Hubbs[3]
- Redside shiner, *Richardsonius balteatus* (Richardson)

Sucker family (Catostomidae)
- Utah sucker, *Catostomus ardens* Jordan & Gilbert
- White sucker, *Catostomus commersoni* (Lacepède)
- Bluehead sucker, *Catostomus discobolus* Cope[4]
- Flannelmouth sucker, *Catostomus latipinnis* Baird & Girard
- Rio Grande sucker, *Catostomus plebeius* Baird & Girard[4]

Characin family (Characidae)
- Mexican tetra, *Astyanax mexicanus* (Filippi)[5]

Killifish family (Cyprinodontidae)
- Plains killifish, *Fundulus zebrinus* Jordan & Gilbert

Sculpin family (Cottidae)
- Mottled sculpin, *Cottus bairdi* Girard

[1] *Although Miller (1952) listed the woundfin (*Plagopterus argentissimus*), his record was based only on a single specimen taken from a boat dock on Lake Mead in Nevada.*

[2] *Listed by Miller (1952) as* Snyderichthys aliciae *(Jouy).*

[3] *Listed by Miller (1952) as undescribed species of* Lepidomeda.

[4] *In his revision of some catostomids, Smith (1966) relegated* Pantosteus *to a subgenus of* Catostomus. *With this and other changes, Miller's (1952)* Pantosteus delphinus *became* Catostomus discobolus *and* Pantosteus plebeius *became* Catostomus plebeius. *Miller (1952) listed the Bonneville mountain-sucker (*Pantosteus platyrhynchus*) and the dusky mountain-sucker (*Pantosteus *sp.) which Smith (1966) merged into the mountain sucker (*Catostomus platyrhynchus*), a native California species.*

[5] *Listed by Miller (1952) as* Astyanax fasciatus mexicanus. *See the account of this species in the Hypothetical List.*

TABLE 1. Fishes found in bait tanks along the lower Colorado River and considered to be alien to California by Evans and Douglas (1950) and Miller (1952). Common and scientific names have been updated to conform with those of the American Fisheries Society (Robins et al. 1991)

12. FISHES INTRODUCED INTO THE SALTON SEA

The Salton Sea, in Riverside and Imperial counties, the largest body of inland water in California, is primarily the result of an accidental diversion of the Colorado River during the 1905–07 period. The diversion created a gigantic lake about 235 ft below sea level, and about 340 square miles in area, but only about 15 ft in average depth. It is essentially an inland sea with a high evaporative rate due to high summer temperatures, a salinity exceeding that of normal sea water, and two inlets carrying wastewater.

The Sea requires a special place in this report since the fish introduced into it have been marine, or at least euryhaline (as in the case of the coho salmon and striped bass). A complete list of the fishes introduced into this very saline environment is reproduced here (Table 2). Take from Walker et al. (1961), it includes both fishes native to California and a group of exotics, totalling 38,730 fish.

As will be seen in Table 2, there have been numerous attempts to introduce fishes into the Salton Sea which would survive, reproduce naturally, and supply food and sport. Some of the earliest attempts strove to introduce fishes which could furnish food (e.g. the anchoveta), but most of the attempts were to institute a fishery for sport fishes. As Lachner et al. (1970) have said, "The Salton Sea is an excellent example of an area where there was good chance to gain and nothing to lose or harm by trial and error introductions." Even scientists who seem generally opposed to fish introductions state that those into the Salton Sea were "... probably the most outstanding examples of well-planned releases where no adverse impacts were likely...." (Courtenay and Williams 1992 following Courtenay and Robins 1989).

Many articles have been written describing attempts to introduce fishes into the Salton Sea, the organisms which are present, and their ecology. The most detailed of these is the California Department of Fish and Game's Fish Bulletin 113, edited by Walker (1961). OC (1978) presented a good popular report on the subject. Some of the problems besetting the Sea were described by Calhoun (1968, 1969), and in recent years its increasing salinity has caused a decided decline in the sport fishery—once one of the largest in California.

With respect to the introductions of fishes from Mexico into the Salton Sea, however, the original published reference appears to be that of Douglas (1953). He briefly recapitulated the history of the Sea, pointed out that prior to 1948 the only fishes present in the Sea were striped mullet, western mosquitofish, desert pupfish, common carp, and possibly some machete (Elops affinis) . Some long-jaw mudsuckers which had been deliberately introduced were found in 1951. With respect to later introductions, Douglas (1953) stated, "Since 1948 four expeditions have been conducted to San Felipe, Mexico, on the western shores of the Gulf of California, by the California Department of Fish and Game to procure

TABLE 2. Known fish introductions into the Salton Sea[1]

Date	Number	Species	Common name	Where acquired
20 Oct 1929	900	*Roccus saxatilis*	Striped bass	Tracy, California
24 Oct 1929	1500	*Roccus saxatilis*	Striped bass	Tracy, California
21 Oct 1930	1800	*Roccus saxatilis*	Striped bass	San Francisco Bay
13 Nov 1930	500	*Gillichthys mirabilis*	Longjaw mudsucker	San Diego Bay
1934	15000	*Oncorhynchus kisutch*	Silver salmon	Forest Home Hatchery
2 Oct 1948	43	*Anchoa mundeoloides*	Anchovy	Guaymas
23 Dec 1948	1000	*Centengraulis mysticetus*	Anchoveta	San Diego (tuna boat)
"	12	*Caranx caballus*	Green jack	San Diego (tuna boat)
10 May 1950	5000	*Centengraulis mysticetus*	Anchoveta	San Felipe
12 May 1950	29	*Albula vulpes*	Bonefish	San Felipe
"	2	*Centengraulis mysticetus*	Anchoveta	San Felipe
"	1	*Paralichthys aestuarius*	Halibut	San Felipe
"	40	*Colpichthys regis*	Silverside	San Felipe
"	1	*Eucinostomus argenteus*	Spotfin mojarra	San Felipe
"	2	*Trachinotus paitensis*	Paloma pompano	San Felipe
"	27	*Cynoscion xanthulus*	Orangemouth corvina	San Felipe
"	14	*Cynoscion parvipinnis*	Shortfin corvina	San Felipe
"	1	*Cynoscion macdonaldi*	Totuava	San Felipe
"	7	*Menticirrhus undulatus*	California corbina	San Felipe

[1]*From Table 25 of Walker et al. (1961). Common family names are used when no specific common name is available. Common and scientific names have not been updated.*

TABLE 2. Known fish introductions into the Salton Sea

TABLE 2. Continued

Date	Number	Species	Common name	Where acquired
12 May 1950	1	*Menticirrhus nasus*	Corbina	San Felipe
"	15	*Micropogon megalops*	Croaker	San Felipe
"	57	*Bairdiella icistius*	Bairdiella	San Felipe
14 Dec 1950	25	*Mugil curema*	White mullet	San Felipe
"	600	*Colpichthys regis*	Silverside	San Felipe
"	1	*Paralichthys woolmani*	Halibut	San Felipe
"	1	*Scomberomorus concolor*	Monterey spanish mackerel	San Felipe
"	1	*Menticirrhus undulatus*	California corbina	San Felipe
"	12	*Eucinostomus argenteus* *Eucinostomus gracilis*	Spotfin mojarra Mojarra	San Felipe
15 Dec 1950	15	*Mugil cephalus*	Striped mullet	San Felipe
"	60	*Mugil curema*	White mullet	San Felipe
"	70	*Colpichthys regis*	Silverside	San Felipe
"	1	*Nematistius pectoralis*	Roosterfish	San Felipe
"	1	*Menticirrhus undulatus*	California corbina	San Felipe
"	75	*Eucinostomus argenteus* *E. gracilis*	Spotfin mojarra Mojarra	San Felipe
28 Mar 1951	30	*Cetengraulis mysticetus*	Anchoveta	San Felipe
"	300	*Leuresthes sardina*	Grunion	San Felipe
"	3	*Cynoscion xanthulus*	Orangemouth corvina	San Felipe

TABLE 2. Known fish introductions into the Salton Sea

TABLE 2. Continued

Date	Number	Species	Common name	Where acquired
28 Mar 1951	2	*Cynoscion parvipinnis*	Shortfin corvina	San Felipe
31 Mar 1951	48	*Albula vulpes*	Bonefish	San Felipe
"	6	*Anchoa mundeoloides*	Anchovy	San Felipe
"	8	*Centengraulis mysticetus*	Anchoveta	San Felipe
"	5	*Mugil curema*	White mullet	San Felipe
"	3	*Colpichthys regis*	Silverside	San Felipe
"	4	*Paralichthys aestuarius*	Halibut	San Felipe
"	140	*Hypsopsetta guttulata* *Etropus crossotus*	Diamond turbot Flounder	San Felipe
"	65	*Anisotremus davidsoni*	Sargo	San Felipe
"	12	*Paralabrax maculatofasciatus*	Spotted bass	San Felipe
"	7	*Girella simplicidens*	Opaleye	San Felipe
"	2	*Halichoeres (?)*	Wrasse	San Felipe
"	200	*Cynoscion xanthulus* *C. othonopterus* *C. parvipinnis* *C. macdonaldi*	Orangemouth corvina Scalyfin corvina Shortfin corvina Totuava	San Felipe
"	10	*Bairdiella icistius*	Bairdiella	San Felipe
"	2	*Menticirrhus nasus*	Corbina	San Felipe
"	1	*Eucinostomus argenteus*	Spotfin mojarra	San Felipe
"	63	*Gillichthys seta*	Mudsucker	San Felipe

TABLE 2. Known fish introductions into the Salton Sea

TABLE 2. Continued

Date	Number	Species	Common name	Where acquired
14 Dec 1951	72	*Colpichthys regis*	Silverside	San Felipe
11 May 1953	6000	*Engraulis mordax*	Northern anchovy	Los Angeles Harbor
13 May 1953	44	*Cynoscion parvipinnis*	Shortfin corvina	San Felipe
"	35	*Micropogon megalops*	Croaker	San Felipe
"	4	*Menticirrhus undulatus*	California corbina	San Felipe
"	1	*Trachinotus paitensis*	Paloma pompano	San Felipe
"	26	*Opisthonema libertate*	Pacific thread herring	San Felipe
15 May 1953	50	*Cynoscion parvipinnis*	Shortfin corvina	San Felipe
"	38	*Cynoscion xanthulus*	Orangemouth corvina	San Felipe
"	4	*Menticirrhus undulatus*	California corbina	San Felipe
10 Mar 1955	3000	*Centengraulis mysticetus*	Anchoveta	Gulf of California
10–11 May 1955	114	*Cynoscion parvipinnis*	Shortfin corvina	San Felipe
"	4	*Cynoscion xanthulus*	Orangemouth corvina	San Felipe
Apr–May 1956	8	*Cynoscion macdonaldi*	Totuava	San Felipe
"	1	*Cynoscion othonopterus*	Scalyfin corvina	San Felipe
"	1545	*Cynoscion parvipinnis*	Shortfin corvina	San Felipe
"	59	*Cynoscion xanthulus*	Orangemouth corvina	San Felipe

TABLE 2. Known fish introductions into the Salton Sea

marine game and forage fishes for experimental plants in the Salton Sea. Approximately 10,000 such fish, of many kinds, have now been planted in this body of water."[174] Another article (prepared by Douglas) also discussed the establishment of a sport fishery in the Sea (California 1954). Few details of the plants themselves were given in either article; pertinent ones appear below. Most of the 1953 article was devoted to an account of the recoveries that were made in 1952: bairdiella and orangemouth corvina.

In 1956, the sargo (Anisotremus davidsoni) was taken from the Salton Sea, and the shortfin corvina (Cynoscion parvipinnis) established a breeding population there for a time. These species will not be discussed here, because, although they were introduced into the Salton Sea from San Felipe, Mexico, they were already resident in California coastal waters.[175] Williams and Jennings (1991) made the same mistake of other authors in listing the sargo as an "exotic."

Details concerning the fishes from Mexico not native to California waters introduced into the Salton Sea follow.

12.1. *Mexican fishes which were successful*

Bairdiella, Bairdiella icistia (Jordan & Gilbert)

The bairdiella, a member of the drum family (Sciaenidae) native to the Gulf of California, Mexico, was formerly known as the Gulf croaker.

Fifty-seven bairdiella from San Felipe, Baja California, Mexico, were planted in the Salton Sea by the Department of Fish and Game on 12 May 1950. This plant was followed by another on 31 March 1951 by the Department of 10 fish from the same place (Walker et al. 1961, p. 78). OC (1958c) stated that the bairdiella were first planted in the Salton Sea on 5 October 1950, and Shapovalov et al. (1981)—apparently following this lead—also said that it was first introduced into the Sea in October 1950. These statements are discounted in view of statements by Douglas (1953) and Walker et al. (1961).

[174] The authors' own calculation, based on Table 2, is that 27,797 fish were planted during the 1929–52 period, but Douglas (1953) was probably alluding only to the marine fish stocked between 1948 and 1953. Table 2 indicates that 7042 fish were stocked in the Sea during this period. OC (1957c) said that since 1948 the Department of Fish and Game had introduced more than 35,000 saltwater fish of 35 species into the Sea. OC (1958c) said that by the end of 1951, the Department of Fish and Game had transported a total of some 34,000 saltwater fish from the Gulf of California into the Sea. Calhoun (1968) said that some 7000 fish were planted during 1950 and 1951. As has been emphasized before, the number of fish introduced varies with the author, and—in itself—is of not much importance. The best figures we have are those in Table 2.

[175] Although the introduction of San Felipe stock into the Salton Sea was a logical move, we cannot resist pointing out that the successful introduction of sargo was not based on "logic" or "science" but on good luck or "gut feeling." See Young (1977).

Douglas (1953) reported the first bairdiella found in the Salton Sea, a 1.75-inch specimen found on 11 July 1952, which he believed to be the spawn of individuals from either the May 1950 or March 1951 planting. Other specimens of bairdiella up to 6.5 inches were found later that year, indicating that a reproducing population had been established.

The population of bairdiella became very large in the Salton Sea where its main role was to provide forage primarily for the orangemouth corvina. Since bairdiella can achieve a length of 15 inches, however, many were caught by anglers.

Orangemouth corvina, Cynoscion xanthulus, Jordan & Gilbert

The orangemouth corvina normally ranges within the Gulf of California, Mexico, where it is a well-known game fish.

It was first stocked in the Salton Sea on 12 May 1950 when 27 specimens from San Felipe, Mexico, were stocked by the Department of Fish and Game (Douglas 1953; Walker et al. 1961). The initial plant was followed by others, up to and including May 1956. The exact number of fish stocked is unknown, but apparently the total number did not exceed 272 (see Table 2). OC (1978) said that 250 were planted; this is probably close enough.

Douglas (1953) reported the first orangemouth corvina caught in the Salton Sea, when a 22-inch fish was caught in a gill net by a mullet fisherman on 17 January 1952, saying that it represented one of the original introductions made either in May 1950 or March 1951. Whitney (1961) said that the orangemouth corvina apparently spawned in the Sea for the first time in 1952, and it has continued to do so.

The orangemouth corvina became the chief game fish in the Sea and revolutionized its fishing. At first, it was difficult to catch on hook and line, but following its capture in this way in 1956, an evolution in angling methods began (OC 1956a, 1957c, 1958c). Although it is predominantly a fish of saline waters, it has also penetrated the fresh or near fresh waters of the Whitewater River which enters the Sea from the northwest (Swift et al. 1993). Prentice (1985) has shown that the orangemouth corvina will survive conversion to completely fresh water.

Circa 1974, it was considered for transplant from the Salton Sea to California coastal waters by an advisory committee to the Department of Fish and Game composed of marine scientists (from California universities, the National Marine Fisheries Service, and the California Academy of Sciences), but the idea was dropped because it was considered that the Salton Sea fishery was having troubles, and that it was injudicious to draw fish from such a troubled source (Young 1974).

12.2. *Mexican fishes which were unsuccessful*

Although none of the fishes listed below is known to have survived in the Salton Sea, and although they were introduced using the "shotgun" method (i.e. a nonselective approach), a few notes are appended on the unlikely chance that any of them should ever be taken here. Unless otherwise indicated, all of the data concerning stocking is derived from Table 2.

"Anchovy," Anchoa mundeoloides

Forty-three anchovy from Guaymas, Mexico, were stocked in the Salton Sea on 2 October 1948, and six more from San Felipe were planted on 31 March 1951. The primary uses for such fish were as bait or food.

"Mojarra," Eucinostomus gracilis

A total of 12 Eucinostomus gracilis and E. argenteus (which is also from California) from San Felipe were planted in the Sea on 14 December 1950. It is used both for bait and food.

White mullet, Mugil carema

White mullet from San Felipe, Mexico, were stocked in the Sea as follows: 25 on 14 December 1950, 60 on 15 December 1950, and 5 on 31 March 1951.

On the other hand, Hendricks (1957) said that 105 "mullet" from the Gulf of California were transplanted to the Salton Sea in 1950. He included 15 Mugil cephalus, which is resident in California and was already in the Sea. Aside from the fact that these were "shotgun" introductions, there seems to have been little point in introducing another mullet into an area where M. cephalus was already present.

"Silverside," Colpichthys regis

All of the silversides (family Atherinidae) planted in the Salton Sea were from San Felipe, Mexico: 40 on 12 May 1950, 600 on 14 December 1950, 70 on 15 December 1950, three on 31 March 1951, and 72 on 14 December 1951. It is assumed that they were introduced as forage fish.

"Flounder," Etropus crossotus

A total of 140 diamond turbot, Hypsopsetta guttulata, (which is native to California) and "flounder," Etropus crossotus, from San Felipe, Mexico, was planted in the Salton Sea on 31 March 1951.

"Halibut," Paralichthys aestuarias

One "halibut" from San Felipe was stocked in the Salton Sea on 12 May 1950 by fishery workers who were obviously unacquainted with sex. Four more from the same place were stocked in the Sea on 31 March 1951 either by a different group or after attending a lecture on the birds and the bees.

"Halibut," Paralichthys woolmani

One "halibut" from San Felipe, Mexico, was stocked in the Sea on 14 December 1950.

"Grunion," Leuresthes sardina

On 28 March 1951, 300 grunion from San Felipe, Mexico, were stocked in the Salton Sea.

"Opaleye," Girella simplicidens

Seven opaleye from San Felipe were stocked in the Salton Sea on 31 March 1951.

Totuava, Totoaba macdonaldi

Then known as Cynoscion macdonaldi, one totuava from San Felipe, Mexico, was planted in the Salton Sea on 12 May 1950. On 31 March 1951, an unknown quantity of this species was planted here, and during the April–May period of 1956, eight more from San Felipe were added. The only member of its genus, the totuava is both a good food and sport fish, and its air-bladder is used as a condiment by Asians.

Scalyfin corvina, Cynoscion othonopterus

An unknown number (less than 200) of scalyfin corvina from San Felipe, Mexico, was planted in the Salton Sea on 31 March 1951, and one more from San Felipe was planted here during the April—May period of 1956.

"Corvina," Menticirrhus nasus

One corvina from San Felipe, Mexico, was planted in the Salton Sea on 12 May 1950, and two more, also from San Felipe, were planted on 31 March 1951 to keep him or her company.

"Mudsucker," Gillichthys seta

The Salton Sea already had a supply of mudsuckers, probably from San Diego Bay, planted there on 13 November 1930 by the California Division of Fish and Game. The resident species, the longjaw mudsucker (Gillichthys mirabilis) is a major bait fish, a relatively unimportant predator, and at certain seasons is important in the diet of the orangemouth corvina in the Salton Sea. Sixty-three G. seta from San Felipe, Mexico, were introduced into the Sea on 31 March 1951.

In summary, of the entire group of fishes deliberately introduced into the Salton Sea and known to have survived until today (three species), two species were alien to California.

13. DISCUSSION

"Almost all human activities, from farming, lumbering and mining to creating and releasing pollutants [and nonresident fishes] make life difficult for the other organisms with which we share the planet."

—A.H. Ehrlich and P.R. Ehrlich 1987

"We choose exotics on the basis of what they can do for us and not primarily on what they can do for the non-human system."

—H.A. Regier 1968

"We of the minority see a law of diminishing returns in progress; our opponents do not."

—A. Leopold 1949

Charles Elton of Oxford may have set the modern scene for viewing introductions in 1958 in his classic "The Ecology of Invasions by Animals and Plants." (His title might have included the words "Human-assisted.") Aside from his "worst case scenarios," he painted a very gloomy picture of the future: "If we look far enough ahead, the eventual state of the biological world will become not more complex but simpler—and poorer. Instead of six continental realms of life with all their minor components of mountain tops, islands and fresh waters, separated by barriers to dispersal, there will only be one world, with the remaining wild species dispersed up to the limits set by their genetic characteristics, not to the narrower limits set by mechanical barriers as well." Since that time, the scientific community has accepted many of his remarks or opposed them with vigor.

Elton's remarks can be supplemented by those of Ross (1994): "... often free of the natural predators they found at home, these [introduced] species sometimes run amok, disrupting food chains and displacing native species." In other words, the "success" of many introduced forms seems to lie largely in the absence of natural checks to their expansion. Similarly, native species are not accustomed to the introduced ones and are sometimes displaced by them. Conversely, if the introduced species is suited to its new home, it usually experiences a rapid population increase, but once local resources are depleted its numbers fall. Eventually, it comes into balance with an altered ecosystem (Flannery 1995).

Many papers have been written concerning fish introductions, and there have been many meetings on the subject. Fish introductions have been discussed on a local and on a worldwide basis. Organizations have been formed to discuss, foster, or to combat introductions. The American Fisheries Society has a special committee and an Introduced Fish Section (both authors have been members), which has issued a newsletter and has devoted a chapter by Li and Moyle (1993) to the management of introduced fishes in its 1993 issue "Inland Fisheries Management in North America." The Biological Resources Division of the U.S. Geological Survey has a computerized data base for exotic fishes. Some areas have advocated the introduction of certain introduced species (e.g. the kokanee) to combat other introduced species (Maher 1969). A number of states have banned the introduction of certain species of fish and provided reasons for their actions. The Aquatic Nuisance Species Task Force (1994) has prepared a report for Congress regarding intentional introductions of non-native species to United States water bodies. In short, there is no dearth of material on the subject, which, as with the value of introductions, is highly controversial.

The general subject of introductions is well covered in several papers in Rosenfield and Mann (1992) and in their many references. With respect to the value of all introductions, plant or animal, the reader may wish to read the objective treatise, "Harmful Non-Indigenous Species in the United States" (U.S. Congress, office of Technology Assessment 1993).

There are a number of people and a number of periodicals which exhibit a repugnance to most, if not all, introductions. Some speak, for example, of "biological pollutants like introduced fishes" (Minckley and Deacon 1991, p. 403). These authors are, of course, also "biological pollutants"—having been introduced to the North American continent by their ancestors, who were just as "invasive"—as today's historians say—as the introductions they condemn (Schwarz 1995). In the State of California or with respect to Californian introductions, there are also a number of gurus or pundits (the words are chosen carefully) who generally side with those who wish to maintain or to succor the native aquatic fauna, and who often blame introduced fishes for depleting it. Conversely, there are others who have little regard for preserving natural fauna, and who will readily promote almost any introduction if they think it will improve fishing or the economy.

Nevertheless, there does appear to be some similarity between both sides. For example, in California, even those who believe that native aquatic resources are superior to those which are introduced seem to partake of most terrestrial introductions without guilt. Thus, they readily buy and eat wheaten products, clothe themselves in wool from imported sheep, sole themselves with leather from introduced cattle, eat lettuce (originally from Europe) bathed in oil from introduced olives, and may drink Napa Valley wine made from European grapes or milk from introduced dairy cows. Incidentally, many of the state's vegetable products are pollinated by the ubiquitous honeybee (Apis mellifera) which was introduced into North America in the 17th century and brought to California in 1852. And even those who wear synthetic clothes may dress in fabrics derived from imported oil. They also give at least lip service to the idea that immigration of foreign stocks of Homo sapiens into California is commendable—a very different thing than the immigration of fishes.[176] We may also point out that it has only been through the migration of Homo sapiens from one area to another that the present complex of human beings exists. There are few "native" stocks.

Some of these people also speak of "the real world." We are not quite sure what the "real world" is, but with respect to some of the American academicians, you may be sure that it does not contain the nefarious black bass, if it is swimming in any of the waters west of the Rockies.

There is something to be said on both sides of the advisability of introducing new species of fish. In fact, there seem to be many sides, and almost no amount of argument will convert one side to the other. Most authors seem to have come out the same door wherein they went. The "sides" grade almost imperceptibly into each other, and one's employment or avocation (e.g. sport fishing) often dictates one's opinion or action. Those who largely oppose introductions are often drawn from academic ranks among whose roles are the collection of fishes (or grants), counting fin rays, use of electrophoresis, and publishing scientific papers. They are rarely subjected to pressures from their constituents or their employers, and derive their financial support from organizations which have taken no stand on the matter.[177] Despite an oft-made statement, their educational background is often quite similar to those who are responsible for introductions. There are also those with no biological background who dwell quite happily in a very unnatural world, and are wholeheartedly in favor of most introductions.

In short, we have a gamut ranging from "Radical environmentalists ... who feel that our ... modern social maladies will be healed as we find true harmony between the land [and water] and human life" (Lewis 1992), to those who couldn't care less if most of the world were paved over with concrete. We stand closer to the first side. But as has been emphasized before, our major purpose in this paper is to present an accurate and unbiased history of the introduction of fishes into California.

We agree with those who believe that if a governmental unit introduces any fish today, that the matter should be studied thoroughly. At the same time, we believe (with most realistic biologists) that the best study in the world may not reveal some of the dangers concerned, and we believe that no matter how many "codes of practice," "guidelines," or "protocols" are established to control introductions

[176] Users of domestic products may consider, of course, that cultivated plants and animals exist "... through watchful tending and in an artificially sustained environment ..." (Graham 1944), or that they are far removed genetically from their wild ancestors (Courtenay and Williams 1992), but both sides still consider that most native and introduced fishes are feral.

[177] Somewhat opposing views of these two "sides" are shown by those of Bruce Schmidt of a state management unit, and Walter Courtenay, Jr., a university professor, as given in U.S. Congress, office of Technology Assessment (1993, p 64).

(e.g. Kohler and Stanley 1984; Bartley 1992), no one has much real control over either accidental or purposeful but illegal introductions. Similarly, we doubt that articles condemning introductions, which are published in scientific journals read primarily by those wearing the same ecological glasses, have much effect upon the practice. Furthermore, we hold to the general premise that in many cases environmental decline (erosion, lack of water, pollution, etc.) may have had perhaps as much or more effect on native populations as the introduction of alien species.

We appreciate the good qualities of each argument and, rather than debate the subject, shall merely ask the reader to decide on his or her place between those who wish to preserve and study endemic fishes (pickled or *in situ*) and those who wish to sit on a heated fishing dock and catch an assemblage of introduced African tiger fish and cichlids from a water that has been "chemically treated."

In addition to these two extremes, each of which has been advocated by thoughtful men, and also noting that there are some who "couldn't care less," we should point out that although certain scientists have generally opposed introductions, these same scientists may have condoned or even praised some specific introductions. Thus, we have G.S. Myers, an outstanding ichthyologist (and not a fisherman) who was very much opposed to the introduction of many fishes either in the United States or in foreign lands, saying that rainbow trout was a most valuable introduction to southern Chile, and that largemouth bass had been a great success in South Africa (Myers 1947), and C.L. Hubbs, also one of the world's outstanding ichthyologists, suggesting the addition of tarpon to the California fauna.

If the reader wishes a modern and fair appraisal of the situation with respect to fish and introductions and the relative roles of habitat changes and fishing, he or she is referred to Moyle (1976b, p. 46–55) or, if the somewhat purple title of their article can be disregarded, to Moyle et al. (1986). The reader is also referred to such papers as those in Courtenay and Stauffer (1984) and Radonski and Loftus (1993). And, from an earlier date, we especially recommend the cogent remarks of Regier (1968).

However, again, this paper is not the place to discuss the general problem of introductions, nor does it wish to pass judgment on each fish introduction that has been made in California. It is, rather, a chronicle or history, primarily an accurate record based to a large extent on printed material.

"I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who."

—R. Kipling 1902

Let us skip Kipling's *How*. The first fish introduced into California obviously came by rail or by sea; the last fish introduced came by air. A few Federal introductions and some illegal introductions have come by automobile.

With concentration on the *W*s—let us change the order of presentation and attempt to answer the five *W*s of fish introductions into California. The first of these is *What*. The foregoing accounts list what species or subspecies have been introduced into California. The second *W* is *When*. Again, the foregoing accounts tell when each form was introduced. The third *W* is *Who* introduced them, or who actually determined the policy or notion behind the introduction. Such a determination is relatively clear and may be outlined by recapitulating six phases of introduction. Both the numbering of the phases and their inclusive dates, which may overlap, are arbitrary.[178]

"Faithfulness to the truth of history involves far more than research.... The narrator must seek to imbue himself with the life and spirit of the time."

—F. Parkman 1865

13.1. *Phase 1 (1871–89)*

Even before California had introduced a single fish, and only 19 years after it had become a state, the California Academy of Sciences (which had been organized in 1853) was interested in the subject. At its meeting on 3 May 1869, it offered the following opinions: "Dr. Gibbons made some suggestions with regard to the possibility of acclimatizing on our coast some of the best Eastern market fish; shad for example, and other species not now existing here. Dr. Blake [President of the Academy] said there was no country in the world where acclimatization would be so useful as in California." Another member stated "... that a company had been formed in San Francisco to introduce the shad in California." And among the other organisms suggested at the meeting for introduction into California were: "New Zealand flax," opium, and teasel (California Academy of Sciences, Proceedings, Vol. 4, 1868–72).

Later, at their meeting of 5 May 1873, the California scientists said, "One of the first efforts of the [Fish] Commission was to get shad from the eastern coast, because it was emphatically a food fish," and "They had taken no account of fancy fishes, but had endeavored to spend the moderate appropriation of the State for some permanently useful purpose" (*Ibid.* Vol. 5, p. 73–74, 86, 88). Thus, given as an example, importuned, praised, and with some regard (as we shall see) for their own pocketbooks, the first California Fish Commissioners set the stage for that which was to follow with respect to introduction of fishes into California.

Even before the California Fish Commission started its action, the California Acclimatization Society was prominent in sponsoring introductions. Information on this Society has been difficult to find. Although it is mentioned in the

[178] Moyle (1976a) grouped the introductions of fish into California by decades for the period 1871–1973, but did not consider the personalities or objectives of those responsible for the introductions as we have tried to do.

literature, the Sutro Library and the California Historical Society have informed us (1993) that they have nothing in their catalogs on this organization, and inquiries of faculty members concerned with fisheries at the University of California at Berkeley have proved fruitless. M.R. Jennings believes that its records may have been destroyed in the fire following the San Francisco earthquake of 1906.[179] From various sources, however, we have pieced together some information on this organization. According to Alta California (13 February 1871), this Society was organized in 1870 to procure a place for the purpose of making ponds and propagating game, birds, and fish so as to have a convenient point for distribution to all portions of the state. Whitefish (Coregonus) and American shad as well as "trout" (probably brook trout) were among the species of fish considered for introduction. We have mentioned some of the other fish which the Society suggested for introduction under the specific species accounts. Behnke (1992) called the Society a "quasi-public organization established to develop a state fish culture program until the California Fish Commission could assume responsibility," but this statement is primarily conjecture as he had little specific information on the Society (pers. comm., June 1993).

Headquartered in San Francisco, the Society had ponds at San Pedro Point, San Mateo County, and hatched "trout" at a hatchery near the old City Hall in San Francisco and at one on the grounds of the University of California in Berkeley. (The latter hatchery was operated by the Society through 1873 when it was taken over by the State Fish Commission as its first hatchery.) According to Stone (1874a), it "... successfully introduced from the east the black bass (Grystes fasciatus) and the brook trout (Salmo fontinalis) . " (See the accounts of these "species.") We do not know whether these fish were planted in public waters.

This Society was decidedly interested in bringing nonnative species to California and in furnishing Californian species to other areas. For example, at its first annual meeting in February 1871, its President, W.A. Hewell, spoke of the desirability of importing into California "... the European skylark, the thrush, blackbird and linnet." He said that these birds differed from those of the same name in California, were birds of beauty and song, and were useful for destroying insects (Alta California, 13 February 1871).[180] In a later edition of Alta California,

[179] Apparently this group functioned under various names such as its original name, "Ornithological and Piscatorial Acclimatizing Society" and "California Acclimatizing Society." It may even have been an incorporated company at one time.

[180] Although some of these European birds (probably Alauda arvensis, Turdus sp., T. merula, and Carduelis cannabina, respectively) are considered to be "songbirds" in the British Isles, they are eaten in countries such as France and Italy. Although none of these were introduced into California, another European bird, the house or English sparrow (Passer domesticus) appeared in San Francisco circa 1871 either as a deliberate introduction to California or as a migrant from the eastern United States where it had been introduced in 1850 as a means of biological control of the canker worm, a geometrid lepidopteran. Held in check to some extent by California's native "linnet" or house finch (Carpodacus mexicanus), the English sparrow was maligned for many years in issues of California Fish and Game as a most undesirable and destructive introduction.

it was said that: "All lovers of the gun and fishing rod should lend their aid, and second the efforts of the Society to increase the game of California" (Alta California, 14 February 1871).

All in all, the Society appeared to be interested in providing fish both for food and sport (see for example, Alta California, 5 May 1873), but was also interested in "acclimatization" for its own sake. The President's statement of February 1871 is proof of this, as is the statement of the Zoological and Acclimatization Society of Victoria (Australia) that it was its intention to obtain the "Eastern and Mountain quail" as well as a supply of salmon eggs from the California organization (Anon. 1873). In other words, it was a Society that formed a part of the worldwide network of "acclimators" and through its actions perpetuated the belief that the importation of alien forms was good for any area.[181] This private group existed for a time, but as time passed, the introduction of fishes to California became centered in the hands of the State Fish Commissioners. In fact, the first fish culturist retained by the Fish Commission was J.G. Woodbury who had been carrying out experiments for the California Acclimatization Society and later for the U.S. Fish Commission (Bryant 1922).

Most of the early Fish Commissioners were laymen; e.g. businessmen or lawyers. They were usually men of means, with enough political weight to be appointed by the Governor. They usually had no real knowledge of fish nor of ecology. They had limited State funds and spent them about as well as they knew and as well as they were advised, concentrating on the provision of access for fish, protection from wanton destruction, and the introduction of new varieties. The latter part of the 19th century (and part of the 20th) was one of expansion, indiscriminate use of the land and water for man's presumed well-being, coupled with the feeling that the natural state would somehow, or to a large extent, endure. "Mid nineteenth century Americans were ... confident, impatient, entrepreneurial, defiant of life's limitations, and determined actively to possess and develop the enormous continental expanse that had opened before them" (Kelley 1989). Generally speaking, man in California did not protect a resource but used it. It was the spirit of the day, and no one could have understood the present concern of many for endangered species such as the delta smelt, snail darter (Percina tanasi) , or spotted owl (Strix occidentalis) . The California Commissioners were

[181] One of the earliest in this network was the Acclimatization Society of the United Kingdom, first formed in 1860 under the name "The Society for the Acclimatization of Animals, Birds, Fishes, Insects and Vegetables within the United Kingdom." This Society was the brainchild of F.T. Buckland, first trained in medicine and later the Inspector of Fisheries for the U.K. Lever (1977) provides an interesting history of this organization.

eager to use their slender resources to import any type of fish which was successful elsewhere.

Although the Caucasian population of California was largely Anglo-Saxon, there was a large "alien" population. About one-third of the people in California in 1880 were foreign-born (McEvoy 1986). Although "alien" fish were widely accepted, the same good feelings were not extended to alien human beings. They were labeled as being inferior and often blamed for many of the woes of the California fisheries. (One is reminded of Thoreau's description of the attitude of many eastern Americans towards certain aliens of the 1840s.) Even at a much later date, this feeling persisted. See, for example, the remarks of Holder (1915), at the first annual meeting of the Pacific Fisheries Society in 1914, who blamed much of the decline in fisheries to the "alien," and the ensuing discussion in which only one delegate pointed out that decline might also be caused by "native" fishermen. Among this "alien" population were the Chinese, who were fond of fish, first employed in large numbers for mining and later for railroad construction, and for whom a cheap and abundant source of food was desired.[182]

As the first Commissioners said, they hoped to add "... to the food supply of the people by the introduction of new varieties," to give "... employment to a large number of men," to furnish "... a cheap supply of nutritious food to many more people" (California Fish Commission Report for 1870–71, p. 5). Furthermore, they were completely convinced that by spending only a little money to introduce fish, they would increase the income and pleasure of many people. They were not, however, completely altruistic, "... care being taken to prevent Indians and others from catching them" (*San Francisco Daily Evening Bulletin*, 2 September 1876), and they were not always averse to augmenting the contents of their wallets.

During the nineteenth century, there was little knowledge of the future productivity of California's oceanic waters. The Pacific salmon fishery had been well started (salmon were first canned here in 1864, and it was the most important fishing industry in the state until about 1914), but it was primarily a river fishery,

[182] Chinese immigration into California started in the 1840s. Although fostered as a source of cheap labor, there was considerable hostility towards the Chinese. For example, in 1869, Governor Henry Haight said, "... [their] servile composition tends to cheapen and degrade labor." It may be noted that Haight appointed the first California Fish Commissioners (WPA 1942). It has often been said that the western railroads could not have been built without the Chinese. C. Crocker, a member of the "Big Four" of the Central Pacific Railroad, was largely instrumental in importing Chinese workmen, and another member, L. Stanford, who was publicly anti-Chinese, actually favored this practice (Asbury 1933; Roske 1968). A number of the early Fish Commissioners owned railway stock, and there is no question but that the "railroad" (Central Pacific and its offshoots, such as the Southern Pacific) dominated the politics of California until about 1900 or 1910 (Lewis 1938; Kennedy 1993).

and there was no realization of the potential magnitude of the marine fisheries.[183] Our three largest seafood fisheries of yesteryear, pilchard or sardine, mackerel, and tuna, were all fairly recent developments. The Fish Commission's attention was centered upon the inland waters of the state, including San Francisco Bay.

Even here, popular opinion was that the fish in California were inferior to those of the eastern United States. "All the fish on the coast except the salmon, smelt and trout are long, coarse, poor and tasteless compared with the same species on the Atlantic coast" (McClellan 1872, p. 246). In fact, this early history of the western states averred that even the trout were "... neither so beautiful nor sweet as the Atlantic trout." Aside from the confusion regarding "species," it is true that the Commissioners were faced with a depauperate population of inland fishes with almost no forms which were familiar to them.[184]

Incidentally, the early California Fish Commissioners were not particularly concerned with introducing fish for sport (unless the fish were planted in their own backyards). Usefulness as food ranked as the first choice; American shad and striped bass were introduced because at the time they were considered excellent food fish. Moyle (1976a) is mistaken in saying that these fishes (as well as carp and tench) were introduced for sport. Li and Moyle (1993) are also mistaken in saying that the shad and striped bass were introduced into California to benefit both sport and commercial fisheries. It is true that both shad and striped bass became sport fish in California, but these species were not introduced for this purpose.

Indeed, sport fishing is a relatively new development in California for the average person. In the 1870s, "Sport fishing was actively pursued mainly by wealthy dudes, but most families netted fish for the table and there were no restrictions on commercial fishing" (Harrell 1970). As several authors have pointed out, the term "sportsman" was generally applied to an urban hunter or fisherman, and, in fact, angling seems to have arisen as a pastime of the royal or wealthy classes (Dill 1978).[185] Even Isaak Walton was originally an urban dweller. The senior author recalls that as a boy on a California cattle ranch, the "sportsmen" came from the nearest urban center. Those who worked on a ranch usually considered that wild animals were either competitors or were to be used for food. As late as 1910, it will be noted that the Chief Deputy of the California Fish and

[183] of all the native fishes, the chinook salmon loomed largest in the eyes of the early Commissioners. It was even planted at an early date without lasting success in waters to which it was not native, e.g. the Kern River and Lake Tahoe (California Fish Commission Report for 1874–75, p. 9).

[184] It is considered that there are about 790 species of native freshwater fish in the United States, but in California there are less than 80 natives including extinct, anadromous, and marine species which occasionally penetrate into fresh water.

[185] Schramm and Edwards (1994) and others say, "U.S. recreational fishing traditionally has been a rural activity...." We disagree.

Game Commission made a clear distinction between "simple hunters and fishermen" and those in the "sportsman class" (letter of 4 June 1910 from C.A. Vogelsang to C.H. Gilbert). In fact, it was not until 1913 that a fishing license was required in California for those "... who may be called either 'sportsmen anglers' or simply 'anglers' ...." (Shaeffle 1915). The situation today is far different, when according to the U.S. Fish and Wildlife Service, 26% of the United States population fish for sport (Sport Fishing Institute 1992b). (In California this figure is closer to 10%.) Furthermore, for some years the California Fish and Game Commission has been almost completely dominated by sportsmen, and since most of the revenue of the Department of Fish and Game is derived from them, its actions are somewhat predictable.

In the past, however, the gurus of the day were almost to a man in favor of introductions if they were acknowledged food fishes. Thus, before the California Fish Commission had even been established, Thaddeus Norris (1868) had devoted a chapter of his "American Fish Culture" to "naturalization," and in speaking of the new "fish-raising fever" (both artificial propagation and acclimatization), he urged: "Let every one who is interested in this movement give whatever time and effort he can spare, and in less time than we suppose, a complete revolution may be effected in our American waters, and our barren rivers and profitless ponds be made the repositories of great wealth." These were, of course, stirring words; he appealed to profit. But at an even earlier time, the State Zoologist of New York had appealed to "patriotic" individuals to import nonnative species to stock American waters (DeKay 1842).[186] Acclimatization was already a worldwide activity. California has long been noted for the grand manner of its enterprises. In introducing fishes it was true to its heritage.

"California ... was permanently changed by the 1870s ... when early agribusiness followed gold miners and shepherds."

—B. McKibben (following W.T. Anderson) 1989

The above statement should be supplemented by one saying that the state was also changed by the development of railways and the gradual displacement of natural cattle grazing. And when the Fish Commissioners first started their work, which to some extent was linked with the development of railways, to whom did they turn to help them import "alien" fishes? They turned to those considered to have the greatest knowledge of fish. Seth Green, for example, was employed to transport shad by rail to California. That Green was a relatively uneducated man, who considered that the ability to be a fisherman was the most important element in being a fish culturist, was unimportant to them. Green was often termed the

[186] The 16th century statement, "Patriotism is the last refuge of a scoundrel" by Samuel Johnson, was not widely accepted. Perhaps a later statement on the subject was more applicable: "No man can be a patriot on an empty stomach" (Brann 1893).

"father of fish culture in America," and was respected as an almost complete authority on anything concerning American fish.

Or the Fish Commissioners readily turned to Livingston Stone who had not only written a book on "Domesticated Trout," but who had attended Harvard University and was a bonafide minister. Great reliance was placed by the California Fish Commissioners on Stone, who, in a joint venture between the U.S. and California, attempted to bring an assortment of fish from the eastern United States to California in 1873 in his first famous "aquarium car." The railway car was wrecked near Omaha and the shipment destroyed. The car contained shad, brook trout, catfish, black bass, yellow perch, walleye, and tautog as well as lobsters, oysters, and forage fish (California Fish Commission Report for 1874–75; Stone 1876b; Smith 1896). What did Stone (1874a) say of his attempted introduction of yellow perch in 1873? "... [I]t is ... far preferable to most of the fish at present existing in the freshwaters of California, and even if it destroyed four-fifths of the other fish there would replace them by a better kind."[187] Furthermore, like most of his colleagues who placed no emphasis whatsoever in the modern idea of not mixing stocks, Stone (1882) spoke blithely of tossing a few eastern fishes into the Mississippi—as he said he always did "for luck"—when he crossed it on a trip to California in 1879.

A third example of a fish expert of the 19th century to whom the California Fish Commissioners turned to for advice was Professor S.F. Baird, a scientist and first head of the U.S. Fish Commission. He was heartily in favor of most fish introductions for the United States, e.g. the huchen (Hucho hucho) , sterlet (Acipenser ruthenus) , gourami, and other exotics (Baird 1873).

Such men were the "experts" of the day. Should not the California Fish Commissioners have taken their advice?

"Immigrants who brought old and familiar organisms to their new locations and returned newly encountered ones to their homelands were oblivious to the potential consequences of these actions."

—F.M. Utter 1994

As early as 1872, the American Fish Culturists' Association had formed a committee to make arrangements with foreign countries for a mutual exchange of food fishes, and reprinted a column of the *San Francisco News Letter* which prophesied that when the waters of California "... were teeming with fish, we could, in case of our vast herds of cattle perishing from thirst in the future, have an abundant supply of the most healthy and nutritious food known to man."

Not only was there a decided emphasis on the value of fish for food, but for the substitution of "better" varieties of fish for "worthless or coarser ones" (see, for

[187] Almost half a century later, we find the head of California's Bureau of Fish Rescue and Reclamation saying, "... I would eliminate all the useless nonfood fishes that are of no commercial or food value...." (Neale 1922).

example, Roosevelt 1877). Furthermore, the claims made by fish culturists (a term which in that day included both those who raised fish and those who studied them) were grandiose. In speaking of the successful introduction of shad and striped bass to California, Blackford (1894) said, "These facts prove that fish-culture is an absolute and exact science, from which undoubted results can always be counted on, if it is carried out intelligently." (We ask ourselves: who would admit to not doing something "intelligently"?) Or, with respect to artificial propagation, one of the California Fish Commissioners stated that if "... the legislature made sufficient appropriation, the commissioners could fill the river so full of salmon that it would be difficult for a steamboat to pass through them" (Smiley 1884b).

Some of the suggestions sent to the U.S. Fish Commission and some of their actions would be considered almost ludicrous today. Thus, we find a suggestion that we introduce "catfish" into Belgium, the actual transference of the Eurasian carp from the United States to Scotland, and shipment of "California salmon" (Oncorhynchus tshawytscha) eggs to France where it was thought that the species might populate the Rhône, Aude, and Herault rivers. Somehow, Americans believed that foreign fish were better than our own; conversely, many Europeans felt that American fish were superior. Chambers (1883), for example, in speaking of foreign fish (among them landlocked salmon, carp, shad, "Rhine salmon," and black bass) for British waters, felt that the "California salmon" could "... sustain life under circumstances that would kill half our European fish."

That the choice of the early Commissioners in their selection of species intended for importation to California may not have been judicious is true. It seems probable that they would have tried to introduce almost any fish reported to be of good food value. Note, for example, their "... correspondence with gentlemen in China, with the object of learning what valuable food-fish can be obtained in that country...." reported in their first Report for 1870–71, p. 14–15, or their susceptibility to the attractions of the gourami, samlai or Chinese shad, and Hawaiian mullet. Possibly, the exotic character of these fishes, or of their names, made them seem attractive. Nevertheless, it must be conceded that in their actual importations, they almost entirely "... confined themselves to the introduction of food fishes fully known to be profitable in other States...." (California Fish Commission Report for 1872–73, p. 12). Furthermore, they were merely following the belief of the American Fish Culturists' Association, who "... believed that it was in the best interests of the country to stock any promising species of fish in any accessible body of water. They gave no consideration to the advisability of stocking or to the suitability of the fish to the waters" (Bowen 1970, p. 83). However, we should not apply the standards of today to those who sponsored early introductions nor to those who condoned them.

Nash, in his excellent book on conservation in America, has expressed this point very well in saying: "Neither the pioneers nor most subsequent resource developers considered themselves unthinking spoilers or were regarded as such by their contemporaries. Instead they acted in a manner consistent with their environmental circumstances and intellectual heritage.... Certainly early Americans made mistakes in using the land, but they became such only in the opinion of later generations. Rather than shaking moralistic fingers, conservation historians would do well to attempt to understand why men acted as they did toward the environment" (Nash 1976).

As Wilson (1992) said, "Presentism is the term that historians use for applying contemporary or otherwise inappropriate standards to the past. An awkward term at best, it nevertheless names a malaise that currently plagues American discussions of anything and everything concerning the past; the widespread inability to make appropriate allowance for prevailing historical conditions."

Those who made most of the early introductions of fish were doing so well within the mores of prevailing historical conditions. Furthermore, few Californians were native to the state. And one must not forget that in the latter part of the nineteenth century California was the home of the grizzly bear and vast herds of elk, and still supported market hunters. It was a new land which welcomed the introduction of wine grapes, citrus, and wheat, the exploitation of the mountains for gold, and the drainage of wetlands to sow imported cereals. All these things were supported not only by "developers," but by most people. "Progress" was a goal.

Furthermore, the success of early fish introductions into California had a marked impact on the "acclimatization" of other organisms throughout the world. "It is not to be wondered at that the same sort of results [acclimatization of introduced fishes] was looked for by those who sought to restock the depleted game covers of our state" (Grinnell et al. 1918, p. 30).

13.2. Phase 2 (1890–95)

Apparently, the next period of introductions (1890–95) can for the most part be credited to the efforts of the U.S. Fish Commission, although all such introductions were probably made with the full favor of the State. Moreover, the State was instrumental in distributing these fish and made additional importations itself. (It must be understood that conflicts between the State and Federal fishery administrations were uncommon at the time. Similarly, private introductions were condoned.)

Even when the State had presumably sought advice from the man touted as the greatest ichthyologist of the day, what words did they hear? In an article on the distribution of freshwater fishes, Jordan (1888) had already said: "A leading feature of the work of the Fish Commissions must be to help the fishes over the barriers, to assist nature in the direction of colonizing streams and lakes with fishes which are good to eat, to the exclusion of the kinds of fishes which man can make no use. This help may be given by the introduction of vigorous kinds of fishes into waters into which they had been unable to find an entrance before." Jordan (1891) had advocated the planting of at least three species of catfish in the Colorado River basin, saying that except for trout "... the whole great basin of the Colorado contains ... no fish of even second-rate character as food for man." At a later date (as we have seen in other accounts), Jordan heartily recommended the introduction of the ayu to California, and at least as late as 1908, on the basis of an anecdotal account and one or two specimens, recommended to the State that an undescribed coregonid should be introduced into California. Can you blame those empowered to protect and enhance California's aquatic resources for trying to introduce new fishes?[188]

13.3. Phase 3 (1896–1930)

Following these two peaks of introductions in the 1870s and 1890s, the next 35 years were marked by only occasional new importations and by the dissemination by the State of several already-established introductions.[189] The Arctic grayling and ayu were introduced for no very good reasons; certainly not to fulfill legitimate needs. Attempts to introduce the landlocked Atlantic salmon continued. In the 1920s and 1930s, the anadromous Atlantic salmon and the lake trout were tried again. Trials of the introduction of the Atlantic salmon were "... a veritable example of carrying coals to Newcastle" as Hedgpeth (1941) remarked, and the introduction of the lake trout had already endured much unfavorable comment. Only the plants of sunfishes and crappies in 1908 can be considered to be introductions which might serve a need.

What can account for the decline of introductions during the first part of the 20th century? It is true that the population of California had grown by 325% from 1870 to 1910 (Murphy 1995), but our marine fisheries for native species had increased to such an extent that we hardly needed any new fish for food. Even the prized alien food fish, the American shad, had really never become more than a minor fishery in California. It had long been realized that the average Californian

[188] The State's debt to David Starr Jordan, the first President of Stanford University, a California Fish and Game Commissioner, an outstanding ichthyologist, and his heritage, i.e. to those trained at Stanford, must be acknowledged. Until about 1940, most of the State fishery biologists (both marine and freshwater) were trained there.

[189] During this period there was a rather indiscriminate dispersion of fishes (both introduced and native) throughout California by men termed "Deputy Commissioners." Some of this fish planting was done on their own initiative; some in response to requests by sportsmen. Ecological considerations were minimized. For example, brown trout were planted in 1912 by a Deputy in Eagle Lake, Lassen County, in the belief that they would spawn in the deep waters of the Lake (The Lassen Advocate, 12 September 1913).

had little desire to cultivate carp or other fishes. Agriculture was more appealing than aquaculture.[190]

The demands of agriculture and the producers of power are not always paramount today, but the role of the power companies is still well recognized politically, and agriculture remains a "king." Eighty percent of California's developed water supply is devoted to agriculture. The role of the farmer—even if he be only a small representative of a large organization—is often foremost.

Our then State Bureau of Fish Culture was more concerned with propagating fingerling trout to aid the sport fishery than in introducing new ones. Or, perhaps more simply, the enthusiasm for "acclimatization," the "fever," had subsided. Anyway, by this time, California had—or thought it had—tried out most of the major freshwater food and game fishes of America.

Moreover, the general role of the California Fish Commissioners (and the same occurred in the Federal Government) shifted from one in which they were all-important to one in which they became the policymakers of a more stable or unchanging governmental organization. Such an organization composed of "professionals" (ichthyologists, hatcherymen, amateurs devoted to sport, and fishery and game biologists) was the new Division of Fish and Game which later achieved Departmental status. Such an organization was not as interested in "quick fixes," was slower to react in using introductions as its principal tool, and—except for political expediency—gradually became the arbiter of the Commission. Bryant (1921a, 1921b, 1922, 1924) described the early onset of this change.

A large amount of the California Division of Fish and Game's work with fishes depended principally upon men such as W.H. Shebley who headed work on the culture of coldwater fishes, and G. Neale, an exponent of warmwater fishes. Shebley, member of a pioneer California fish-cultural family, entered service with the State in 1883 and continued until 1931. Head of the Sisson (Mt. Shasta) Hatchery, once said to be the largest in the world, for 20 years, and later in charge of the California Department of Fish Culture and Distribution, he was primarily concerned with the rearing and planting of fingerling trout. Neale (1857–1946), a hunter and fisherman, advanced from a game warden to Executive officer of

[190] Despite some pious statements, the first Bulletin of the California State Water Resources Board (1951) made it perfectly clear that the major concern of water use in California was and had been irrigation. Even J.O. Snyder, an ichthyologist who later became head of the California Division of Fish and Game's headquarters unit concerned with freshwater fishes, wrote (with respect to fisheries in the Lahontan system),"... any consideration of methods of propagation and protection must begin and end with the assumption that agricultural and manufacturing interests are of paramount importance. A considerable and constantly increasing amount of the flowing water must be used first for power and then for irrigation, and when any measure intended for the protection of fishes is found to seriously interfere with the working of power plants or the demands of agriculture it will have to be abandoned" (Snyder 1917b, p. 41).

the Division of Fish and Game (1922–25), and was head of the Bureau of Fish Rescue and Reclamation.

Neither of these men was opposed to introductions; neither had much scientific knowledge of fish. Aside from working out a good trade, one reason for continued attempts to introduce fishes from the east and midwest may simply be that advanced by Neale (1931b): "The story of their importation from waters east of the Rockies is an interesting bit from the history of California, and well illustrates the desire of those people who have traveled westward to have about them reminders of the pleasures of their old home." This very human desire for the familiar still prompts Californians to suggest the importation of fish which will recall their boyhood days in the eastern United States. In his "Coming of the Pond Fishes," Lampman (1946) went almost all out in expressing this nostalgia by writing of "... the men who helped develop the west as a better place in which to live" as "... men of foresight who brought them [introduced pond fishes] from back home." One may not agree with either Neale or Lampman, but it is obvious that some people felt this way. Again, one must realize that almost none of the native food or game fishes, except salmonids and one species of centrarchid, had any resemblance to the fish of the eastern seaboard and midwest from where most Californians came.

There were, however, a few inklings that not all introductions should be condoned, although at first criticism merely took the form of tirades such as those against the carp and catfishes. Even then this was mostly hindsight. Both Neale and Shebley (in many articles) warned against promiscuous introductions. The latter's criticism was primarily concerned with the illegal planting of "predacious or spiny-rayed fish" (why else should Shebley have been interested in introducing "Sunapee trout"), and most of the criticism by both men was directed towards those who had made introductions outside the sacred chambers of the State wherein they were august representatives. This conjecture is well exemplified by a statement that no one should import or transplant fish without the authority of the State following directly upon a description of another State attempt to introduce Atlantic salmon—which most fishery people today feel was unwarranted (CFG 1932a).

It was not until comparatively recently that even professional biologists advanced any arguments against fish introductions. One of the earliest of these was Eigenmann (1890), who, in speaking of the inland food fishes of California, said: "By saying that the number of species of fresh-water fishes is limited, I do not wish to imply that the food fishes are less in number or inferior in quality, but merely that we have less variety, a defect which can be remedied by introducing other species." While this is a quasi-endorsement of the "natural" state, it is still an argument for introductions. Note the word "defect" and the remedy.

A more emphatic argument was that of Rutter (1908), naturalist of the U.S. Bureau of Fisheries, who wrote: "Fortunately only a few of the 24 species [recorded by Smith, 1896, as having been introduced into California] ... have obtained a foothold in California waters." Another biologist was Snyder (1917b, p. 84) who, in speaking of introduced fishes in the Lahontan system, said: "This has usually been done without any serious study of local conditions which might affect the introduced form or of any consideration of the relations which might arise between introduced and native species." Later, while still at Stanford University, speaking of trout, he said: "... we have already made a great mistake in introducing inferior species to cope with our native [California] forms, and any proposition to introduce others such as the Atlantic salmon, is a tacit admission of our inability to cope with the problem of conservation of our own superior species" (Snyder 1928).

Later, when the old State Bureau of Fish Culture widened its responsibilities and became the Bureau of Fish Conservation (inland fisheries, especially for sport) with Snyder as its first Chief, he reiterated his warning against fish introductions in the Division of Fish and Game's Report for 1934–36: "There is a constantly recurring agitation for the introduction of exotic species of fish. While some requests and suggestions are so evidently ill-considered as to be dismissed at once, others remain to be brought up from time to time. Our native species together with those already introduced furnish an ample fauna, and if with proper conservation and propagation these can not be made to sustain a reasonable amount of sport fishing, the remedy is not to be found in the introduction of other species. The introduction of a foreign species may be simple enough while the result may be appalling" (Snyder 1938). He did not characterize native "rough fish" as harmful to trout as do many sportsmen and fish managers.

Aside from these fishery biologists or ichthyologists, there were few scientists who spoke of the possible dangers from fish introductions into California. One of these was T.I. Storer of the University of California at Davis, who pointed out that the original distribution of animals over the earth was a matter of age-long adjustment involving many factors, and the occupancy of new territory involved long periods of time and numerous intricate biological adjustments (Storer 1931).[191] Man's advent and improvement in his means of transportation had brought forth almost immediate changes in this distribution. With specific reference to fishes in California, he listed about 15 species which had become "naturalized," but felt that most of these introductions were decidedly beneficial. In fact, he wrote of California's rather poor original fish fauna and stated that there had been a reduction of only one desirable native species. (We assume that he referred to the Sacramento perch.) He was emphatic, however, upon the need for thorough study before any formal action be taken for introduction.

[191] One introduction, Bermuda grass (Cynodon dactylon) from the Old World, was thoroughly disliked by Storer, who claimed that he had never allowed it to establish itself in his lawn (also of introduced species) in Davis (pers. comm.).

13.4. *Phase 4 (1931–51)*

The fourth stage of development came with the inclusion of "scientific" workers within the California Division of Fish and Game's freshwater unit which until then had been composed almost entirely of hatcherymen. J.O. Snyder, a competent ichthyologist, an authority on trout and salmon, and one who had traveled widely in California, was the first of these in 1931.[192] He was followed in 1937 by A.C. Taft, who had trained at Stanford under Snyder. Taft was a fishery biologist of experience and proceeded slowly to build up a staff of other fishery biologists who provided the nucleus for the present assemblage.

Both Snyder and Taft generally resisted introductions into California. It is true that the spotted bass was introduced during Snyder's term, and that Taft, together with B. Curtis, introduced the kokanee. From the standpoint of the angler, however, the introduction of both species was an attempt to fill suspected "niches" in otherwise unproductive waters. Curtis, who for many years supervised the California inland fishery biologists, felt that it was "... man who has altered the situation, and while he has made some mistakes in the way of unnecessary adulterations of native stock, he has on the whole been moving in the right direction" (Curtis 1938). Curtis was originally an engineer, however, and entered his second profession, fishery biology, primarily because he loved angling.

Taft, who had a better and longer fishery education, was usually adamant in his considerations. He even instructed some of his staff (the senior author is one) not to consider fish introductions. He opposed the suggestion of H.S. Davis, of the U.S. Bureau of Fisheries, circa 1939, to introduce forage fish into California's streams, and was generally opposed to introducing new warmwater fishes or forage fish. (See the account of the threadfin shad.) However, throughout most of California's history, i.e. up to about the time Millerton Lake was opened to fishing in 1945, California was primarily a land with a lotic environment with trout and salmon as its principal game fishes. It is true that in the Central Valley and in parts of southern California the "spiny rayed" or warmwater game fishes such as the centrarchids had a place, but the emphasis—both for sportsmen and those who managed the resource—was clearly on coldwater species. But, even at this stage, California salmonids such as Pacific salmon were being planted in waters to which they were not native, and there was no real effort to oppose all out-of-state introductions.

The criteria concerning introductions were evidenced by the policy established for the management of inland fisheries by the Fish and Game Commission at its meeting of 20 July 1951:

[192] G.A. Coleman, a scientist, was employed by the Division of Fish and Game during the 1908–10 period and from 1924 until 1932. He was, however, primarily an expert on scale insects (Coccidae) and apiculture rather than an ichthyologist or fishery biologist. It is doubtful if his work contributed much to the advancement of fishery work in California.

"Constant vigilance will be maintained to prevent the introduction, either officially or unofficially, of plants, fishes, or other animals which might prove harmful to existing fishes, either directly or indirectly. At the same time, continuing studies will be made to discover new introductions which could be made safely to improve the productivity of certain waters.

"California was naturally endowed with an excellent supply of trout and salmon in the cooler waters. Fishes suitable for warmer reservoirs, lakes, and streams were few in number. A wide variety has been introduced by the Fish and Game Commission over the years. On the whole, these introductions were useful, but some mistakes were made. Introduction of other game and forage fishes may be desirable in the future but new fishes will not be brought in unless all available evidence indicates that the benefits will be substantial and the hazards few. Initial introductions should be made where spread to other waters in the State can be controlled." (From Appendix F, Commission Policy Statements, California Department of Fish and Game Report for 1950–52, p. 161).

Few, except those completely opposed to introductions, could have quarreled with this policy, and it should be noted that it was based largely on Taft's attitude—although he may have had a few misgivings at its final phrasing. Furthermore, under his leadership, fish introductions into California were almost nonexistent.

This was not consistent with the general attitude within the United States concerning fish introductions at that time. An examination of the influential *Progressive Fish-Culturist* during this period demonstrated that only a few fishery workers and ichthyologists pointed out the dangers of introduction. For example, Lake Titicaca in South America was planted with North American whitefish (Coregonus) , and rainbow trout were planted in Venezuela not only to promote a fishery but as a measure of "good will"! Again, politics determined biological history.

And with specific reference to California, even C.L. Hubbs, a noted ichthyologist and one prominent in the new field of freshwater fishery management, was not really opposed to introductions. He thought, for example, that the red shiner might improve fishing conditions in the Colorado River, and even suggested the introduction of the tarpon into the California Delta. Furthermore, the Fish and Game Commission's policy statement of 1951 gave carte blanche to the fifth phase of California's introduction of fishes.

13.5. *Phase 5 (1952–75)*

The real change came with the period following Taft's retirement in 1952, the change in status from Divisional to Departmental of the State agency for fish and game (which lessened the power of the Branches of the group), and the advent of a new Chief of the newly called Inland Fisheries Branch, A.J. Calhoun.

Although endorsing the 1951 policy of the California Fish and Game Commission concerning introduced fishes, Calhoun cleverly recommended that the Commission itself approve any proposed introduction because some might become controversial (letter of 14 November 1952 to the Director of the Department of Fish and Game). Calhoun did bow to pressure to a greater extent than did Snyder or Taft and was more amenable to the desires of sportsmen, but he was also confronted by a decided change in the waterways of the State. By the time he assumed office, and during his term (1952–73), the major fishing waters tended to be lentic rather than lotic because of an enormous increase in the number of reservoirs. The dams of the Central Valley Project alone were designed to store almost as much water as all the other reservoirs in California (totalling six hundred or more). "Originally a land of flowing waters supporting abundant trout and salmon populations, California ... [had] ... become a state where warmwater game fish species significantly contribute to the total inland sport catch" (Pelzman 1973b). Although the first large irrigation reservoirs appeared in California in 1859 (Jenkins 1970), by 1940 California had only about 35,000 acres of impounded water and most of these were located south of the Central Valley. However, by 1950 the acreage of reservoirs rose to about 70,000, and by 1983 there were about 350,000 acres of reservoirs open to public angling (Fisk and von Geldern 1983). In addition, about 94% of the freshwater wetlands of the Central Valley had been destroyed by 1980 (Jones 1980). At one time, these wetlands furnished spawning and nursery grounds for many fish.

The state was no longer the same. Completely new aquatic environments were created and many of the older ideas about their management were discarded. Furthermore, sport fishermen, who had increased in large numbers, sought out reservoirs as one of their primary places to fish. In order to keep up with their demands (we do not say "needs"), it seemed imperative to the biological staff of the State to consider the introduction of different forage and game species. We can do no better here than quote from an article prepared for popular consumption by the Inland Fisheries Branch Staff (1959): "The most promising possibilities [for improving fishing in a reservoir] are offered by new species of game-fish.... However, it is doubtful if any North American fish will solve the problem. We need to comb other parts of the world...." With sentiments such as this, it is small wonder that a resurgence of activity concerning introductions occurred. Moreover, the new California Fish and Wildlife Plan emphasized, with specific reference to warmwater fish, that the search for suitable new game fish would be intensified (California 1965; OC 1966b).

It is true that a number of studies were commissioned before introductions were made. Nevertheless, there was a greater leniency than in the previous phase, and we feel that some of these introductions were not warranted. Certainly, the reintroduction of the grayling fulfilled little except to add some novelty to angling.

Furthermore, chemical treatment (a euphemistic term for poisoning originally limited to the control of stunted populations or elimination of introduced bait fishes or other competitors in small lakes and ponds) increased in use.[193] The State entered in a large way on a program of species elimination through chemical means, and many miles of stream and some very large lakes and reservoirs were treated to eliminate both native and introduced fishes which were not of sporting value. Perhaps the most drastic of these efforts in California was the treatment by the Department of Fish and Game of nearly half of the entire Russian River system in 1952–54 (Pintler and Johnson 1956) in which 256 miles of river and tributaries were largely denuded of fish life (Hubbs and Miller 1961). Emphasis on the destruction of native nongame species had, of course, a long history in California. The California Division of Fish and Game Report for 1922–24, p. 80, pointed out that "... predatory fish, such as suckers and hardheads have been cleared out of many trout streams...."

Even in the case of natural waters such as Lake Tahoe, emphasis continued on attempts to utilize introduced other than native fishes; it was felt that the rehabilitation of native stocks was useless.

"California was America tomorrow."

—C. Gentry, circa 1969

All of these activities led to a more artificial type of environment and fishing. Coupled with the advent of the catchable trout program, fishing in California became more and more designed and less and less natural. In the meantime, snow-making machines supplemented the gifts of nature for skiers, and children were introduced to the great out-of-doors by fishing for tagged hatchery trout in plastic indoor pools. We regret such changes, but this seems to be the way of the world. California is not unique in such aspects; it is merely a forerunner of the future.

As the inland fishery program of the Department of Fish and Game was presented in 1953, "... the management of an inland fishery resembles that of a big, modern farming program" (California 1953b). Sport fishing was considered paramount, and the idea of administering a natural resource was almost abandoned. Obviously, the concept of finding suitable sport fishes through introduction became a way of life within the Department.

Although the idea of fostering a natural aquatic resource was not entirely abandoned, the pronouncement of 1953 did signify acceptance of the fact that California was no longer an area of natural stocks or natural waters. Original cutthroat stocks had been usurped by rainbow (native) and brown (exotic) stocks. California's lotic environment had become artificially lacustrine (reservoirs), and migratory stocks of fishes had been barred by dams or sucked into diversions. Its countless barren waters (high Sierran lakes) had become populated by stocked

[193] See the section on goldfish for some detail on chemical treatment.

trout. Completely unnatural stocks (striped and black bass) had become major game fishes. Food fish (salmon) had become primarily sport fish.

13.6. Phase 6 (1976–)

California is now in its sixth phase. Its dependence upon trout for fishing lies in the protection and enhancement of wild stocks (native and introduced) primarily through restoration of the environment, the continuance of a program of management for its high natural lakes, and the judicious stocking of catchable trout. It should be noted that the policy concerning inland water fisheries established in 1951 stated, "The basic objective should be to supply the best possible fishing for the greatest number of anglers...." (California Department of Fish and Game Report for 1950–52, p. 159). Although this policy did include the use of freshwater fish as food as well as for sport, its considerations of fish excluded any reasons for their existence except for their direct use by man.

There is now a revolution against fish introductions among some anglers, especially fly fishers, and a number of scientists who place emphasis upon a natural state, and there is a general awareness by the public that natural life is somehow sacrosanct and should remain untouched. True, a good many politicians and "big business men" give only lip service to this view, but the idea has at least been engendered.

There is a much greater interest by fishery biologists and others within the Department of Fish and Game in "biodiversity." (It is not confined to rainforests.) Many articles published in *Fisheries* by the American Fisheries Society testify to this point. Furthermore, the fish and game agencies within California and a number of other states have begun to support nonsport or nongame programs—rather than confine themselves to those sought for sport or food (McCloseky 1979). As one advocate of exotic fish introductions wrote us (somewhat sadly): "Considering the present political climate, I wouldn't like trying to get permission now!"

It was during this sixth phase when concerns about the impacts of introduced fishes really took hold in California. The Fish and Game Commission and the Division/Department of Fish and Game for many years have had legal control over the stocking of fish in public waters. However, it was not until 1957 that the Legislature passed laws to control the importation, transportation, possession, or release alive of species of fish and wildlife considered a menace to fish and wildlife resources, agriculture, and public health (Section 2118 of the Fish and Game Code). Authority was granted to the Fish and Game Commission to designate harmful species. Their designation became known as the Commission's prohibited species list. The concept is similar to that of the Federal Government and some of its species are also on the Federal Government's list of injurious species. The Commission's list of prohibited fish and wildlife is found in Section 671, Title 14, California Code of Regulations.

The list is amended as the need arises and as new information becomes available. At the present time, 22 families of bony and cartilaginous fishes are listed, e.g. all parasitic catfishes (family Trichomycteridae), six genera of the more dangerous piranhas (family Characidae), and the sheepshead minnow (family Cyprinodontidae).

The Fish and Game Commission's policy on fish introductions was also strengthened during this phase. It requires the Department of Fish and Game to: i) evaluate carefully any proposed introduction to insure it will not have an unacceptable negative impact on native species, ii) introduce an approved alien only under conditions that will permit the action to be reversed, and iii) clearly demonstrate that the proposed introduction is needed and cannot be satisfied through improved management to enhance native species or previously established non-native species.

Federal involvement in legal matters concerning issues involving exotic species began with passage of the Lacey Act in 1900 and has continued to the present time. The Lacey Act regulates the importation and transportation of fish and wildlife. Subsequent amendments of the Act and the adoption of regulations under authority of the Act added legal constraints on the importation and shipment of injurious fish and wildlife. The President's Executive Order of 1977 further emphasized the need to restrict the introduction of exotic species (i.e. those not naturally occurring in the United States) and reaffirmed the purposes and policies of the Lacey Act and the National Environmental Policy Act of 1969.

Growing public concern about the depletion of native fish and wildlife populations led to the passage in 1973 of the Federal Endangered Species Act and in 1984 to the California Endangered Species Act. Federal and State fish and wildlife agencies, including the California Department of Fish and Game, established programs devoted to the protection and management of species threatened with extinction. Numerous university and college professors became involved in the problem.

Many studies demonstrated that introduced fishes can seriously threaten the well-being of native fishes, including some that are officially listed as endangered, threatened, or species of special concern. A supportive literature, including entire books, has accumulated. Some of the more significant publications are: Lachner et al. (1970), Moyle (1976a), Deacon (1979), Courtenay and Hensley (1980), Schoenherr (1981), Courtenay and Stauffer (1984), Courtenay et al. (1986), Herbold and Moyle (1986), Mooney and Drake (1986), Moyle et al. (1986), Miller et al. (1989), Courtenay and Meffe (1989), Minckley and Deacon (1991), Rosenfield and Mann (1992), Baltz and Moyle (1993), Li and Moyle (1993), and Courtenay and Moyle (1996). Furthermore, the possible effect of introduced fishes upon certain amphibian and reptile species in California is well covered by Jennings and Hayes (1994). Additional references can be found in the sections on individual species.

Passage of the Federal Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 was stimulated by the invasion of the Great Lakes by the exotic zebra mussel and the ruffe (Gymnocephalus cernuus) , a European percid which is abundant and widening its range. These harmful Eurasian species were likely accidental introductions via ballast water. The potential damage from these events provided the opportunity for a nationwide evaluation of the impacts of all nonnative species on native aquatic ecosystems.

An interagency task force was established by the Act to recommend measures to cope with the problem, and a final report was issued in March 1994 (Aquatic Nuisance Species Task Force 1994). The Act addressed not only unintentional introductions but intentional ones. The latter included both accidental releases from private and public holding and production facilities and intended releases (e.g. stocking of sport fishes) directly into aquatic ecosystems. It was the question of intentional releases that most concerned State fish and wildlife agencies which were opposed to any new Federal regulations that would ban or complicate their authority to stock nonnative sport fishes. A final draft of the report was summarized by Lassuy (1994) and critiqued by Moyle and Li (1994) and Horak (1994).

A sixth phase does exist in the minds of those who determine the fate of our fish and fisheries. We leave it in their hands.

We have two more *Ws* to discuss. First, let us speak of the fourth *W. Where* were the introduced fish planted? We have not sought out every planting site, but unlike most writers who have accepted without inquiry the places in California where introduced fish were stocked, we have wondered why they were selected.

Many of the early plants seem to have been made at particular places because: i) they were well known, close at hand, or big waters, e.g. Sacramento River, San Francisco Bay, Lake Merced, Lake Tahoe; ii) they were on or close to a railroad line, e.g. shad were planted at Tehama, about 12 miles below Red Bluff, because it was close to the end of the railroad (California and Oregon) at the time; iii) they were private waters owned by those with influence, e.g. the Spring Valley Lakes or those belonging to the Country Club of San Francisco; iv) they were publicly owned waters, e.g. Laguna Honda or Mountain Lake in San Francisco; v) they were waters where special requests had been made by those who were influential, e.g. the lakes of the Country Club, Lake Cuyamaca, and those belonging to the Del Monte property owners near Monterey, or waters close to the property of Senator L. Stanford.[194] (The Del Monte properties were managed by a holding company stemming from the "Big Four" of California.)

[194] The California and Oregon Railroad Company, actually part of the Central Pacific Railway Company, did not provide service to Red Bluff, the upper end of the Sacramento Valley, until 6 December 1871 (pers. comm. from S.E. Drew, Senior Curator, California State Railroad Museum).

We believe that many of the VIPs of the past resemble those of today, and that political considerations may have been just as important in the early days as those which were economical or biological. Thus, we note that the Country Club of San Francisco had among its members, R.E. Wilson and E.L. Bosqui, both of whom were California Fish and Game Commissioners.[195]

Unrecognized (or at least unexpressed) by previous historians, there does seem to be somewhat of a link between the early Commissioners, especially S.R. Throckmorton, L. Stanford and other railroad owners, the Shafters of Marin County, the Spring Valley Water Company, those in charge of Lake Cuyamaca, and even David Starr Jordan. However, this is only conjecture on our part.

Some fishes, such as the brown trout, may simply have been first planted in waters close to the hatchery where they were reared in California. The localities of more recent introductions (particularly those of "Phase 5") seem to have been selected because: i) they were isolated or could otherwise be controlled, e.g. Lake Nacimiento for white bass; or ii) were waters thought to be suitable and "needing" a species with certain characteristics, e.g. the small streams where redeye bass were first planted.

Finally, as to *Why* any of the introductions were made in California (the last *W*), this subject has already been covered in the accounts of each species. Many authors (Welcomme 1988, 1991 is one) have provided lists of why fish species have been introduced. Fishes have been introduced into California for all of the reasons that have been enumerated. Some of them have been introduced for biological control of unwanted organisms. The muskellunge may have been planted for the specific purpose of destroying carp. Gambusia was definitely planted to destroy mosquitoes, and more recently the "instant fishes" or pearlfishes were planted in experimental plots in an attempt at mosquito control. Some, such as the "tilapias" and grass carp have been planted for aquatic weed control. There has been a good deal of activity with respect to using fishes for biological control, a method which is very popular today. Such work has been carried out with cooperation of the State's fishery people, but it should be noted that the actual experimentation or planting has been carried out by other agencies.[196]

195. No doubt is cast upon their presumed ability as Commissioners, but it can be noted that then and now the Commissioners for fish or game in California are appointed by the Governor, and that many of the appointments seem to have been of a political nature.

196. Although we know of no formal proposals in recent years to introduce any of the fishes mentioned below, it should be pointed out that a number of experiments have been made, especially at State agricultural colleges such as the University of California at Davis and Riverside, and by irrigation districts, to determine the usefulness of various organisms to control animal and particularly aquatic plant "pests." (This is especially true in potable water supplies where the use of pesticides or herbicides is not advisable.) For example, Yeo (1967) conducted experiments on aquatic weed control from 1962 to 1967 at Davis, using a reservoir, aquaria, and plastic pools. His more extensive experiments were with characids, the silver dollar fish (Metynnis roosevelti) and (Mylossoma argenteum), but limited experiments were also made with other exotics: tinfoil barb (Apuntius schwanenfieldi), black shark (Morulius chrysophekadion), black-banded leporinus (Leporinus fasciatus), and the gourami (Osphronemus gouramy).

Perhaps both the golden shiner and the green sunfish were initially introduced accidentally or as forage fishes. Some, such as the gobies, have probably been introduced accidentally, possibly in ballast water. The carp and tench were first brought in as food fishes by private individuals, and there has certainly been an opportunity for private individuals to import fish for either food or sport from private firms such as those which advertised in popular hunting and fishing magazines. For example, the Game Breeding column of the December 1967 issue of *Sports Afield* advertised the sale not only of baby alligators, but of many game fish for stocking. See also Carlton (1992, p. 20–21). Furthermore, with the advent of plastic bags and easy methods of aeration, it is extremely easy for private persons to carry and plant fish without detection. Some fish have escaped from aquarium dealers or have been released by aquarists and some of them have survived. Others have escaped from commercial aquaculture or food-fish farms. Some have been stocked initially or at least transplanted directly by sportsmen, or, based on their actual or vicarious experience, they have brought such pressure on the State agency (Commission, Division/Department) concerned with fisheries that even against their differing judgment the authorities have permitted the introduction. Sportsmen often read glowing accounts of "alien" game fish in outdoor magazines and readily accept the opinions of the author, especially when actual introduction is recommended. See, for example, the popular article by Howland (1957), an oilman who suggested that not only South American game fish but South American forage fish might be introduced into the United States.

Some introductions, such as the fish planted from exhibits at the San Diego exposition, were afterthoughts. Some, such as some of those alien to the lower Colorado River were undoubtedly planted in other states and may be said to have arrived in California by accident.

Some introductions stemmed from importations by private individuals who received fish from the Federal Government, often as political gestures. For example, in the United States as a whole, in 1883, 298 out of 301 congressional districts received shipments of carp from the U.S. Fish Commission (Boyle 1979, p. 90). The 1908 introductions into California by the Federal Government seem to have been made partially in payment of a political debt, but were also made as a response to an honest request for useful fishes. However, even representatives of governmental agencies (State) have provided fish illegally (if mistakenly) to private individuals (e.g. channel catfish).

Many of the others, especially the early introductions, were selected purposefully by the State simply because they were familiar food and game fishes of the eastern United States, because they might serve an economic need, and often because their importation was sponsored by prominent "authorities" on fish.

The latest fishes to be imported purposefully were selected because it was thought that they would fill particular ecological niches (some people believed, and still do, that they exist), or at least particular aquatic situations such as a fluctuating reservoir where they might improve angling.

In other words, the reasons for fish introductions into California have been manifold.

Again, we must emphasize this point. The State agency concerned with fish has not really been a resource agency. It has been primarily a fish and game agency and—especially since it has been supported by funds derived primarily from anglers, hunters, and commercial fishermen—has worked primarily for these interests. It has not drawn from the general State treasury, or been subject to the whims of a State legislature or budget. In fact, for a time it even boasted that it had no true allegiance to the State Department of Natural Resources.

Today, it is labeled as part of the Resources Agency and has widened its fields of action. In fact, it sometimes seems so concerned with the protection of native stocks and/or the environment that its deriders claim that it has ceased to be a "fish and game" agency. The Inland Fisheries Division is expected to maintain and enhance resident fishes, amphibians, reptiles, invertebrates, and the habitats these resources require for their survival. Sport use of these resources is permitted, but the Division's primary charge now is to protect and perpetuate native species, e.g. fairy shrimp, salamanders, turtles, and pupfish. In short, fishery management objectives in California are now following the course, typical of most State fishery agencies, outlined by Radonski (1995); i.e. they are tending towards the promotion of "aesthetic interests" and biological diversity.

California has obviously been a model for fish introductions throughout the world. Its successful establishment of American shad and striped bass, for example, has prompted suggestions for their introduction into many waters. (See, for example, Rass 1969.) It has also been the staging grounds for the transport of introduced fishes to other states (e.g. Hawaii, Nevada, and Oregon) and to countries such as Mexico and New Zealand (Hunter 1915; Neale 1922; Brock 1960).

On the discredit side, introduction of "alien" fish species often seems to have been harmful to our native stocks, and some biologists promote this theory at almost every opportunity. We have previously mentioned some of the opinions voiced by ichthyologists and some of the early Fish Commissioners. At a later date, Curtis (1942) dismissed the shad and perhaps the sunfishes as "... entirely harmless, at least in so far as we know, to the native fishes," and then ranked

"... in increasing order of criminality": brook trout, crappie, brown trout, lake trout, striped bass, black bass, catfish, and carp. One can find but little disagreement with this indictment, except that it might have included mosquitofish, and that we do not think that fish are criminals. Moyle and Williams (1990), following Minckley (1983), said that introduced species consume eggs, larvae, and juveniles of native fishes; but, as Rutter (1903) noted in a little known but delightful and informative article, native fishes as well as introduced ones prey upon each other or their eggs.

Both Hedgpeth (1941) and Clark (1942) suggested that the almost complete extermination of the sturgeon (Acipenser) in California (a view of the times) might have been correlated with the rise of introduced fishes. Miller (1958) said that the reduction in abundance of the Sacramento perch is due "presumably" to competition with introduced species. Miller and Pister (1971) attributed the complete disappearance of the Owens pupfish from three springs in Fish Slough, Mono County, "... chiefly to direct predation by largemouth bass...." Hopkirk (1973) said, "There can be little doubt that the bluegill and other introduced centrarchids have had a detrimental effect on the native fishes of the lake [Clear Lake], especially the Sacramento perch." (He also said, however, that angling for male Sacramento perch during the breeding season may be one of the main factors responsible for the decline of the species.) Mills and Mamika (1980) said that the extinction of the native thicktail chub (Gila crassicauda) may be due to a combination of modification of the aquatic habitat and the predation of exotic and competitive species. And, at a much earlier date, Hubbs (1947) suggested that in the Central Valley, this chub appeared to be approaching extinction "... probably as the result of the introduction of piscivorous fishes."

On the basis of a study of food habits, Moyle et al. (1974b) have suggested that bluegill may have been responsible for the decline of the Sacramento perch. Aceituno and Nicola (1976) suggested that the decline of the Sacramento perch may be due to incursions of introduced centrarchids, but, as have others, they point out that alteration of habitat may also have had a hand in this decline. Moyle (1976a) also drew the same conclusion for several native species and has reiterated this opinion in many papers.

All of these authors and many others have blamed introduced fishes for having at least a part in the decline of native fishes, and their conclusions—even if qualified—may well be valid. In fact, conjecture or not, there is little to be said on the other side.[197] Still, the relationship between the introduction of fish species and the decline of native ones is very difficult to document experimentally and

[197] In a survey of almost all of the coastal streams from southern San Luis Obispo County through San Diego County, only one native fish, the tidewater goby (Eucyclogobius newberryi), seemed to have suffered local extirpation due to introduced fishes (predacious centrarchids), and most introduced fishes were common where habitats had deteriorated (Wells and Diana 1975).

rests to a large extent upon inference. Like many recent biologists, we shall readily grant that introductions may well be a factor in the decline of native species, but we also say that correlations between them are not necessarily pertinent.

Schoenherr (1988) has a good discussion (p. 126–130) of the general thesis that native fishes have often been replaced by introduced species, and he and others have often associated the decline of native fishes with the advent of introduced ones. Obviously, the larger predators have received much of this blame, but much smaller fishes, such as the mosquitofish, some of the aquarium fishes, and the young of fishes such as the "tilapias" have also been cited as causing such declines.

Whether or not most of the aliens found "niches"—a frequent catchword of an earlier day—is not apparent. In at least a number of cases, the newcomers appear to have been "wedged" in, and it can be seriously questioned if most "niches" were not already occupied by native species. The eastern lake whitefish (Coregonus clupeaformis) , for example, was planted in a lake (Tahoe) already swarming with native coregonids.

It is also entirely possible that some of the fish introduced into California are responsible for the occurrence of a number of major fish parasites or diseases or nonpathogenic organisms. For example, the introduction of the largemouth bass in some waters was also accompanied by the introduction of the bass tapeworm, Proteocephalus ambloplitis, which infects trout and other fishes. A major threat to cyprinids, the definitive hosts, is the Asian tapeworm, Bothriocephalus acheilognathi, which was imported with the grass carp in the 1970s (Brouder and Hoffnagle 1996). This parasite is common in the southeast and midsouth and has spread to the southwest where, for example, it was found to infest 54% of the federally endangered humpback chub (Gila cypha) in a 15-mile stretch of the Colorado River. Some other cases have already been mentioned, but we must note that there have been relatively few studies of fish parasites in this state; the California literature on the subject has been summarized by Hensley and Nahhas (1975). It is obvious that many freshwater fishes, both introduced and native, are parasitized, but few conclusions can be drawn from these studies.

Hazel (1966) has suggested that the eastern freshwater polychaete, Maneyunikia speciosa, may owe its presence in the Delta to transport waters associated with catfish introductions, and the transport waters of many fishes introduced into California may well have brought in other organisms.

It is of regret to many biologists, most of whom are somewhat sentimental in this regard, whenever an introduced species displaces a native one. And if it can be proved that any of the introduced fishes has succeeded in doing this, it will be viewed with a bit of disapprobation. Yet from the standpoint of man alone—call it the "larger" one or the "narrower" one—it is our opinion that fish introductions into California as a whole have proved to be a valuable measure.

The economic value of this resource is quite outstanding to commercial fishermen, sportsmen, tackle and bait dealers, resorts, restaurants, gasoline companies, retailers, etc. It is generally assumed that promotion of the economy is a good thing. As one author said: "If there is one notion that virtually every successful politician on earth—socialist or fascist or capitalist—agrees on, it is that 'economic growth' is good, necessary, the proper end of organized human activity" (McKibben 1989, p. 173). Although we question this conclusion, as we have said before, economic growth seems to be the goal of many people, especially in California. As Vogel (1991) said, "... State Board of Trade pamphlets [have] depicted it as a blossom-blessed, golden 'Land of Promise,' California's population has only risen, never declined. And for most of the state's history, growth was encouraged as fuel for the economy."[198]

Clark (1942) appraised the economic value of California introduced fishes rather uniquely (at the time) about 50 years ago, and it is unquestionable that their economic value has since increased. However, another of Clark's conclusions may be of even more importance, "... it is obviously impossible to even estimate the value to anglers of the physical and recreational benefits derived from fishing [for introduced species]." The authors would add "emotional" benefits to these values.

A part of this paper has stressed some of the negative aspects of introductions and these must certainly be acknowledged. However, if one looks at the question purely from the standpoint of the angler (the food value of most introductions is no longer a major consideration), the reader must ask how much freshwater fishing would exist today in California had not introductions been made. What would one have today in its lakes, ponds, streams, and impoundments?

One would have some salmon fishing, but this is fast disappearing today. One could fish for Sacramento perch in a few places. One could fish for such native and usually "despised" minnows such as the Sacramento squawfish or hardhead. Or one could fish for suckers (Catostomus) , a sport which seems to be fairly popular in some parts of the east, if not in California. We do not agree with Moyle (1976b, p. 57) that the Californian angler will fish deliberately for native minnows and suckers. And since there have been introductions, what can anglers find now? At least several of the following will be found in most of these waters: black basses, sunfishes, crappies, striped bass, and catfishes.

We must except the coastal streams, most of the trout waters in northern California, and the larger streams of the Sierra Nevada from having received any marked angling benefits from introduced forms. Good native food and game

[198] Sportfishing alone in California is said to have generated about $5 billion to the economy and 154,000 jobs in 1992 (McWilliams and Goldman 1994). It is quite true that all of this sum cannot be attributed to the presence of introduced fishes since it included fishing for many natives (especially marine fishes), but it is illustrative of the economic value of angling in this state.

fishes (salmon, rainbow trout, golden trout, and cutthroat trout) were already there. Such alien forms as brown trout now found in these waters can only be considered as replacements or possibly additions to the native forms. But in many of the higher streams and countless natural lakes and tarns, the alien brook trout provides sport fishing which was nonexistent before its introduction.[199]

We can agree with Moyle (1989) who says: "I am convinced that many highly altered habitats (e.g. reservoirs) in California would be dominated by native fishes if introduced species had not been brought in." (In fact, we find it difficult to see how anyone cannot agree with him.)

On the other hand, one must recognize that the Owens River (to the east of the Sierra Nevada) and therefore its impoundment, Crowley Lake, Mono County, originally contained no game fish of any species. Today, those waters support an abundant population of trout (all of which are introduced, whether Californian or exotic) and provide a large sport fishery (Pister 1965).

Ellis (1922) presented an eyewitness account of fishing in Tulare Lake in about 1867 before any introduced fishes had been brought to California, when the lake was still extant and full of native fishes: the Sacramento sucker, Sacramento squawfish, Sacramento blackfish, a few other cyprinids, and Sacramento perch. All were a source of food for the "common people," but there was no angling as we know it. Furthermore, the disappearance of Tulare Lake (at flood level once the largest body of fresh water west of the Mississippi) and its native fishery was not caused by the introduction of other fishes.

Most of the freshwater fish which are actually caught in California have been introduced. And—in a state where angling is very important—we ask with Shafland (1989a): "How many people would really want to go freshwater sportfishing in California if it were not for introduced fishes?"

Man's ability to introduce animals, to deliberately increase their geographic range, gives him a valuable tool to use in fish management. It can scarcely be said that in California—or in any state for that matter—this tool has been employed with much discretion. But there is considerable reason for this, and even if it has been somewhat hit-or-miss, or through trial and error, its summation of results seems to have been beneficial to the principal users. Conversely, we recognize that the ability to bring about abrupt changes in the biota is a potent one and in some cases may have had a disastrous effect.

The present policy of California with respect to fish, stated briefly, is this: introductions will be made only if a species already present cannot serve the

[199] It should be pointed out here that most of these waters (which include almost every natural lake in the state) were entirely barren of any fish until they were planted. Our plants of "native" rainbow trout there have been just as alien an introduction as those of the brook trout. And since it so happens that many of these waters appear to be more suitable for brooks than for rainbows, it is considered that that introduction has increased the fishing waters.

same function, and only if the new species in question can be kept in isolation and under control until its effect is thoroughly tested. As we have pointed out, such a policy has many loopholes, but it is better than none. Meanwhile, let us sadly admit it, one of the men cited in Cohen (1992) has referred to California as a place "... where everything is introduced."[200]

"I know of no way of judging the future but by the past."

—P. Henry 1775

The future of fish introductions into California is relatively clear.[201]

Introductions by the Department of Fish and Game have virtually ended. It is true that the eggs of both kokanee salmon and lake trout continue to be imported, but both species are already well-established in the state. Similarly, and also constituting part of the remaining vestiges of a once active importation program to test new species for fishery management purposes, occasional importation of different strains or races of sport fishes, such as the brown trout, can be expected to continue. The importation of either species or subspecies new to California by the Department is unlikely but cannot be ruled out.

Aside from purposeful introductions by the State, other potential sources for the establishment of alien species of fish in California waters include: i) illegal intentional release of sport or food fishes; ii) escape of aquaculture species; iii) escape or release of ornamental fishes; iv) accidental release of fish as in ballast water; v) escape of fish imported for projects such as bioassays for toxicity testing; and vi) use of fish for biological control.

[200] California has been "introduction prone" for many years. Some of the organisms which were either deliberately introduced or considered during the 19th century were for agricultural or industrial use: silkworms, tobacco, honeybees, cochineal, indigo, sugar cane, opium, tea, etc. Others such as game birds were introduced for sport. It is believed, for example, that in the 1860s unsuccessful attempts were made to introduce the greater prairie chicken into California, possibly to give the pioneers "... a feeling of having a bit of the old homeland in their new state ...," and that between 1889 and 1960 about 30 varieties of nonnative game birds were released into the state (Naylor and Bailey 1961). Even as late as 1970, the Fish and Game Commission granted permission for the stocking of three new species of nonresident game birds (white-tailed ptarmigan from Colorado and Idaho, ruffed grouse from Utah, and woodcock from Louisiana) in an exchange for Afghan white-winged pheasants, seesee partridges, and bandtail pigeons. Two of the "California" birds had actually been introduced into this state! (OC 1970b).

[201] The introduction of new species to California is discussed by Collins (1992) of the Department of Fish and Game. However, his discussion is largely on marine invertebrates, and the specific impacts on fishes are limited to a few words on striped bass, white bass, and tilapia. Incidentally, the white bass is primarily in competition with introduced fishes rather than native species as he says.

Illegal importation and release of live fish by California anglers have achieved more prominence recently. Reproducing populations of northern pike in Frenchman and Davis lakes and adjacent waters most likely originated with anglers eager to fish for pike despite the consequences to other aquatic resources. Further examples of this activity, although they represent transplants within the state, include the transfer of white bass from Lake Nacimiento to Kaweah and Pine Flat lakes, and the growing number of trout lakes and reservoirs populated with largemouth bass and other centrarchids. Modern technology and transportation have simplified this practice and we can expect it to continue.

One of the more unusual examples of illegal movement of fish across state lines, in this instance from California to New Mexico, was described by Yeager and Janos (1985). At the urging of an Air Force General, C. Yeager (the famous test pilot) and C. Anderson, along with two New Mexico Fish and Game Department game wardens, helicoptered into California golden trout country, collected golden trout by hook and line, and stocked them in New Mexican lakes. The operation was successful, but permanent populations were apparently not established (California biologist E.P. Pister, pers. comm.). Similarly, commercial aircraft pilots were said to have exported crappies from the U.S. to Guatemala.

Like the Europeans who transported their preferred fishes to North America, and the easterners who moved their favorites west to California, Asian-Americans apparently also seek to import the aquatic foods with which they are familiar. The discovery of the Chinese mitten crab (Eriocheir sinensis) in San Francisco Bay (*San Francisco Chronicle* 29 November 1994) probably represents an effort by Asians to establish a local source of what is considered a delicacy in its native land.[202] The popularity of freshwater eels in the diet of Asian-Americans may account for multiple findings of these fish in the wild (McCosker 1989). Although the mitten crab and freshwater eels are prohibited species in California, such activities will probably continue.

A ceremonial ritual by Asian-Americans, that may have religious significance and might lead to the establishment of new fishes in California, was reported in the *San Francisco Chronicle* (23 October 1965 and 30 April 1993). It involved the release of live turtles into San Pablo Reservoir, Contra Costa County, and Lake Merritt, Alameda County. Dozens of turtles, which apparently had been purchased from food markets in San Francisco's Chinatown, were released alive. M. Young, Wildlife Protection officer of the Department of Fish and Game, said that this practice is fairly common in the Bay Area (15 December 1994 pers. comm.). An Asian tradition considers turtles to be a symbol of good luck and long life, and their release confers these benefits to the rescuers. It is not known if fishes are used in the ceremony, but if they are, it might lead to their establishment.

[202] The addition of mitten crabs to the Federal Register of injurious wildlife took more than 2 years according to Peoples et al. (1992). However, even this addition made no difference whatsoever.

Fish and birds are also involved in a similar ceremony. The Sacramento Bee (12 July 1996) described an "animal release ceremony" by Tibetan Buddhist monks in which "minnows" from a pet store were released in a stream and caged birds were set free. This can readily lead to the establishment of exotic fishes in California.

Large numbers of a variety of fishes are imported annually into California for private aquaculturists (fish farmers) who are part of an industry that gives every indication of increasing in size and value. Requests by California aquaculturists to rear fishes not already part of our fish fauna may be approved by the Fish and Game Commission, provided special care is taken to prevent escape; e.g. indoor culture, complete recirculating water systems, isolated desert sites, and an effective security system. Such approval has been granted for pacu, paddlefish, and Nile tilapia. However, no operation is completely foolproof. Certain episodes like sabotage or unusual floods may result in escape of alien fish into public waters. There are those who believe that escape by introduced fishes from aquacultural facilities is almost inevitable.

The aquarium industry has also been identified as the origin of many established exotic species in the United States. Courtenay and Stanley (1990) claimed that the majority of the established species of nonindigenous fishes in this country were popular in the aquarium trade and hobby. The industry in California remains strong, with huge numbers of ornamental fishes imported annually into the state. Escape of fish from aquarium fish culture facilities was apparently the origin of permanent populations of several ornamental species. Other species, especially livebearers, were also identified from this source but are not known to have established reproducing populations. Improved aquaculture facilities and stronger controls by the Fish and Game Commission and the Department of Fish and Game make such occurrences less likely today than they were in past years.

The release of tropical fish by individual aquarists, however, will continue and will be manifested by the occasional appearance of pacu, arawana, and perhaps other exotic species in public waters. It is believed that because such fishes cannot survive or reproduce in our colder waters—some isolated warm waters in southern California may be exceptions—these releases probably will not result in reproducing populations. The widespread presence of goldfish, however, demonstrates what can happen when cold water-tolerant (temperate zone) fishes enter the aquarium trade. In its pursuit of new species to satisfy the aquartist's demand for variety, the industry may market more cold water-tolerant species, such as the paddlefish, which could lead to the establishment of new nonnative fishes in California.

The introduction of exotic fishes into California by virtue of the transport of eggs on fouling organisms on the hulls of ships or of releases of eggs and fry with ballast water remains a potent source of new species. Regarding the latter, water is pumped into the tanks of large ships in one port and released in another port when cargo is loaded. Moyle (1991) described the ballast water problem, summarized some of the literature on the subject, and recommended actions to be undertaken by the American Fisheries Society. He also observed that four exotic invertebrate species found in the Sacramento–San Joaquin Estuary probably represent recent ballast water introductions, and conjectured that these organisms might reduce the survival rates of larval fishes, including those of the striped bass.

Among exotic fishes possibly introduced into California with ballast water or fouling organisms are the yellowfin, chameleon, and shimofuri gobies. A Federal bill, the Ballast Water Management Act, designed to identify and test ballast water control technologies, was introduced in 1994 but did not pass.

Fish also enter California to be used for research purposes or bioassays. However, they are held indoors or in outdoor tanks under recirculation or other conditions designed to prevent escape into public waters. Escape into the wild, however, is always a possibility.

Currently, the use of fish as biological control agents for nuisance aquatic plants has been reduced to that of the grass carp. This will continue and—as we have previously said—may eventually result in its establishment.

Currently, the most abundant of the fishes entering the state are rainbow trout for the stocking of private and public waters, golden shiners and fathead minnows for use as bait fish, goldfish for aquarium use and as feeder fish, white bass x striped bass hybrids for food, largemouth bass for food and sport, and inland silverside for bioassay testing. Since all of these species are established in California, the potential of new aliens rests with their accidental inclusion in loads of approved fish entering the State. A prime threat is the rudd which superficially resembles the golden shiner. Both are cultured by Arkansas fish farmers in areas prone to flooding; areas where most of California's golden shiners originate.

14. CONCLUSIONS

"The introduction of exotic fishes into California was both inevitable and necessary...."
—P.B. Moyle 1976b

"We have radically modified the biotic stream; we had to."
—A. Leopold 1949

"It must be recognized that the welfare of people and not fish is the raison d'etre for a management program...."
—R.A. Cooley 1963

"Transportation of aquatic animals for commodity distribution, research purposes, by the general public, and for aquatic animal husbandry purposes is inevitable within North America and, I believe, between continents."
—R.A. Elston 1992

The term "introduced fish" has excited much attention from those who study or manage fisheries, even if they seem to have forgotten that the introduction of many terrestrial plants and animals forms a major basis of our nutrition and economy. Given, however, the fact that many introductions of fish have been made in California, one must also recognize that the state originally possessed a depauperate fauna of native fishes in its inland waters; perhaps only one-third or one-half that of the midwestern United States.

The early successes—which were quite fortuitous—of some of the introductions paved the way for others. The profit motive for introducing fish to serve as food for cheap labor was also quite evident. Both financial and political considerations, as well as altruism, weighed heavily in this pattern of introduction. Furthermore, many Californians—like many throughout the world—were caught up in the frenzy of acclimatization, and introductions would have been made whether or not the fauna was adequate. Lastly, with only a few exceptions, and up to recent times, most of the fish "experts" (scientists and hatcherymen) supported introductions.

It is also noteworthy that up to comparatively recent times most Californians were of Caucasian ancestry, and stemmed from the eastern seaboard or the midwest. Many of them were anxious to provide fish which were familiar to them, and as interest in sport fishing grew, this tendency also grew.

Although the time came when introductions by the State were resisted for a while (as "scientific" elements took over much of the management of the fisheries), as the stream area declined there was need or at least desire for fishes which would populate and furnish fishing in the new impoundments. Increased desire for fishing grew with population growth and increased leisure time.

Partially due to increased political pressure, often directed at the local fish managers (primarily biologists), a host of new species, subspecies, or "strains," especially centrarchids, were planted, resulting in the present potpourri of ichthyofauna in California.

Meanwhile, and throughout it all, the physical environment changed remarkably. Stream area diminished, the great overflow areas were gone, and dams and reservoirs began to dominate the aquatic scene. With such changes and in the presence of introductions, there came a decline in the native fish fauna.

Thus, with urging from the public, the actual transfer or illegal introduction of non-autochthonous stocks, concomitant trials of introduced fishes for biological control, and accidental introductions, a once-limited fish fauna increased to an assemblage of species readily accepted by the general angling public. Some biologists do not like the new mosaic, but in general their complaints go unrecognized except by a small group of "environmentalists." And even the latter group indicated that "... the massive water projects that have usurped most of California's water in combination with introductions of fish species better suited to altered habitats than native species are largely responsible for the decline [of native species]" (Moyle and Williams 1990). In other words, it may be noted that even without introductions, the native fish fauna would have suffered a severe decline.

As expressed by the Inland Fisheries Branch Staff (1983): "Clearly, what constitutes an undesirable fish population depends on one's personal point of view, and we cannot expect all angler groups or segments of the public to use unified criteria for making these judgments." As expressed more recently, the American Sportfishing Association (1995) reiterated this conclusion and pointed out that "... rapidly escalating efforts in the states to understand and protect the assemblage of nongame, native species, is rapidly creating problems for the licensed angler.... The conservation of non-game, native assemblages is the responsibility of all citizens, not anglers alone...."

Summing it up, as far as we can determine (and recognizing that taxonomists differ in their definition of species), as of the close of 1996, 58 taxa including 53 full species of fish have been introduced into California and established successfully.[203] These established fishes are referred to 34 genera and 17 families. Twenty-seven of the 58 have been introduced deliberately by the California fish agency (Fish and Game Commission and Division/Department of Fish and Game) acting either alone or in concert with others. Twelve other introduced fishes have uncertain status. Thirty-nine have achieved no lasting success. Eight introduced fishes are listed as "hypothetical." Five were scheduled by authorities to be introduced, but the introduction was never completed. Three species have been listed erroneously in scientific papers as having been introduced. About 26 other species have been formally suggested as introductions. Three species are likely candidates

[203] Salton Sea fishes are excluded from this summary.

for introduction. All but one of the fish deliberately introduced into California were freshwater or euryhaline. The one species of marine fish introduced deliberately (the tautog) was unsuccessful in establishing a population.

Moyle and Williams (1990) listed 113 native California fishes which included 63 full species, of which five are extinct or extirpated from the state. The remainder are subspecies, both described and undescribed, and several salmonoid races. The 58 extant native species plus 53 introduced species total 111 established California freshwater and anadromous fishes. See Table 3 for a chronological list of all established introduced fishes, including the year(s) of introduction, the responsible party, and the probable reason for the introduction.

From the history of such introductions, we have derived the following opinions:

1. We say realistically, with Kendall (1918), a man who was a fishery biologist long before the term was in wide use, and with special reference to California: "But the evil, if it were an evil, has been done and cannot be undone." Or, as Caughey (1975) said: "History as a nonexperimental science, is confronted by an irrevocable past in whatever has happened has happened."
2. Even more specifically, we suggest to the California Department of Fish and Game that:
    a. California has a rather full complement of fish useful in promoting good fishing and utilizing the ecological niches (assuming that they exist) that are present.
    b. If, however, introductions are to be made, we commend the present trend of those who pay attention to races, strains, and other genetic distinctions of the newcomers. For example, the hypothesis has been erected that fishes which evolved together are more apt to coexist in harmony than those that did not. Consequently, some years ago, California adopted a strategy of importing southern rather than northern races and strains of those centrarchids which evolved with threadfin shad and inland silverside (Fisk and von Geldern 1983).
    c. It should cease using the term "experimental introduction." An "experiment," using rigorous standards of definition, is a trial that can be repeated. The study of a species of fish new to the state in a limited number of waters, followed by a decision concerning introduction within a few months or even years, can hardly be called an "experiment."

       Incidentally, we do not maintain that real experiments are necessary. We do say that the "success" of an introduction should be measured by its benefits to the community and the fact that it should not unduly harm existing species. "Success" cannot always be determined even by long and direct observation (an alternative to experiment), but consideration and observation should always precede introduction.

TABLE 3. A chronological list of the established introduced fishes of California[1]

Species	Date of initial plant	Responsible agent	Probable reason for introduction
Goldfish	19th century	Private	Escapement
American shad	1871	State fish agency	Food
Brook trout	1871(?), 1872	Calif. Acclimazation Society (1871?) and/or State fish agency (1872)	Food/Sport
Common carp	1872	Private	Food
Brown bullhead	1874	State fish agency	Food
White catfish	1874	State fish agency	Food
Smallmouth bass	1874	State fish agency	Food/Sport
Striped bass	1879	State fish agency	Food
Lake trout	1889(?)	Nevada fish agency	Food/Sport
Yellow perch	1891	Private and Federal fish agency	Food/Sport
Channel catfish	1891(?)	Private and Federal fish agency	Food/Sport
Golden shiner	1891(?)	Private and Federal fish agency	Accidental/Incidental
Warmouth	1891(?)	Private and Federal fish agency	Food/Sport
Northern largemouth bass	1891(?), 1895	Private and Federal fish agency (1891?) State fish agency (1895)	Food/Sport
Black crappie	1891(?), 1908	Private and Federal fish agency (1891?) State fish agency (1908)	Food/Sport

[1]*When two dates are given, the second is known to have been successful in establishing the species.*

The "State fish agency" includes: California Fish Commission and its derivatives, California Division of Fish and Game, and California Department of Fish and Game, or official representatives of these groups.

The "Federal fish agency" includes the U.S. Fish Commission and its derivatives such as the U.S. Bureau of Fisheries and the U.S. Fish and Wildlife Service.

The two deliberately introduced fishes now established in the Salton Sea are excluded.

We cannot understand the statement of Miller (1961, p. 397) that "Only 8 exotic [fish] species are known to have become established in the West prior to 1930." He used the term "exotic" to include all introduced fishes.

TABLE 3. A chronological list of the established introduced fishes of California[1]

TABLE 3. Continued

Species	Date of initial plant	Responsible agent	Probable reason for introduction
White crappie	1891(?), 1908	Private and Federal fish agency (1891?) State fish agency (1908)	Food/Sport
Green sunfish	1891(?), 1908	Federal fish agency (1891?) State fish agency (1908)	Accidental/Incidental Food/Sport
Northern pike	1891 (?)	Private and Federal fish agency	Food/Sport
	Late 1980s & early 1990s	Angler(s)	Sport
Brown trout	1893	Federal fish agency	Sport
Arctic grayling	1906, 1970	State fish agency	Sport
Bluegill	1908	State fish agency	Sport
Pumpkinseed	1918(?)	Private and Federal fish agency	(?)
Tench	1922	Private	Food
Western mosquitofish	1922	California Board of Public Health	Mosquito control
Colorado River cutthroat trout	1931	State fish agency	Sport
Northern spotted bass	1936	State fish agency	Sport
Black bullhead	Prior to 1940	Unknown	Food (?)
Kokanee salmon	1941	State fish agency	Sport
Yellow bullhead	Prior to 1942	Unknown	Food (?)
Kamloops rainbow trout	1950	Private and State fish agency	Sport
Redear sunfish	Prior to 1951, 1954	Arizona fish agency State fish agency	Migration Sport
Red shiner	Prior to 1953	Private	Escapement
Bigscale logperch	1953	Federal fish agency (U.S. Air Force)	Accidental/Incidental
Fathead minnow	1953(?)	Private and State fish agency	Forage
Threadfin shad	1954	State fish agency	Forage
Rainwater killifish	Prior to 1958	Unknown	Unknown

TABLE 3. A chronological list of the established introduced fishes of California[1]

TABLE 3. Continued

Species	Date of initial plant	Responsible agent	Probable reason for introduction
Florida largemouth bass	1959	County of San Diego and State fish agency	Sport
Wakasagi	1959	State fish agency	Forage (belived native)
Chameleon goby	Prior to 1960	Unknown	Ballast water (?)
Shimofuri goby	Prior to 1960	Unknown	Ballast water (?)
Blue tilapia	Early 1960s	Arizona fish agency	Migration
Nile tilapia	Early 1960s (?)	Arizona fish agency	Migration
Redeye bass	1962	State fish agency	Sport
Flathead catfish	1962 (?)	Arizona fish agency	Migration
Yellowfin goby	Prior to 1963	Unknown	Ballast water (?)
Sailfin molly	Prior to 1964	Private	Escapement
Shortfin molly	Prior to 1964	Private	Escapement
Mozambique tilapia	Prior to 1964 Prior to 1968 1972	Private Arizona fish agency U.C. Riverside	Escapement Migration Midge control
White bass	1965	State fish agency	Sport
Redbelly tilapia	Late 1960s & early 1970s	U.C. Riverside State fish agency Irrigation districts	Weed and midge control
Wami tilapia	Late 1960s & early 1970s	U.C. Riverside	Midge control
Giant rivulus	Prior to 1967	Private	Escapement
Inland silverside	1967	Lake County Mosquito Abatement District and University of California	Midge control
Oriental weatherfish	Prior to 1968	Private	Escapement
Blue catfish	1969	State fish agency	Sport
Porthole livebearer	Prior to 1974	Private	Escapement
Alabama spotted bass	1974	State fish agency	Sport
Brook stickleback	Prior to 1991	Unknown	Unknown

TABLE 3. A chronological list of the established introduced fishes of California[1]

d. Although purposeful introductions to improve the fishery (be they made as food fish, game fish, forage fish, or to control certain components of the ichthyofauna) are rightly your province, the introduction of fish by other agencies to control aquatic pests, either animals (such as mosquitoes) or plants (such as Hydrilla) , should also be treated with great caution. The State agency possessing the authority to control such introductions should exercise more control and less leniency than has been afforded in the past. (Attention has been called to the illegal introduction of the inland silverside in Clear Lake.) The aid of State agencies such as the agricultural universities to mosquito abatement and irrigation districts may have been beneficial to agriculture and the general public, but may also have been detrimental to the natural fauna and to anglers.[204]

3. We also agree with most fish managers that some of the university people and their colleagues still dwell in ivory towers, and while their concern for a "natural" environment is quite genuine, they are somewhat out of touch with what the man in the street or the ordinary angler really feels or desires. "Joe Doakes" will do about what he wants to do, regardless of the "tsk! tsk!" to be found in certain journals read primarily by those who have the same opinions. See, for example, Horak (1994) versus Moyle and Li (1994).

4. It is difficult not to be ambivalent. As two British biologists have said, "Our own position as freshwater biologists is equivocal. We do not think our waters should be open to indiscriminate introductions but neither do we think that exotic species are something which should not be considered" (Stott and Solomon 1978). As Maher (1969) said, "To prohibit the planned introduction of desirable exotic fish after careful investigation, and yet reap the evil results of unplanned introductions, is surely senseless." As we are also applied or fishery biologists, we look at the subject "... from a management viewpoint where the criterion of success of an introduction is the maintenance of a perennial fishery which is satisfactory to anglers [or commercial fishermen] with respect to both numbers and size of fish.... Consequently, if the practical fish culturist wishes to improve fisheries, he must be prepared to make frequent, bold, and what may subsequently turn out to be ill-advised experiments if he is going to accomplish anything by introductions" (Larkin 1954).[205]

204. According to Dowell and Krass (1992), about 400 species of invertebrates have been deliberately introduced into California in efforts to control accidental invaders biologically.

205. We recognize that this statement was made many years ago (when we were also developing as fishery biologists), and that Larkin was using the term "fish culturist" in a wide sense. His "bottom line" in 1993 was still, however, that scientific understanding should be used to ensure wise use of resources even if it inevitably means making some mistakes along the way (P.A. Larkin pers. comm.).

On the other hand (by taking his statement slightly out of context), we must agree completely with Regier (1968) that: "Fishery biologists ... feel some responsibility for the mess that the system is in, and rightly so. However, the greatest blame goes elsewhere. It belongs to those who have fouled the waters, dammed the tributaries, and in one of a hundred ways destroyed the native communities. If one sought to identify who in society benefited most directly from such acts, one might in fact find a considerable overlap with the more brassy, aggressive, demanding part of the angler brotherhood. I suggest that we try to identify whom we are seeking to please by providing 10-pound salmon or striped bass [in lakes to which they are not native]! If we find these are by and large uninhibited exploitive personalities, then I suggest we reflect on whether we really want to knock ourselves out to provide them with the sort of diversions they seek."[206]

5. We endorse the remarks of Shafland (1989b, 1991) as some of the best summations of the question of fish introductions, especially from the standpoint of the fishery manager; the reasoned and objective discussion of Welcomme (1988, p. 1–35); the general conclusion of Hocutt (1984, p. 384); the excellent summary made by Regier (1968); and the host of excellent articles in Rosenfield and Mann (1992).

6. We must admit that the fisheries of California are no longer "natural" but have become "homogenized." An article by Skrabo (1987) shows that Lake Oroville on the Feather River provides sport fishing for rainbow, brown, and lake trout; kokanee; chinook and coho salmon; largemouth, smallmouth, and redeye bass; crappie; bluegill; and catfish. Only the rainbow and chinook are native to the area. The reservoir itself is manmade. So is the fishing.

Interestingly enough, although its nongame fish fauna has declined, the aquatic fauna of the state as a whole exhibits a greater biodiversity than ever before. Although the components may differ, one must recall that biodiversity is a goal of "environmentalists."[207]

7. We believe with Miller (1961) that modern man is the chief agent in producing changes in the natural fauna through: removal of vegetation, the construction of dams, water diversions, mining operations, pollution, use of toxic elements, depletion of ground water, and the introduction of alien species. With respect to the last named cause, he stated (p. 397) that many of the established aliens (fish) have affected the native species either directly—through

206. "Where wildlife is concerned, every layman is his own physician" (Dasmann 1965, p. 55).

207. Although the word "natural" is often used in articles (see for example, the statement by the so-called "father of biodiversity," E.O. Wilson by Anon. 1994c), it does not appear to us that its inclusion is really necessary to describe the concept. To our surprise, this idea appears to be accepted in a letter by Carl Safina of the National Audubon Society in Fisheries, 18(8): 38–50.

predation, competition, and hybridization—or indirectly by altering the habitat. Similarly, we believe with Courtenay and Moyle (1996) that by "playing God" man is severely altering the course of natural evolution. Nevertheless, water development and politics have already had such a deleterious effect upon California's "natural" fisheries that the impact of introductions may have been a relatively minor factor in causing their decline. Anyone doubting the effects of engineering and political choice need only read Snider (1985), McEvoy (1986), or Conniff (1993).

8. We are completely in favor of trying to preserve our natural fish fauna, and are distressed to see the disappearance of native species such as the thicktail chub.[208] Every effort should be taken to preserve native Californian fishes.[209]
9. We are completely cognizant that many scientists of today feel that any change in the components of the environment (such as the introduction of a new species) may bring about totally unrecognized changes. Thus, as expressed by Weiner (1994) and especially in the many examples given in Wiener (1995), any one of the California fish introductions may have brought about changes in the "natural state." For example, despite Curtis' (1942) belief that the introduction of the American shad to California was "entirely harmless," it may be that its entry brought about many changes in the biota which we do not recognize.
10. Finally, we agree with Balon and Bruton (1986): "Ultimately the best advice [on introductions] is that given by individuals who are trained in unbiased deductive reasoning, possess a thorough knowledge of the subject and an understanding of the overall socio-economic milieu." We have no problem whatsoever with adopting this advice. The only problem seems to be in finding such individuals.

In closing, and considering introductions as a whole, we wish to point out that even in the "worst case scenarios," where there is a pessimistic point of view which considers that in the future "... one place looks like the rest and no one cares ...," the optimistic point of view considers that life will be in balance and that "An appropriate respect for preserving indigenous species becomes a national goal by consensus...." As the "wrap-up" says, "... deciding the vision's worthiness—and choosing whether to pursue it—are not choices that science can make. Nor does nature provide answers. Which species to import and release,

208. It is true that introduced fishes may have played some part in its demise, but it is more likely that habitat modifications played the major role (Mills and Mamika 1980).

209. The California Fish and Game Commission was once completely against such an avowal. For example, at a meeting held in 1916 it stated that it would like to see the native Dolly Varden (Salvelinus malma) exterminated (Scofield 1916b, p. 208).

which to exclude, and which to control are ultimately cultural and political choices—choices about the kind of world in which we want to live" (U.S. Congress, office of Technology Assessment 1993).

We do not think it feasible nor do we believe it desirable to prohibit all introductions of fish into California. Still we know that California is no longer the state it once was, and introductions have been among the changes that have affected it. Nevertheless, physical changes have had an even greater contribution to this effect. The future inhabitants of the state will not regard it as some of us still do, nor have the regret for its change that some of us now have.

15. LITERATURE CITED

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CC—*California Conservationist*
CFG—*California Fish and Game*
OC—*Outdoor California*

"California" is used for an author when the article appears in an official State publication other than one of the above.

Although the full reference is given in this Literature Cited section, it should be noted that all of these articles represent the opinion of an unknown author with the official State agency concerned with fish and fisheries.

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Both authors have been fishery biologists for the California Department of Fish and Game in addition to their other experience.

Following studies in zoology and fisheries at Stanford University, Mr. Dill held positions in the United States at Stanford's Hopkins Marine Station, the University of Santa Clara, and the California Division/Department of Fish and Game. At the latter agency, his work centered on lake and stream surveys, maintenance of aquatic habitat, and management systems. He became coordinator of the State's Federal Aid to Fish Restoration program and supervisor of its freshwater and anadromous fishery projects.

After 17 years of service with the State, he joined the Food and Agriculture Organization of the United Nations (FAO) with headquarters in Rome, and later became Chief of its Inland Fishery Resources Branch. There he was in charge of inland fishery biology, aquaculture, and aquatic environmental protection, as well as having technical supervision of experts in developing countries, fellowships, and training centers. He was also a Technical Secretary of two international fishery councils (for the Mediterranean and Indo-Pacific countries) and two international fishery committees (Europe and Africa).

Mr. Dill organized one of the first world meetings on the influence of the environment on fisheries (Athens), and the first international inland fisheries meeting (Helsinki) which led to the formation of the European Inland Fisheries Advisory Committee (EIFAC) for which he was the Secretary for six years. He was also instrumental in organizing the United Nation's Inter-Secretariat Group on Water Pollution Control and participated in many international meetings held on the subject.

Since leaving FAO, Mr. Dill has had assignments with FAO itself, the United Nations Development Programme, the United States Agency for International Development (AID), the U.S. Fish and Wildlife Service, and the California Department of Fish and Game. He has also been a member of a senior advisory panel studying research on fisheries in developing countries, and has been an invited fishery scientist to Finland and the United Kingdom.

In addition to the publication of over 150 scientific papers and technical reports, his printed works have included: "Advances in Aquaculture" (as co-editor with Dr. T.V.R. Pillay), and the two encyclopedic volumes, "Inland Fisheries of Europe."

Mr. Dill's professional affiliations have included: the American Fisheries Society (where he has been the Chairman of the Committee on International Relations, a member of the Committee on Introduced Fishes, and a Certified Fisheries Scientist), the Western Society of Naturalists, Pacific Fishery Biologists, California Fish and Game Biologist's Association (President), American Institute of Fishery Research Biologists (Fellow), and Sigma Xi.

In addition to scientific activities, he has been Secretary of both the Roeding Park Casting Club and the Fly Fishers of Davis.

Mr. Cordone attended the University of California at Berkeley, where he majored in Wildlife Conservation and Zoology. In 1955 he became a fishery biologist for the Department of Fish and Game and remained with this organization until his retirement in 1993. He specialized in freshwater fisheries research and management. His duties encompassed water project and pollution analyses, management coordination, lake and reservoir investigations, aquaculture coordination, Fish and Game Commission coordination, editing, exotic species evaluations, angling regulation evaluations, and threatened and endangered species problems.

From 1960 to 1966, Mr. Cordone supervised a study of the Lake Tahoe sport fishery with headquarters at Tahoe City. In 1969–71, he and his family lived in Jinja, Uganda, where he served as a stock assessment officer for the United Nations Food and Agriculture Organization in a two-year investigation of Lake Victoria fish stocks. In 1973, he took an assignment for the U.S. Agency for International Development to survey environmental problems posed by southern encroachment of the Sahara Desert.

Mr. Cordone is a long-time member of the American Fisheries Society and served as president of that organization's California-Nevada Chapter. He received the Chapter's Award of Excellence in 1974. He is also a member of several conservation organizations.