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Growth Characteristics of Two Southern California Surffishes, the California Corbina and Spotfin Croaker, Family Sciaenidae

By
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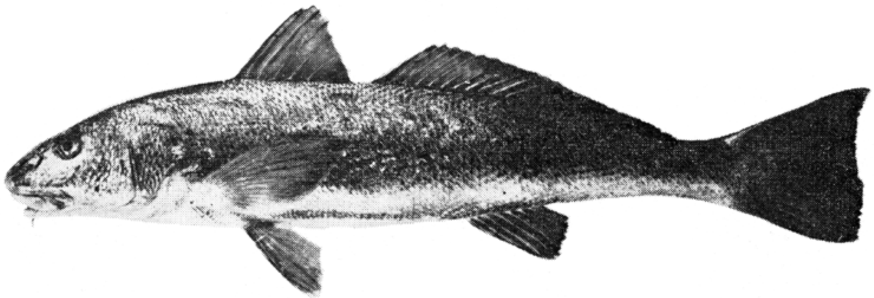
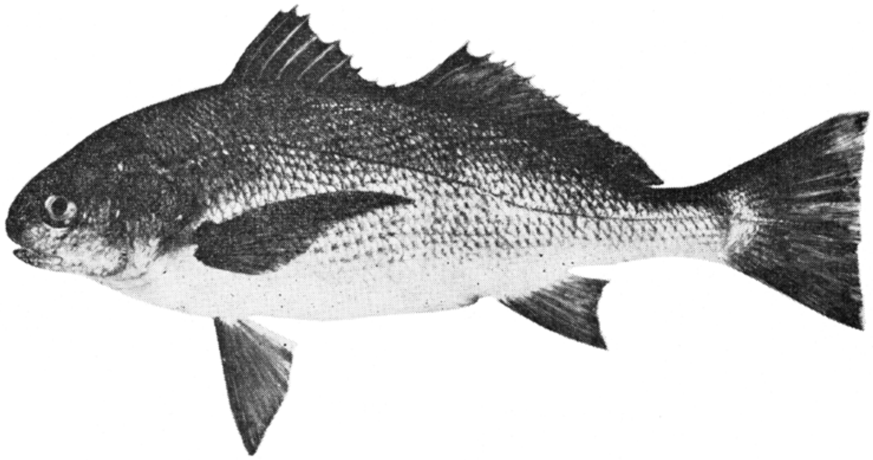


CALIFORNIA CORBINA
Menticirrhus undulatus (Girard)



SPOTFIN CROAKER
Roncador stearnsi (Steindachner)

CONTENTS

2. INTRODUCTION

Sciaenids live along shallow, sandy shores in most of the tropical and temperate seas. While many species tolerate or seek out estuarine waters and a few live only in fresh water, the family is essentially marine.

Along the southern California coast this fish family is represented by seven genera (and species): queenfish, Seriphus politus; white seabass, Cynoscion nobilis; black croaker, Cheilotrema saturna; white croaker, Genyonemus lineatus; yellowfin croaker, Umbrina roncador; spotfin croaker, Roncador stearnsi; and California corbina, Menticirrhus undulatus.

Jordan and Evermann (1898) reported that shortfin seabass, Cynoscion parvipinnis, ranged as far north as Santa Barbara and were, "common along the coast of southern California as far north as San Pedro." They no longer are full-year residents but may visit our area from the warmer waters of southern Baja California. Their former intrusion into the California fauna was presumably a response to the warmer waters of the last century (Hubbs, 1948).

Hubbs (1921a) erroneously described Sciaena thompsoni, from a malformed sciaenid taken off Santa Catalina Island that has since been identified as a yellowfin croaker (Hubbs, personal communication).

Wherever sciaenids occur in any abundance, their moderate to large sizes, excellent flesh, and susceptability to a variety of simple fishing gear have placed them among the most desirable of all food and game fishes.

In southern California, as along most temperate and tropical shores of the world, sciaenids have attained prominence both as commercial and sport fish. Commercial landings of white seabass ranged between 405,000 and 3,386,000 pounds from 1948 to 1960 and have consistently ranked high in public favor. Moreover, their fighting qualities, excellent flesh, and size (up to a reported 80 pounds) make white seabass among the most sought-after of all California sport fishes.

Minor landings of queenfish and white croakers are annually made for the fresh-fish market and both species, although seldom esteemed, are taken in large numbers by sportfishermen.

The other four California sciaenids—black croaker, yellowfin croaker, spotfin croaker and California corbina—are completely protected from commercial exploitation and are reserved by State law solely for sport anglers. Yellowfin croakers, spotfin croakers and California corbinas have been protected from nets of all kinds since 1909 and their purchase or sale has been illegal since 1915. It has been illegal to buy or sell black croakers since 1933.

California corbinas and spotfin croakers, the forms considered in this study, are perhaps the most desirable of any of the southern California surf fishes. The sport fisheries for these species are of high importance, from both economic and recreational considerations. Although there are no records to indicate the numbers of southern California surf fishermen or their catch, devotees of the sport total many thousands.

2.1. Previous Work

In spite of their importance and the long-standing interest displayed in California's sciaenids, essentially no life-history work has been conducted on any of the species. Clark (1930) determined the size at first maturity of white seabass and her work formed the basis of a 28-inch minimum size limit on commercially taken fish. Skogsberg (1939) reviewed and compiled systematic data on the California sciaenids and presented brief details on range and ecology, feeding habits, time of spawning, size at maturity, and fishing activities for each.

Considerable work has been published on the life histories of various Atlantic and Gulf Coast sciaenids, as well as on the freshwater drum, Aplodinotus grunniens. Welsh and Breder (1923), Hildebrand and Schroeder (1928), and Hildebrand and Cable (1930, 1934), studied reproduction, development, movements and other life-history aspects of numerous Atlantic Coast croakers. Pearson (1928) investigated the natural histories of redfish, Sciaenops ocellata, and other commercial sciaenids of the Texas Coast.

Pearson's (1928) life-history work has been considerably expanded by subsequent workers. In addition to more completely defining previously conducted life-history work, recent emphasis has centered on the relationships of the sciaenids and other Gulf Coast forms to the variety of ecological situations along the Texas Coast. Notable among these have been Reid (1955a, 1955b) and Reid, Inglis, and Hoese (1956), who have studied croaker biology and ecology in East Bay, Texas. Similar ecological work was conducted by Breuer (1957) in Baffin and Alazan Bays and Simmons (1957) in Upper Laguna Madre, Texas.

Extensive age and growth studies have been conducted on sciaenids by numerous workers. The first work directed specifically toward determining age and growth by means of scales was carried out by Taylor (1916) on weakfish, Cynoscion regalis. Pearson (1928) determined age and growth by means of scales on the redfish, black drum, Pogonias chromis, and spotted trout, Cynoscion nebulosus. Age and growth determinations were made on Lake Erie freshwater drums by Van Oosten (1937) and similar studies were conducted by Butler and Smith (1950) in the upper Mississippi.

2.2. Purpose and Scope

Since World War II, southern California has witnessed an explosive growth in population and physical development. The growth of beach-front communites has led to extensive dredging and filling operations, to pier and jetty construction with subsequent changes in beach profiles, and to increased industrial and domestic sewage discharges. Unquestionably all these activities are exerting detrimental influences on the abundance and distribution of surf-dwelling species. Much thought and effort will be required in the future to assess the degree of damage suffered by these fisheries resources and to prevent increasing losses.

It is generally believed the abundance and catch of both the spotfin croaker and California corbina are far less now than in the past. However, there are no statistics to substantiate this opinion since annual landings and estimates of fishing effort are unavailable. Both species have been protected from commercial exploitation since 1909 but there has been no attempt to evaluate the effect of this protection. Certainly there is no knowledge as to what additional management practices, if any, might assure their maintenance and well-being.

To utilize and manage our sciaenids intelligently will require an understanding of their life histories and interrelationships with their physical and biological environments. A primary purpose of this study therefore was to investigate some aspects of spotfin croaker and California corbina life histories that will be useful for managing their fisheries.

To accomplish this task, efforts were directed in both species toward describing the typical annual growth, and the relationship of monthly growth and total annual growth to water temperatures. A study was also made of food habits with emphasis on change in diet as it relates to growth.

Although such studies are not wholly novel, the data and conclusions on these relationships may prove valuable to fisheries workers, to fishermen and to students of surf-dwelling species.

3. ACKNOWLEDGMENTS

No study of this magnitude could be undertaken and completed without the guidance, advice, and physical help of a great many people, and to all, whose generous aid and encouragement have contributed to its completion, I offer my sincere thanks.

I am indebted to Boyd W. Walker, U. C. L. A., for his sponsorship, guidance, and patience during the course of the work, and to Carl L. Hubbs, Scripps Institution of Oceanography for his review of the thesis manuscript. I am particularly grateful to John E. Fitch, Research Director of the California State Fisheries Laboratory, for his critical editorial assistance.

This investigation was begun in 1950 as a graduate study at the University of California, Los Angeles. In 1952, the California Department of Fish and Game, aided by Federal funds under the Dingell-Johnson Aid Program, initiated a surf-fish investigation (California F5R) to determine the life histories and management needs of the major surf fishes along the southern California coast. Since both the California corbina and the spotfin croaker were to be included in the surf-fish study, a duplication of effort and interests between my graduate study and the Departmental investigation would have been inevitable. Therefore, Frances N. Clark, former Director of the California State Fisheries Laboratory, Terminal Island, and John E. Fitch, her successor, decided that I should continue to handle the age and growth work on these two species. Accordingly, scales (for aging) accumulated by the surf-fish investigation personnel between 1952 and 1957 were made available for inclusion in my study.

As a result of these cooperative arrangements, it is impossible to enumerate and acknowledge each of my colleagues from the Department of Fish and Game who contributed so generously to all phases of the work. However, a particular expression of gratitude is owed to John G. Carlisle, Jr., Jack W. Schott, and David Ganssle for securing and processing specimens. often their efforts in my behalf went far beyond the requirements of their own project investigations.

Jack W. Schott generously contributed his time and talents to produce and process the scale photographs. The graphs were drawn by Cliffa Corson and photographed by George Farnham.

Special thanks must be expressed to Norman Abramson, Joyce Tolladay and Betty Wright of the Department's biostatistical section for their valuable advice and help in treating statistically the calculated growth data.

As in many prolonged investigations, the real sacrifices are borne, not by the investigator, but by his family. To my wife and children, whose loving though incessant urgings have finally borne fruit, I shall be forever grateful.

4. METHODS AND MATERIALS

4.1. STUDY AREA

Spotfin croakers and California corbinas occur along sandy shores and in bays from Point Conception, California, to at least San Juanico Bay, Baja California. However, the material used in this study was limited, for practical reasons, to a rather restricted portion of this range.

Collecting at typical open-coast areas proved extremely difficult and generally unproductive with a small crew. Effort, therefore, was largely concentrated in the Los Angeles-Long Beach area where there is the variety of inshore habitats normal for both species. Conditions in this region range from typical open-coast surf in the Seal Beach-Belmont Shore area to quiet bay waters within the extensive harbor itself and in Alamitos Bay. Both species appeared in the general Los Angeles Harbor area in relatively greater numbers than in other coastal locations and could be collected with greater efficiency. Their life histories here probably did not differ from the mode of life exhibited by either species in other areas along the southern California coast.

4.2. Collecting Methods

Growth characteristics of spotfin croakers have been derived from 1,553 fish sampled in the general Los Angeles-Long Beach Harbor area.

of the 2,096 corbina examined, 1,955 or 93 percent were collected in the surf zone of the Long Beach-Belmont Shore area. The remaining 141 fish were from Redondo Beach (9), Laguna Beach-Emerald Bay (64), and La Jolla (68). No significant growth differences were observed in the several locations, so conclusions are based on the combined samples. However, too few fish were taken in localities other than the Long Beach-Belmont Shore area to permit a really critical evaluation of possible coastal growth differences.

Because taking either species commercially was prohibited by law, and since the sport catch is rather uncertain, it became apparent early in the study that most samples would have to be collected by personnel actually engaged in the surf-fish investigation.

Beach seining was the most effective means of collecting samples for age, growth and other life history data. A variety of seines, ranging from 60 to 100 feet long, was used. These were constructed of either cotton or marlon webbing with ¾-inch stretched mesh in the wings and #-inch mesh in the central bag portion.

The net, after being set (from a skiff) parallel to shore and approximately 200 feet off the beach, was pulled through the surf to the beach by means of manila lines attached to spreader bars at each end. Depending on surf conditions and the size of the net, the seining operation required three to five men.

All of the corbinas and most of the spotfin croakers were collected by beach seining. On several occasions large adult spotfin croakers were taken by experimental trawling or in lampara nets in the deeper waters of Los Angeles Harbor and 318 of these were used in this study. Their numbers and dates of capture were: 1 April 1953 (222), 28 March 1956 (18), 2 April 1956 (27), 8 November 1956 (5), 31 January 1957 (33), 21 March 1957 (13). All of these were collected from deeper water during the period November to April. During these months they were notably absent from the surf zone and from shallow portions of the bay.

On the basis of life history findings on Atlantic and Gulf Coast sciaenids plus a lack of gravid individuals in surf collections, it was thought that spotfin croakers and California corbinas spawn offshore or in waters considerably removed from their surf zone habitat. If such was the case, the youngest bottom-dwelling stages should be living at depths somewhat greater than the outermost surf zone. In an effort to collect these young stages a special "sled," containing a ¼-meter coarse-mesh plankton net, was constructed. The sled, with runners of #- by 3-inch strap iron, was towed behind a skiff powered by a 10 h.p. outboard motor. The mouth of the net was adjusted so its lower edge skimmed within an inch of the bottom.

From June through August in 1951 and again in 1952, efforts were made to capture larvae and very small juveniles of both species. This should have been the time that they first assumed bottom living habits. The sled was towed at all depths from the surf zone to 60 feet at the inner and outer face of the Los Angeles Harbor breakwater, but no spotfin croaker or corbina larvae or juveniles were taken. Some comfort, however, was derived from the fact that the device captured a variety of other larval fish and small invertebrates. Among the larval and very small juvenile fish taken were: northern anchovies, Engraulis mordax; clingfish, Gobiesox rhessodon; queenfish; two gobies, Clevelandia ios and Quietula y-cauda; and tonguefish, Symphurus atricauda.

4.3. Measurements

The body lengths of fish used in this study were recorded in millimeters (standard length or total length or both) by the methods described in Hubbs and Lagler (1958). Generally, in the interest of speed, the specimens tagged and released by Fish and Game personnel were recorded by total length only.

All growth calculations were based on standard length measurements. It was therefore necessary to determine the standard length-total length relationship for converting data to standard length measurements. Straight lines adequately describe the relationship for each species. For California corbina this is S.L. = 0.852T.L. - 4.720 and for spotfin croaker the relationship is S.L. = 0.833T.L. - 4.382.

4.4. Selecting and Processing Scale Material

Scales for determining age and for back-calculating growth were taken from below the lateral line on the left side of the body. In both species the selected area lay approximately midway between the dorsal and ventral profiles, vertically beneath the notch between the spinous and soft dorsal fins where the scales were large and rather uniform in size. Since many individuals removed scales under field conditions, this area, approximately under the tip of the extended pectoral fin, could be quickly and accurately determined.

From five to perhaps a dozen scales were removed from each fish and stored in labeled coin envelopes for future processing. In the laboratory the scales were cleaned by soaking them in tap water. Dirt and residue were removed by gently scrubbing them with a small wedge of rubber eraser on the tip of a dissecting needle. From two to four scales from each fish were selected and mounted dry between glass microscope slides. (No particular advantage was gained by using a variety of mounting media recommended by other workers.)

For a preliminary age assessment, all scales were examined under a binocular microscope, where both the direction and intensity of transmitted light could be altered by means of the substage mirror. This was most helpful on older or difficult scales. Final age determinations and most back-calculation measurements were made at 30 magnifications using a very simple, but effective, projector. About 30 percent of the scales showing more than two annuli were rechecked and remeasured on a commercially-produced machine patterned from the projector described by Van Oosten, Deason, and Jobes (1934).

Magnified scale images from each fish were projected directly onto punch cards of the type currently used by the Department of Fish and Game in its sardine and anchovy age work (Miller, 1955). The distances from the focus of the scale to the various annuli were marked directly on the millimeter scale along the right margin of the card, and calculated lengths and increments were entered in the two center columns. The card also provided ample space for entering other pertinent data such as sex, date of capture, year-class and age.

Each scale was measured from its focus toward the anterior or embedded edge along the antero-posterior axis. Selecting and relying on a "key" scale for back calculations was infeasible because of the numerous individuals taking scales under field conditions. Estimating length at any previous age was therefore based on an average calculated from two or more scales.

The California corbina body length-scale length relationship was likewise based on average measurements of two or more scales from each fish.

Late in the study I discovered that considerable bias had entered into the selection (from the coin envelopes) of the spotfin croaker scales. The bias was apparently brought about in an effort to maintain a constant number of scales on each slide. Thus, smaller-than-average scales were selected from the larger fish making it impossible to define accurately the body length-scale length relationship for large spotfin croakers.

4.5. Differential Growth Between Sexes

Since more than three-fourths of the adult fish taken during 1953 to 1956 were tagged and released in an effort to determine movements and migrations, possible differential growth between males and females could not be thoroughly analyzed. Age and growth data are therefore based on average values of the combined sexes and are believed to represent average growth characteristics of the populations in the areas sampled. Sufficient evidence was obtained, however, to indicate that male and female spotfin croakers grew at similar rates over the ages represented in the study.

Corbinas, for which sexes were determined, grew at similar rates at least through age three. Commencing at age four the females appear to grow faster than males.

It should be noted that the sections in the study dealing with monthly growth and total annual growth of each species were based on fish three years old or younger. Therefore, insofar as these sections are concerned, possible growth differences between the sexes in older fish are of no consequence.

5. AGE AND GROWTH

Over a half century ago, Hoffbauer (1898) demonstrated that the number of annuli on carp scales provided valid estimates of their ages. With the subsequent contribution of Lea (1910), who showed that the distances between annuli on herring scales were proportional to body growth in previous years of life, age and growth studies based on scale analyses have become a significant tool of fisheries research.

Excellent publications dealing with the methods and validity of age and growth studies on fishes (Lee, 1920; Creaser, 1926; Van Oosten, 1929; Graham, 1929) make any general review of the subject unnecessary here. Based on a 50-year history of success, age and growth studies utilizing fish scales have proven feasible and practical for a very large and growing list of species.

Briefly, the successful use of scales for determining age and growth depends upon fulfilling the two fundamental concepts inherent in the works of Hoffbauer (1898) and Lea (1910). These are, (1) that the scales of the species in question show an identifiable ring or other mark which forms annually and (2) that there is a definable relationship between body length and scale radius or other appropriate scale dimension. This latter requirement must, of course, be met in order to determine accurately body length at the formation of previous annual marks.

5.1. Age Determinations

My age and growth studies were the first to be carried out on California sciaenids. However, both scales and otoliths have been used to determine ages and growth of several Atlantic and Gulf Coast sciaenids. With the exception of accessory checks or false annuli and the problem of differentiating between crowded annuli on the scales of older fish, no unusual difficulties have been encountered in determining sciaenid ages.

From the few published photographs of sciaenid scales, there are strong resemblances in scale characteristics among widely-separated members of the family. Spotfin croaker and California corbina scales resemble each other markedly in spite of great morphological differences between the two species. The major difference between their scales is the tendency of the corbina's to be somewhat more angular or "square cornered" than the spotfin's. In addition, although the difference is slight, circuli on corbina scales are more widely-spaced than are those on spotfin croaker scales.

5.1.1. Appearance of the Annulus

The criteria used for identifying annuli on scales of both species were essentially the same as those used by other workers aging fishes having ctenoid scales. That is, a true annulus can be traced completely around the scale and generally exhibits crossing over in the posterior portions of the lateral fields (Carlisle, Schott and Abramson, 1960).

In the anterior field, the annulus is typically marked by one or two straightened circuli. Both anterior and posterior to these, the circuli tend to arch between the radii, with their convexity toward the focus of the scale (Figure 1). often the circuli preceding and following the

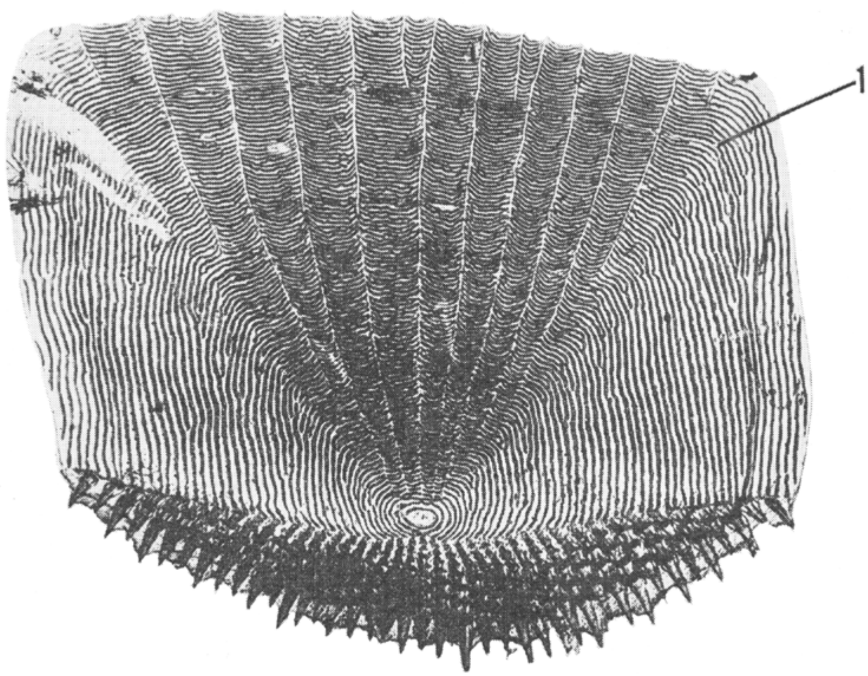


FIGURE 1. Scale from a one-year-old female California corbina, 149 mm standard length, taken April 24, 1950. Configuration of the annulus is typical. Across the anterior field, the annulus consists of one or two straightened circuli—in contrast to the arched circuli anterior and posterior to the annulus.

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annulus are somewhat crowded. These crowded circuli do not transmit light as well as do surrounding areas so the annulus in the anterior field may appear as a light, translucent line either within or adjacent to a dark band of closely-spaced circuli. In the anterior and middle portions of the lateral fields, the annulus is a thin line of broken and

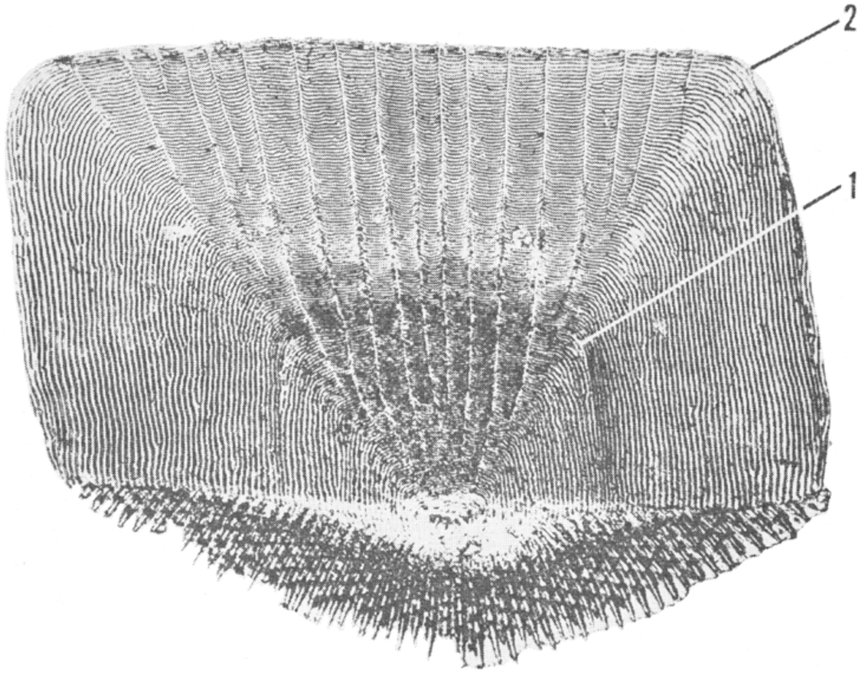

FIGURE 2. Scale from a two-year-old female California corbina, 244 mm standard length, taken in the Los Angeles-Long Beach Harbor April 27, 1950.

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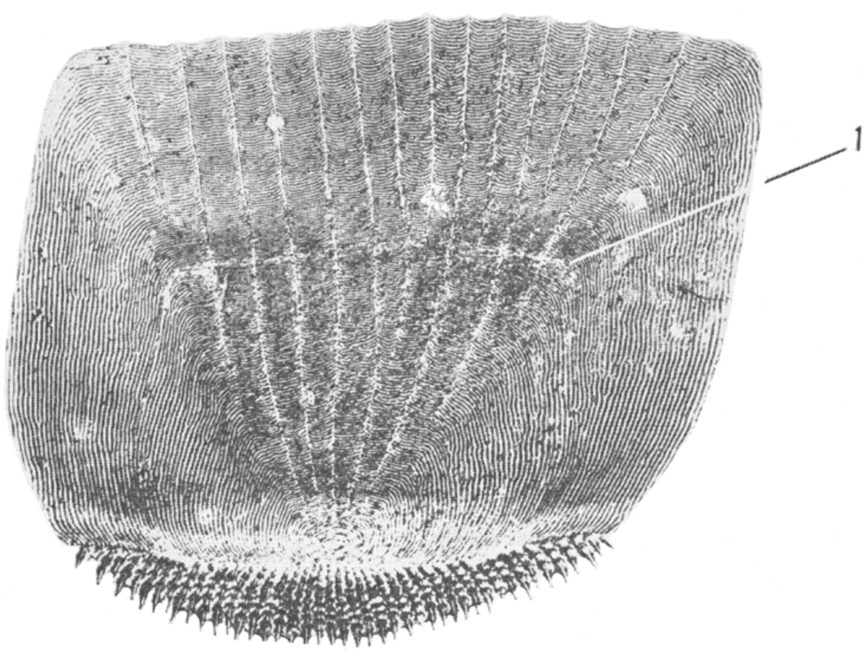

FIGURE 3. Scale from a one-year-old female spotfin croaker, 147 mm standard length, taken September 1, 1955, in the Belmont Shore area of Long Beach Harbor.

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coalesced circuli and typical "crossing over" is seen where the lateral fields meet the ctenoid area.

False annuli or accessory checks were common on the scales of older fish. Their infrequent appearance on the scales of fish younger than three years indicates they probably reflect growth changes resulting from spawning activity. Some false annuli are almost identical to true annuli across the anterior field of the scale; however, they tend to be indistinct or absent in one or both of the lateral fields. In addition they are often spaced in such a manner between true annuli that to use them in back calculations would result in unreasonable estimates of lengths at previous ages.

Scale annuli were judged to be valid year marks for both species because:

1. Scales from fish collected during the fall and winter showed no annulus on the periphery. Fish taken in spring and early summer showed an annulus close to the periphery of the scale, and scale growth beyond the annulus steadily increased throughout the summer and fall.

2. Good correlation existed between fish length and the number of annuli. Significant differences in length were evident between one age group and the next.

3. There was close agreement between back-calculated lengths and actual lengths at the same age as determined from scales.

5.2. Growth Determinations

In the simplest and earliest method of determining length at previous ages (the Dahl-Lea method), it was assumed that, "the ratio of body length to scale length is constant for all lengths of fish beyond that at which the first annulus is laid down" (Lagler, 1952). The relationship between body length and scale length was thus expressed by the formula $L = cS$, where L = body length, S = scale length and c = a constant.

Following closely on Lea's basic work on the herring (1910) and the successful application of his formula by others (notably Dahl, 1910) on scales of Norwegian salmon and trout, it was pointed out by Lee (1912) that the premise of a constant linear relationship between body length and scale length may not necessarily be assumed to exist. She showed by critically examining Lea's data that, "for corresponding years (of life) the total lengths calculated from the scales of old fish were always lower than those calculated from the scales of young fish" (Van Oosten, 1929). In other words, calculating the first year's growth from a 10-year-old fish would, according to Lee, result in a shorter length estimate than would be calculated from the same fish when it was two years old.

Although this "Lee's Phenomenon" has not been demonstrated for all fish, a variety of discrepancies in calculated lengths has been described from many species, when it has been assumed without justification that a constant linear relationship existed between body length and scale length. Therefore, much recent work has been devoted to develop correction factors to improve the Dahl-Lea method.

Shuck (1949) and Whitney and Carlander (1956) reviewed the general topic of body length-scale length relationships, and Lagler (1952) presented an excellent summary of the several commonly used correction factors. It is now evident that no single correction method can necessarily be applied to growth studies on all species. However, on theoretical grounds, the Segerstrale method is believed satisfactory (Jobes, 1952; Lagler, 1952).

Segerstrale (1933), working on several freshwater fishes, determined average scale lengths at various body lengths by measuring key scales or "Normalschuppen" from a selected body area. The resultant empirically-determined curve assumes no fixed mathematical relationship between scale length and body length. Obviously, if adequate samples are obtained over the complete range of body lengths, this method results in the most truly descriptive curve obtainable.

5.2.1. Spotfin Croaker Growth

As was pointed out previously, it was impossible adequately to determine the body length-scale length relationship of the spotfin croaker

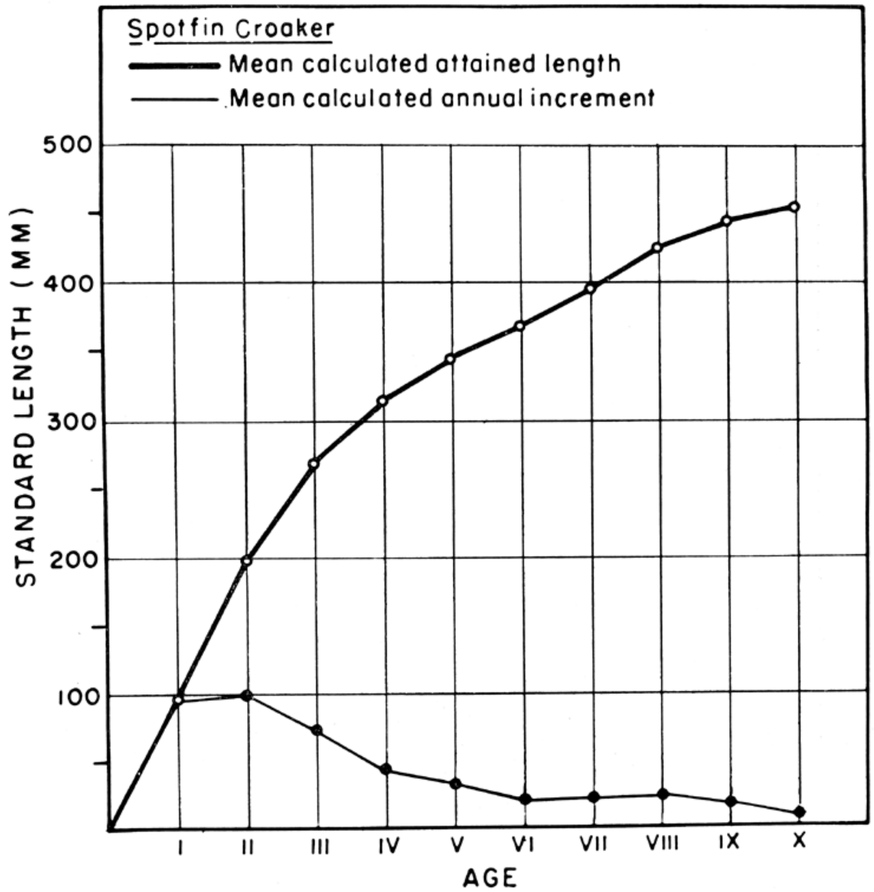

FIGURE 4. Calculated growth curves based on 1,553 male and female spotfin croakers taken in the vicinity of the Los Angeles-Long Beach Harbor. The mean calculated attained lengths at the end of each year of life from I through X are: 97, 197, 269, 312, 345, 367, 394, 422, 442, and 453 mm respectively.

FIGURE 4. Calculated growth curves based on 1,553 male and female spotfin croakers taken in the vicinity of the Los Angeles-Long Beach Harbor. The mean calculated attained lengths at the end of each year of life from I through X are: 97, 197, 269, 312, 345, 367, 394, 422, 442, and 453 mm respectively

TABLE 1

Calculated Lengths of 1,553 Spotfin Croakers by Year-Class and Age

Year Class	Year of Capture	Age at Capture	No. Fish	Calculated Lengths* at Each Age I	II	III	IV	V	VI	VII	VIII	IX	X
1955	1956	I	2	102	--	--	--	--	--	--	--	--	--
	1957	II	1	106	194	--	--	--	--	--	--	--	--
Avg.				(104)	(194)	--	--	--	--	--	--	--	--
1954	1955	I	284	88	--	--	--	--	--	--	--	--	--
	1956	II	124	94	188	--	--	--	--	--	--	--	--
	1957	III	33	87	184	240	--	--	--	--	--	--	--
Avg.				(90)	(187)	(240)	--	--	--	--	--	--	--
1953	1954	I	3	104	--	--	--	--	--	--	--	--	--
	1955	II	20	84	192	--	--	--	--	--	--	--	--
	1956	III	10	83	188	254	--	--	--	--	--	--	--
	1957	IV	2	103	178	256	294	--	--	--	--	--	--
Avg.				(86)	(190)	(254)	(294)	--	--	--	--	--	--
1952	1955	III	92	98	195	262	--	--	--	--	--	--	--
	1956	IV	8	97	202	263	293	--	--	--	--	--	--
	1957	V	3	104	206	269	311	333	--	--	--	--	--
Avg.				(98)	(196)	(262)	(298)	(333)	--	--	--	--	--
1951	1952	I	2	86	--	--	--	--	--	--	--	--	--
	1954	III	7	103	192	247	--	--	--	--	--	--	--
	1955	IV	66	102	198	257	295	--	--	--	--	--	--
	1956	V	9	117	220	275	304	322	--	--	--	--	--
	1957	VI	3	107	211	274	315	341	360	--	--	--	--
Avg.				(103)	(200)	(259)	(297)	(327)	(360)	--	--	--	--
1950	1951	I	77	84	--	--	--	--	--	--	--	--	--
	1952	II	30	86	167	--	--	--	--	--	--	--	--
	1953	III	6	114	212	268	--	--	--	--	--	--	--
	1954	IV	8	112	207	266	307	--	--	--	--	--	--
	1955	V	31	107	208	272	312	342	--	--	--	--	--
	1956	VI	17	103	196	253	274	312	328	--	--	--	--
	1957	VII	4	101	202	267	299	325	347	363	--	--	--
Avg.				(93)	(193)	(267)	(300)	(331)	(332)	(363)	--	--	--
1949	1950	I	32	91	--	--	--	--	--	--	--	--	--
	1951	II	299	101	186	--	--	--	--	--	--	--	--
	1952	III	17	99	193	240	--	--	--	--	--	--	--
	1953	IV	68	107	219	282	314	--	--	--	--	--	--
	1954	V	2	92	197	282	324	345	--	--	--	--	--
	1955	VI	22	108	223	294	334	364	384	--	--	--	--
	1956	VII	9	103	202	263	301	328	345	359	--	--	--
Avg.				(101)	(194)	(276)	(317)	(353)	(373)	(359)	--	--	--
1948	1950	II	4	92	193	--	--	--	--	--	--	--	--
	1951	III	4	92	192	250	--	--	--	--	--	--	--
	1952	IV	3	109	229	292	332	--	--	--	--	--	--
	1953	V	107	102	212	281	321	346	--	--	--	--	--
	1954	VI	3	83	187	258	309	339	363	--	--	--	--
	1955	VII	16	116	223	299	341	372	395	413	--	--	--
	1956	VIII	2	99	194	282	318	339	358	373	387	--	--
Avg.				(103)	(212)	(282)	(323)	(349)	(386)	(409)	(387)	--	--
1947	1950	III	17	102	192	247	--	--	--	--	--	--	--
	1951	IV	16	105	189	245	277	--	--	--	--	--	--
	1952	V	4	101	192	252	303	338	--	--	--	--	--
	1953	VI	56	105	209	279	318	345	365	--	--	--	--
	1954	VII	1	89	201	266	324	365	384	399	--	--	--
	1955	VIII	3	126	248	321	359	384	403	418	[illegible]	--	--
	1956	IX	1	101	190	265	310	345	373	392	405	421	--
Avg.				(105)	(203)	(268)	(311)	(347)	(367)	(409)	(425)	(421)	--

TABLE 1

Calculated Lengths of 1,553 Spotfin Croakers by Year-Class and Age

TABLE 1—Continued

Calculated Lengths of 1,553 Spotfin Croakers by Year-Class and Age

Year Class	Year of Capture	Age at Capture	No. Fish	Calculated Lengths* at Each Age									
				I	II	III	IV	V	VI	VII	VIII	IX	X
1946	1950	IV	5	100	202	268	298	--	--	--	--	--	--
	1951	V	4	89	196	256	285	305	--	--	--	--	--
1943	1950	VII	10	98	200	275	323	354	377	395	--	--	--
	1951	VIII	2	100	217	316	350	376	397	418	436	--	--
	1952	IX	2	84	207	288	338	369	396	419	441	455	--
	1953	X	2	157	251	306	335	357	379	398	422	439	453
Avg.				(101)	(205)	(277)	(316)	(348)	(382)	(401)	(433)	(447)	(453)
Total Fish..........1,553													
Total Average Calculated Length......				97	197	269	312	345	367	394	422	442	453
Average Increment........					100	72	43	33	22	27	28	20	11

* Average length of each year-class at each age in parentheses.

TABLE 1

Calculated Lengths of 1,553 Spotfin Croakers by Year-Class and Age

over the range of lengths used in this study. Therefore, the direct-proportion method of Van Oosten (1929) was employed wherein:

$$\frac{\text{Length of scale included in annulus of year } X}{\text{Total length of scale}} = \frac{\text{Length of fish at end of year } X}{\text{Length of fish at time of capture}}$$

EQUATION

This assumes there is a straight line relationship between body length and scale length with the graphical intercept at 0,0. Since such a precise relationship is rare, the method will, for most species, result in values that must be considered approximations whose accuracy will depend on the degree to which the true body length-scale length relationship differs from the assumed straight line.

In spotfin croaker growth determinations, the direct-proportion method proved sufficiently accurate. Although there was considerable variation in estimates of lengths at previous ages, no particular trend was apparent. Moreover, no significant differences could be demonstrated between back-calculated lengths and measured lengths on fish of known ages.

The calculated lengths of spotfin croakers, separated by year-class and age, are summarized in Table 1. The curves, based on the grand average calculated lengths and increments of the 1,553 aged fish are seen in Figure 4. The curves were derived by summarizing the data of Table 1.

These summary data indicate that annual growth during the first and second year of life is rapid, averaging approximately 100 mm (standard length) each year. Beginning with the third growth year and the onset of reproductive activity, annual growth increments decrease.

The apparent irregularity in this decreasing increment, which shows up as an increased average increment during the seventh and eighth growth years, can best be attributed to unrepresentative sampling and to relatively small numbers of older individuals.

5.2.2. Weight-Length Relationship of the Spotfin Croaker

The weight-length relationship for the spotfin croaker was calculated from 291 specimens (Figure 5). No significant differences were detected in the weight-length relationship of the sexes when treated separately so the data for males and females have been combined. The logarithmic expression of the relationship is Log $W = -4.49356 + 2.94436$ Log L.

Substituting average standard lengths at each age into the logarithmic equation results in the following estimates of average weight in grams at each age from *I* though *X* respectively: 23; 183; 458; 708; 952; 1,142; 1,408; 1,724; 1,975; and 2,124.

The net weight gain is greatest (275 grams) in the third growth year (between the formation of the second and third annuli).

5.2.3. Body Length-Scale Length Relationship of the California Corbina

Calculating lengths at previous ages for corbinas was done essentially by the method Jobes (1952) used on yellow perch, and can be considered a modification of the Segerstrale method.

My entire sample of 1,643 corbina having one or more annuli was utilized to determine the body length-scale length relationship. Since key scales were not taken, the scale radius for individual fish was averaged from two or more scales. In addition, scale measurements were made on 50 age zero fish ranging from 32 to 100 mm standard length.

The computed regression line for standard length on scale radius (for fish having one or more annuli) gave the following equation: $Y = -17.921 + 2.629X$ where Y = standard length and X = scale radius.

The negative intercept of this line, which is relatively rare in body length-scale length relationships, has been reported for another sciaenid, Cynoscion regalis (Merriman, 1941).

Such an intercept is unrealistic insofar as the overall body length-scale length relationship is concerned. Obviously, scales cannot be formed prior to the time a fish has attained a body. It is therefore apparent that the relationship of body length to scale length is a changing one and, at smaller sizes, scale growth is more rapid in relation to body growth.

This was verified when the body length-scale length relationship among 50 age zero fish was analyzed. Over the range of standard lengths from 32 to 100 mm, the relationship was a straight line having the equation: $Y = 10.004 + 1.994X$.

Therefore, the overall body length-scale length relationship can be best described for the California corbina by two separate, straight

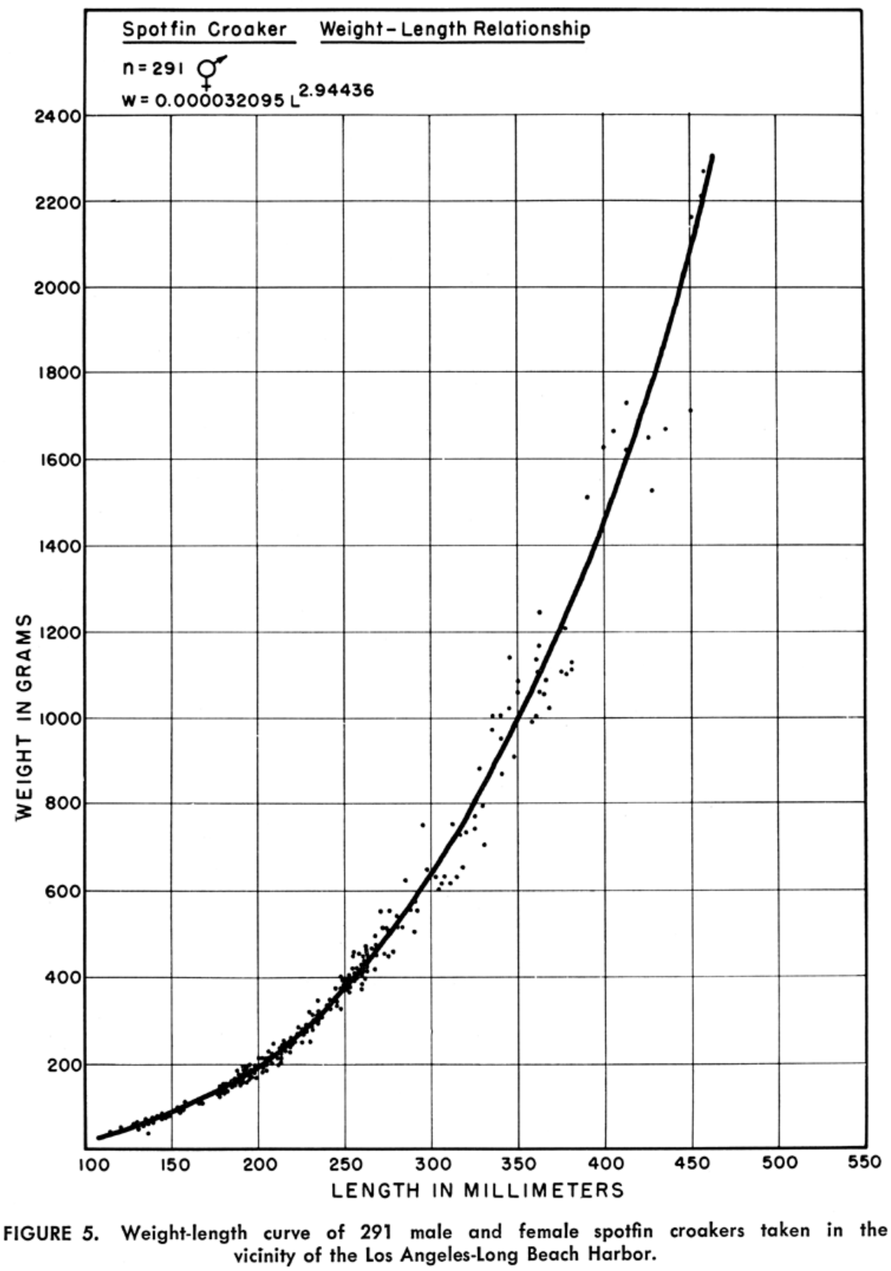

FIGURE 5. Weight-length curve of 291 male and female spotfin croakers taken in the vicinity of the Los Angeles-Long Beach Harbor

regression lines which intersect at a standard length value of approximately 97 mm (Figure 6).

The points in Figure 6 represent the average standard length corresponding to each 10 mm increment (read at a magnification of 30) in scale radius.

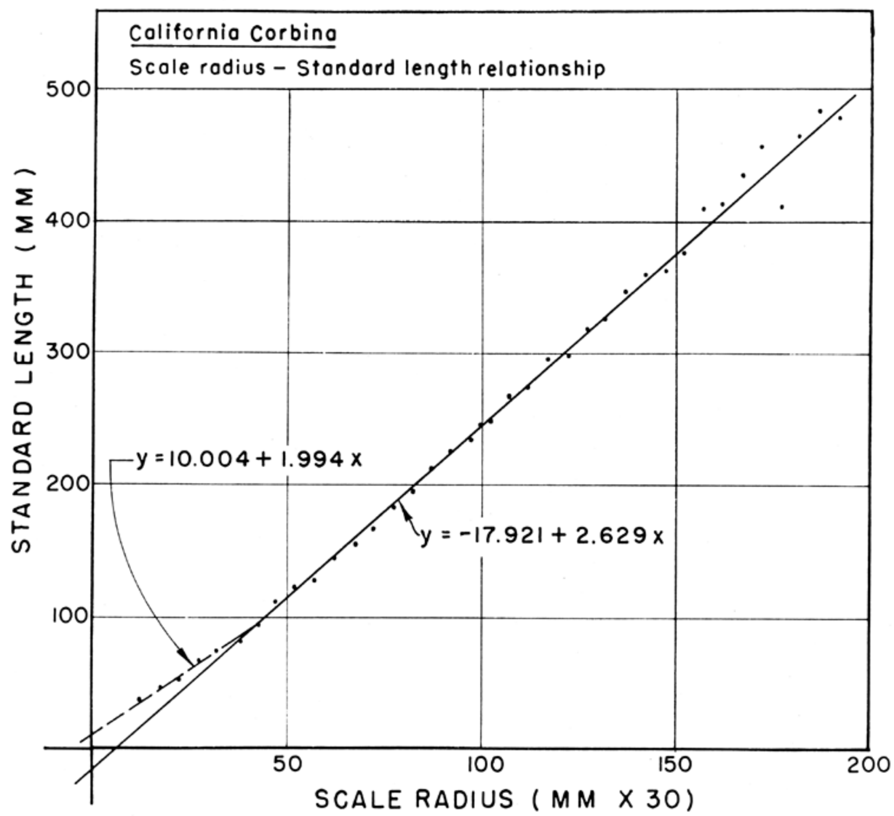

FIGURE 6. Body length-scale length relationship in the California corbina.

FIGURE 6. Body length-scale length relationship in the California corbina

5.2.4. California Corbina Growth

Individual calculated lengths at previous ages were obtained by assuming the relationship of standard length to scale radius can be represented by a straight line with an intercept of -17.921 mm of standard length. (Further correcting, to be described below, was performed on first year's lengths which were calculated below 97 mm.)

Calculating lengths at previous ages was based on the following computations: If we let Y_i = standard length at age i X_i = scale radius at age i Y_c = standard length at time of capture X_c = scale radius at time of capture $Y_o = a = -17.921 = Y$ when X is 0 $X_o = 0$ Then the slope of the line representing an individual fish was $b = (Y_c - Y_o)/(X_c - X_o) = (Y_c + 17.921)/(X_c - 0)$, and the Y *i* 's for each fish were computed from the straight-line equation

$$
\begin{aligned}
Y \cdot &= a + bX_i \\
&= a + \frac{Y_c - Y_o}{X_c - X_o} X_i \\
&= -17.921 \ - \ \frac{Y_c + 17.921}{X_c} X_i
\end{aligned}
$$

EQUATION

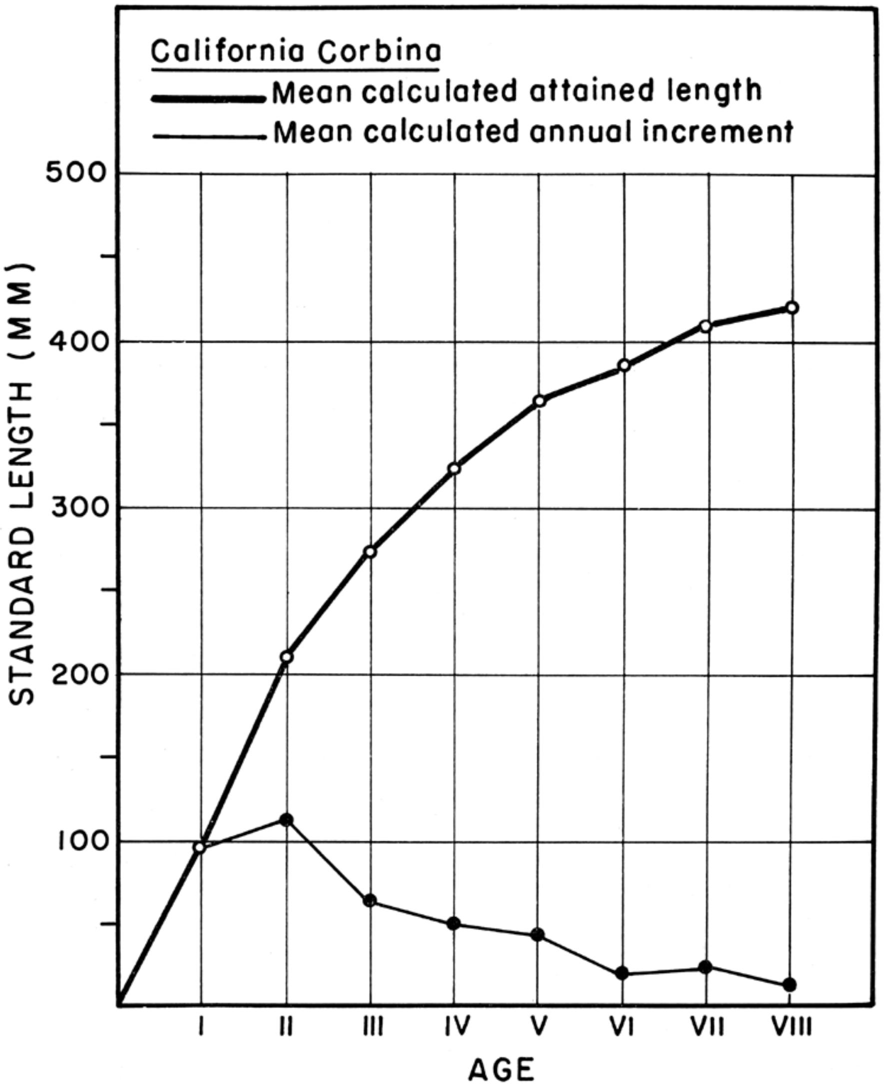

FIGURE 7. California corbina growth curves based on 1,724 fish.

FIGURE 7. California corbina growth curves based on 1,724 fish

For those individuals where the calculated length at the first annulus fell below 97 mm, a correction was added in the manner described by Jobes (1952). The two intersecting regression lines were carefully

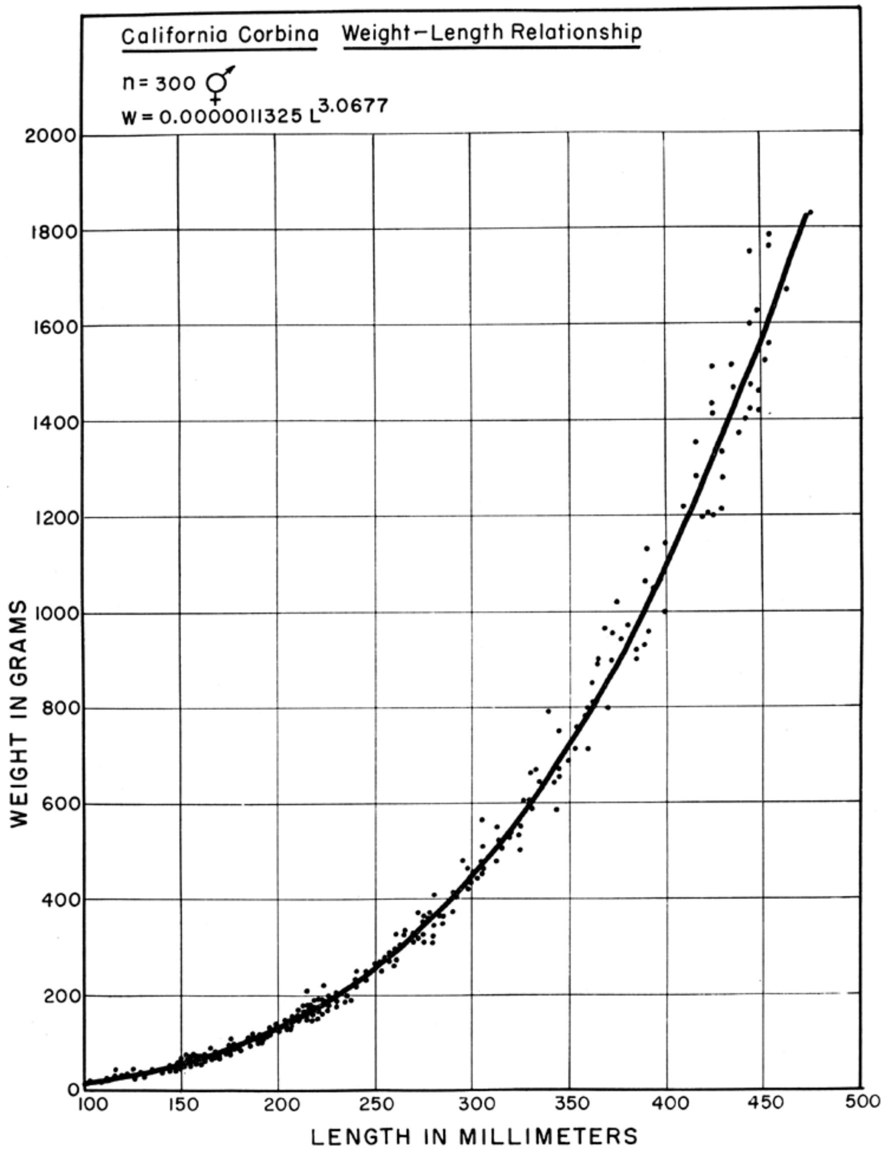

FIGURE 8. General weight-length curve of 300 male and female California corbinas.

FIGURE 8. General weight-length curve of 300 male and female California corbinas

drawn on cross-sectional millimeter paper. The short line with a *Y* axis intercept of 10.004 is based on 50, age zero fish 32 to 100 mm long and intersects the major line at a standard length value of 97 mm. For each back-calculated length which fell below 97 mm, a correction was made by adding, to the originally calculated length, the number of millimeters which vertically separated the lower from the upper line (Figure 6).

The average calculated lengths of the 1,724 California corbinas, separated by year-class and age, are summarized in Table 2 and the calculated growth curves, based on their average calculated lengths and annual increments are shown in Figure 7.

The mean calculated lengths attained at the end of each year of life from I through VIII are: 97; 210; 278; 323; 366; 386; 410; and 421 mm respectively.

TABLE 2

Average Calculated Lengths of 1,724 California Corbinas by Year-Class and Age

Year Class	Year of Capture	Age at Capture	No. Fish	Calculated Lengths* at Each Age I	II	III	IV	V	VI	VII	VIII
1954	1955	I	603	103	--	--	--	--	--	--	--
	1956	II	19	101	213	--	--	--	--	--	--
Avg.				(103)	(213)	--	--	--	--	--	--
1953	1954	I	73	96	--	--	--	--	--	--	--
	1955	II	438	95	215	--	--	--	--	--	--
	1956	III	34	98	223	302	--	--	--	--	--
Avg.				(95)	(216)	(302)	--	--	--	--	--
1952	1953	I	2	78	--	--	--	--	--	--	--
	1954	II	43	79	198	--	--	--	--	--	--
	1955	III	50	87	200	281	--	--	--	--	--
	1956	IV	10	94	217	289	340	--	--	--	--
Avg.				(84)	(201)	(282)	(340)	--	--	--	--
1951	1952	I	5	91	--	--	--	--	--	--	--
	1953	II	4	97	180	--	--	--	--	--	--
	1954	III	23	100	204	276	--	--	--	--	--
	1955	IV	29	97	205	273	327	--	--	--	--
	1956	V	5	106	196	268	326	355	--	--	--
Avg.				(98)	(202)	(274)	(327)	(355)	--	--	--
1950	1951	I	88	105	--	--	--	--	--	--	--
	1952	II	3	114	209	--	--	--	--	--	--
	1953	III	9	118	219	279	--	--	--	--	--
	1954	IV	19	94	209	272	311	--	--	--	--
Avg.				(104)	(212)	(274)	(311)	--	--	--	--
1949	1950	I	102	103	--	--	--	--	--	--	--
	1951	II	51	91	213	--	--	--	--	--	--
	1953	IV	3	95	206	277	327	--	--	--	--
	1954	V	16	89	217	298	346	377	--	--	--
Avg.				(98)	(213)	(294)	(343)	(377)	--	--	--
1948	1950	II	22	79	205	--	--	--	--	--	--
	1951	III	16	76	192	275	--	--	--	--	--
Avg.				(77)	(199)	(275)	--	--	--	--	--
1947	1950	III	5	86	180	262	--	--	--	--	--
	1951	IV	25	84	185	259	310	--	--	--	--
	1954	VII	6	84	176	253	314	360	386	411	--
Avg.				(84)	(183)	(259)	(310)	(360)	(386)	(411)	--
1946 Thru 1943		IV	10	85	191	257	309	--	--	--	--
		V	7	93	207	272	325	358	--	--	--
		VI	3	92	188	264	325	362	388	--	--
		VIII	1	77	186	243	312	354	378	401	421
Avg.				(88)	(196)	(262)	(317)	(358)	(385)	(401)	(421)
Total Fish 1724											
Total Average Calculated Length				97	210	278	323	366	386	410	421
Average Increment					113	68	45	43	20	24	11

* Average length of each year-class at each age in parentheses.

TABLE 2

Average Calculated Lengths of 1,724 California Corbinas by Year-Class and Age

The general weight-length curve, based on 300 male and female corbinas is shown in Figure 8. Its expression is $W = 0.0000011325\ L^{3.0677}$. The straight-line logarithmic expression of the relationship is Log W = -4.94579 + 3.06773 log L. The average estimated weight in grams attained at each age from I through VIII are: 14; 151; 356; 564; 828; 975; 1,175; and 1,273 respectively.

6. MONTHLY GROWTH

Determining growth rates throughout a growth season can be fundamentally significant in our general understanding of fish growth and the factors that may control or modify it. Although much can be inferred by evaluating and comparing total seasonal growth in different years or locations, it is my opinion that for some purposes, more intimate and significant information can be obtained by analyzing growth rates within a single season. The immediate relationship between growth and such factors as temperature, light, and perhaps nutrients, which vary more within a season than between seasons, may often be most readily evaluated during the period of maximum change—within the growth season.

The growth rate of any year-class within a growing season can be rather easily determined—provided adequate periodic samples are available and the fish can be accurately aged for assignment to the year-class in question. If sampling is adequate and representative throughout the year, it is relatively simple to determine the modal or average size of individuals of the year-class at any particular period. By subtracting their average length at any date from the length attained at a subsequent date, their growth increment during the elapsed period will be evident.

Merriman (1941), in tracing and comparing the seasonal growth rates of Atlantic Coast striped bass, Roccus saxatilis, provided an outstanding example of this straight-forward type of analysis. Similar though less extensive analyses have been performed on various sciaenids of the eastern United States. Welsh and Breder (1923), Hildebrand and Schroeder (1928), Pearson (1929), and Hildebrand and Cable (1934), made estimates of monthly growth in their life-history studies on Atlantic and Gulf Coast sciaenids.

Although many workers have failed to consider seasonal growth, presumably because it is difficult to obtain adequate samples throughout the growing season, seasonal growth studies have been conducted on some marine invertebrates and fishes of California.

Weymouth (1923) demonstrated a positive correlation between monthly growth rates of young Pismo clams in Monterey Bay and average air temperatures. Similar monthly growth determinations were performed by Clark (1925) on grunion, Leuresthes tenuis, by Hubbs (1921b) on the embiotocid, Micrometrus aurora, and by Scofield (1931) on the striped bass of the San Francisco Bay area. More recently Orcutt (1950), in his life-history investigations on the starry flounder, Platichthys stellatus, described the monthly growth in Monterey Bay during the first 18 months following metamorphosis, and Miller (1955) calculated the bimonthly growth rate of the northern anchovy in Monterey Bay and southern California waters.

All these workers based their estimates on monthly progressions of actual fish lengths, the method generally used by workers for estimating monthly growth. It is the only means of estimating monthly growth for age zero fish and is completely valid and practical so long as samples are withdrawn from a stock under conditions in which the determinations are not biased by differential availability of various size groups, and in which there is no continuing recruitment.

In determining the within-season growth rates of fish showing at least one annulus, a more accurate estimate can often be gained by calculating individual growth increments based on peripheral scale growth beyond the last annulus. This method, as exemplified by Hile (1936), Beckman (1943), and Jobes (1952), takes advantage of the fact that, within a year-class, the range of body lengths at the beginning and end of a growth season is almost always greater than is the range of individual growth increments during the course of the season. This is particularly true in those species with extended spawning periods, where early-spawned individuals acquire a length advantage and maintain it in succeeding years. Thus, differential availability of particular sizes within a year-class can lead to erroneous estimates of short-period growth if these estimates are based solely on the attained lengths at the time of capture. Orcutt (1950), for example, found that monthly length-frequency measurements of starry flounders during their second summer of life resulted in progressively shorter average length estimates due to a differential movement of larger individuals to unsampled offshore locations.

TABLE 3

Monthly Growth of 1954 Year-Class California Corbinas in 1955
Growth From Age I to II

Month	Week	No. Fish	Avg. S.L. I[1]	Avg. S.L. at Capture	Average Increment[2]	Pct. Expected Increment
May	3	15	115	127	12	11
June	3	14	114	141	27	25
	4	32	106	149	33	30
July	1	77	104	146	42	38
	4	19	111	163	52	47
Aug.	2	120	97	163	66	60
	3	23	97	179	82	75
Sept.	1	53	90	164	74	67
	3	67	99	193	94	85
	4	64	103	198	95	86
Oct.	2	40	97	195	98	89
	4	36	102	197	95	86
Nov.	1	21	90	196	106	99
	2	11	106	219	113	103
	3	5	129	225	96	87
Dec.	2	6	104	223	119	108

[1] Average calculated L_1 = 103 mm. (Table 2)
[2] Expected S.L. at II = 213 mm and expected increment = 110 mm.

TABLE 3

Monthly Growth of 1954 Year-Class California Corbinas in 1955 Growth From Age I to II

6.1. California Corbina Monthly Growth

During 1955, 603 one-year-old fish (1954 year-class) and 447 two-year-old fish (1953 year-class) were sampled. The 1954 year-class corbinas were collected from May 19 to December 14, and 1953 year-class fish were taken from April 29 to December 14. Since April through December represents essentially the entire growing period for the California corbina in southern California, it was possible to determine the monthly growth rate of both these year-classes during 1955.

In 1955, individual fish growth was calculated by measuring scale growth from the outermost annulus to the periphery. These data, accumulated and averaged by weekly intervals, are shown in Tables 3 (1954 year-class) and 4 (1953 year-class).

The tabular data express seasonal growth in millimeters of increment beyond the preceding annulus and also in the percentage attainment of the season's total expected growth.

The latter values were obtained by dividing the average increment (completed up to the week of capture) by the total expected seasonal increment for the year-class. The expected increment of the 1954 year-class during 1955 (Table 3) was estimated to be 213 - 103, or 110 mm. The expected increment of the 1953 year-class during 1955 was estimated to be 302 - 215, or 87 mm (Table 4) .

The increment data of Tables 3 and 4 are shown graphically in Figures 9 and 10. Figure 9 presents the accumulated increments of both year-classes during the 1955 growing season. Although the separate

TABLE 4

Monthly Growth of 1953 Year-Class California Corbinas in 1955
Growth From Age II to III

Month	Week	No. Fish	Avg. S.L. II[1]	Avg. S.L. at Capture	Average Increment[2]	Pct. Expected Increment
Apr.	4	27	216	220	4	5
May	3	45	218	227	9	10
June	3	23	232	254	22	25
	4	17	229	254	25	29
July	1	37	221	249	28	32
	4	26	223	263	40	46
Aug.	2	18	218	266	48	55
	3	4	201	245	44	51
Sept.	1	10	193	248	55	63
	3	30	203	269	67	77
	4	34	207	281	74	85
Oct.	2	24	225	297	72	83
	4	67	208	289	81	93
Nov.	1	20	202	279	75	86
	2	10	226	314	88	101
	3	36	215	302	87	100
Dec.	2	10	215	309	94	108

[1] Average S.L. at II = 215 mm. (Table 2)
[2] Expected S.L. at III = 302 mm and expected increment = 87 mm.

TABLE 4

Monthly Growth of 1953 Year-Class California Corbinas in 1955 Growth From Age II to III

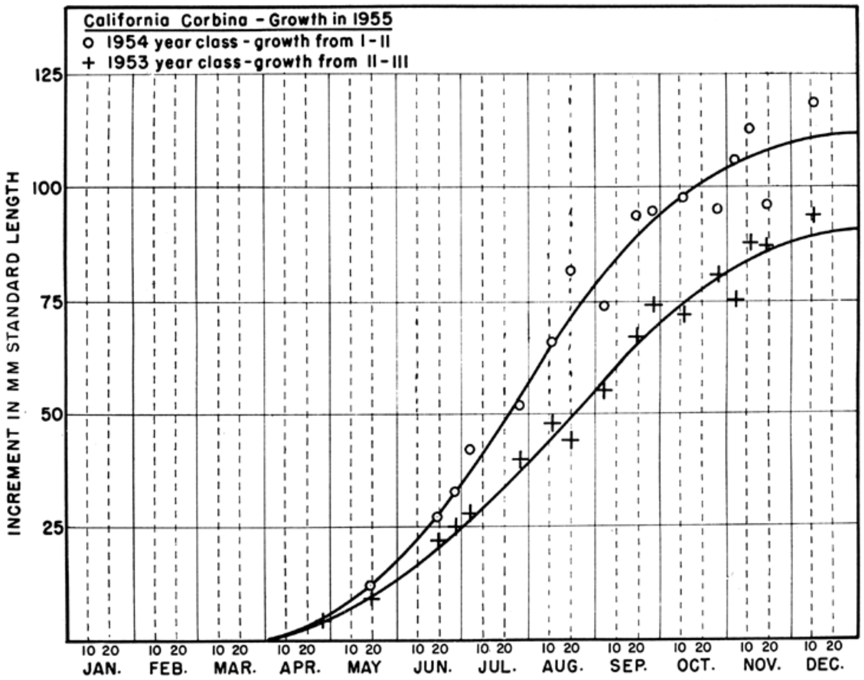

FIGURE 9. Calculated monthly growth of one- and two-year-old California corbinas during 1955. The separate curves describe the absolute monthly growth of each year-class in mm of standard length.

FIGURE 9. Calculated monthly growth of one- and two-year-old California corbinas during 1955. The separate curves describe the absolute monthly growth of each year-class in mm of standard length

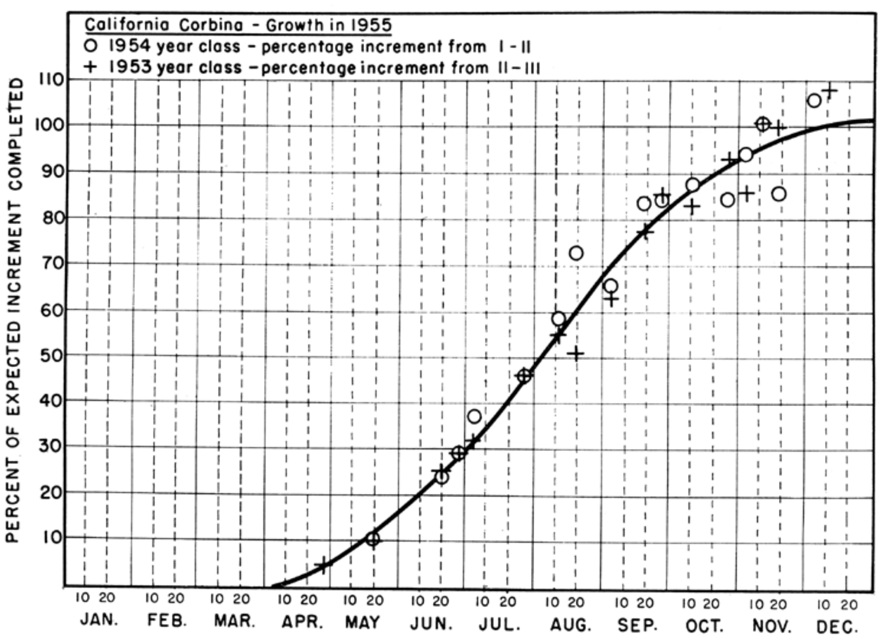

FIGURE 10. Monthly growth of the 1953 and 1954 California corbina year-classes during the 1955 growth year. The single curve, fitted by inspection, describes the growth of both year-classes in terms of percent of the total expected annual increment completed during each month.

FIGURE 10. Monthly growth of the 1953 and 1954 California corbina year-classes during the 1955 growth year. The single curve, fitted by inspection, describes the growth of both year-classes in terms of percent of the total expected annual increment completed during each month

growth curves for each year-class have been fitted to the data by inspection, and may therefore be subject to some error, the seasonal growth of both one- and two-year-old fish obviously follows a typical sigmoid curve, with maximum growth from July through September.

Figure 10 shows the percentages of total expected increment both year-classes attained throughout 1955. These percentage values seemed sufficiently similar for both one- and two-year-old fish to warrant fitting a single curve to the combined data by inspection. If the configuration of this curve is accepted, the cumulative percentages of total expected increment completed at the end of each month of the 1955 growth season were: April (6), May (17), June (31), July (48), August (67), September (82), October (93), November (99), December (100).

6.2. Spotfin Croaker Monthly Growth

Data revealing the complete monthly growth pattern of spotfin croakers were generally fewer than might have been desired due to the lack of sufficient samples throughout the course of most growth seasons. However, adequate 1954 year-class fish were taken from July through October 1955 to permit valid growth rate estimates for yearling fish in at least that growth season. Fortunately, the collections of one- and two-year-old California corbinas were also particularly well represented throughout the 1955 growing season, so it was possible to compare the growth patterns of the two species in a single growth season.

The method used to estimate growth increment for spotfin croakers was the same as described for California corbinas. In Table 5 are the tabulations of calculated growth increments exhibited by 1954 year-class spotfin croakers during the period of July through October, 1955. The values from the right-hand column of Table 5 (percent attainment of total expected annual increment) were plotted in Figure 11 and the resultant curve was fitted by inspection.

Based on Figure 11, the cumulative percentages of total expected annual growth completed at the end of each month from June through October were: June (32), July (46), August (63), September (83), and October (94).

TABLE 5

Monthly Growth of 1954 Year-Class Spotfin Croakers in 1955
Growth From Age I to II

Month	Week	No. Fish	Avg. S.L. I[1]	Avg. S.L. at Capture	Average Increment[2]	Pct. Expected Increment
July	1	3	98	133	35	35
	4	56	94	139	45	45
Aug.	2	98	87	137	50	51
	3	23	84	140	56	57
Sept.	1	67	84	145	61	62
	3	10	89	163	75	76
	4	18	94	173	79	80
Oct.	2	4	100	196	96	97
	4	5	93	182	89	90

[1] Average calculated L_1 = 88 mm. (Table 1)
[2] Expected S.L. at II = 187 mm and expected increment = 99 mm.

TABLE 5

Monthly Growth of 1954 Year-Class Spotfin Croakers in 1955 Growth From Age I to II

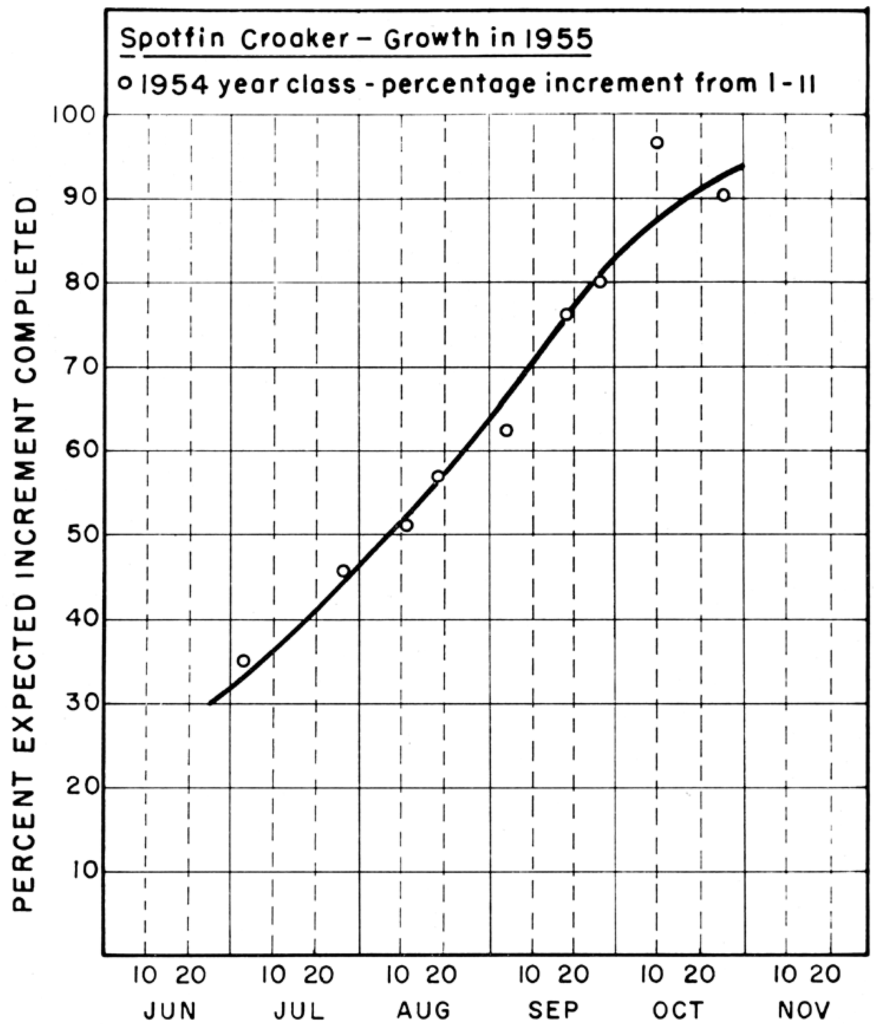

FIGURE 11. Monthly growth of 1954 year-class spotfin croakers during July through October, 1955. The curve expresses growth as the percent of total expected annual increment completed up to the time of capture.

FIGURE 11. Monthly growth of 1954 year-class spotfin croakers during July through October, 1955. The curve expresses growth as the percent of total expected annual increment completed up to the time of capture

Since the cumulative percentage increment for one- and two-year-old corbinas taken during these same months were 31, 48, 67, 82 and 93, it is apparent that young fish of both species grew at similar rates during 1955.

6.3. Relationship of Monthly Growth to Temperature

On the basis of their monthly growth curves, California corbinas and spotfin croakers obviously attain maximum growth during the months of maximum water temperatures in southern California. The sigmoid growth curves suggest moreover there may be a direct relationship between growth and temperature levels, or some other environmental stimulus that parallels the typical increase and decrease in temperatures throughout the year.

The general observation that the rhythmic increase and decrease in fish growth is directly correlated with the rise and fall in environmental temperatures has been substantiated by numerous workers in the past. So far as I am aware, the only marine fish having a decreased growth rate during summer months is the grunion. Clark (1925) showed that the growth of this species ceased or slowed greatly during the spring and summer as a result of spawning activities, but increased in the fall and continued during the coldest months of the year.

Although the growth rates of one- and two-year-old corbinas and yearling spotfin croakers are obviously greatest during the months of highest water temperatures, it was felt that because of the fundamental role temperature may play during other times of the year, a more detailed analysis of the relationship between monthly temperature and monthly growth was warranted.

For reference, average monthly surface water temperatures for the outer Los Angeles Harbor from 1949 through 1955 are presented in Table 6. Also shown are the grand average monthly temperatures at this station for the 31 years 1924 through 1955.

Surface water temperatures in the outer Los Angeles Harbor were taken at the Immigration Landing on the main shipping channel on the west end of Terminal Island. Thus, temperature recordings were some distance from the Belmont Shore surf zone where most fish were collected, and over considerably deeper water than that in which corbinas are commonly found. However, since the trends of Los Angeles Harbor temperatures correspond very closely with reliable inshore data from other southern California stations and, moreover, since temperatures actually taken in the surf zone are both scanty and highly variable, it is doubtful whether corbina or spotfin croaker habitat temperatures can be further refined at this time.

Most emphasis has been placed on the California corbina growth data because of their greater reliability. However, the general conclusions are probably also applicable to spotfin croakers.

In order to relate monthly corbina growth to average monthly temperatures, growth increments were determined by interpolation from the curve of Figure 10. The percentage attainment of total expected annual increment was estimated for each four-week interval from April 15 through December 15, 1955. Thus, from annulus formation to 15 April 1955, 2 percent of the expected seasonal growth was completed; between April 16 and May 15, an additional 8 percent of the expected growth was added; from May 16 to June 15 another 13 percent, and so on. The complete progression of monthly increments, as calculated at mid-month intervals and expressed in percent of total annual growth, was estimated to be: annulus formation to April 15 (2), May (8), June (13), July (15), August (20), September (18), October (12), November (9), December (2).

In Figure 12, the 1955 monthly percentage increments of one- and two-year-old fish are related to outer Los Angeles Harbor surface water temperatures. Growth increments were superimposed on the progression of mean monthly temperatures for 1955 as well as on the grand average monthly temperatures for the years 1924 through 1955. Average

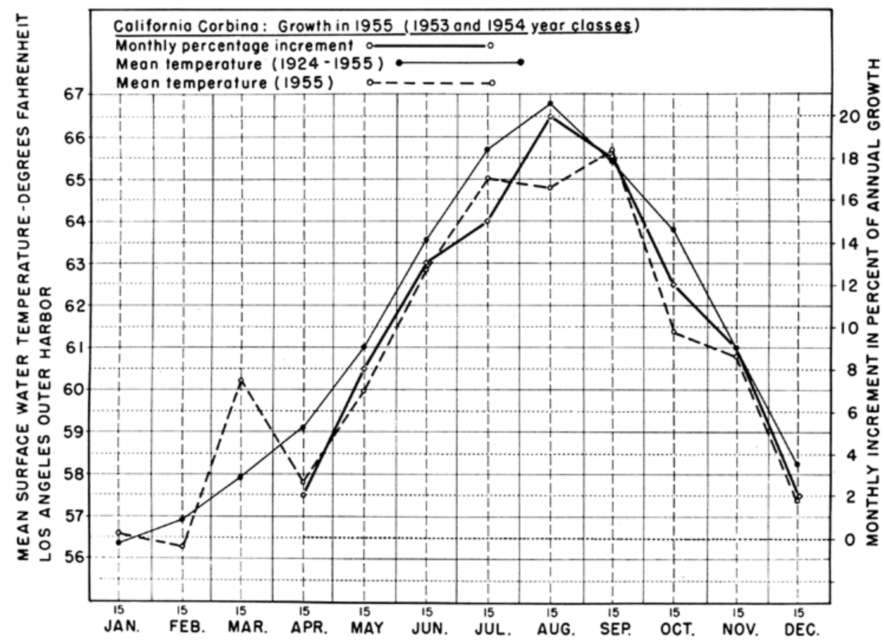

FIGURE 12. Relationship between monthly growth increments of one- and two-year-old California corbinas in 1955 and monthly surface water temperatures in the Los Angeles Harbor area. Each point on the curve represents the percentage of the total annual growth completed from the middle of one month to the middle of the next.

FIGURE 12. Relationship between monthly growth increments of one- and two-year-old California corbinas in 1955 and monthly surface water temperatures in the Los Angeles Harbor area. Each point on the curve represents the percentage of the total annual growth completed from the middle of one month to the middle of the next

monthly water temperatures are assumed to be represented by the temperature that prevailed at the mid-month point.

California corbina growth rates throughout the year in southern California apparently are very closely related to the typical progression of inshore surface water temperatures. The relationship is exceptionally good between growth in 1955 and average monthly temperatures during the period 1924 through 1955. With the exception of the growth for August, which appeared somewhat higher than might be expected if based on temperature alone, growth from April 15 through December 15, 1955, agreed remarkably well with the progression of 1955 surface water temperatures.

7. TIME OF ANNULUS FORMATION

In most spiny-rayed teleosts the annulus, or so-called winter ring, is a mark that first becomes evident on their scales in the late winter or spring indicating resumption of normal spring growth (Creaser, 1926; Van Oosten, 1929; Beckman, 1943). The typical annulus, which exhibits the phenomenon of "crossing over" is defined by Creaser (1926) as the "change in sculpturing produced when the normal scale pattern of the fall is discontinued by the cessation of growth and the unfinished edge of the scale is circumscribed by the resumption of the normal spring growth, the elements of which are developed without reference to the unfinished parts of the fall edge."

While the winter growth cessation or change in growth rate could be caused by a variety of factors, all of which may interrupt the normal scale pattern, typical annulus formation usually is brought about by temperature-induced changes in growth. Thus, even though growth is obviously dependent upon food intake and assimilation, a number of workers have demonstrated that growth cessation in the late fall and winter occurs independently of the food supply (Weymouth, 1923; Van Oosten, 1923; Creaser, 1926).

By analyzing California corbina and spotfin croaker growth throughout the year, it was apparent that their annuli typically were formed in the spring following a cessation of growth during the winter.

Although collections taken during December, January, and February were limited, neither species during these months showed any indication of annulus formation on the periphery of their scales. In no case, was an annulus judged to have been formed prior to the first week in March.

Evidence that would delimit the time of annulus formation was not available for all collection years. Sufficient data were collected, however, to indicate the annulus on yearling and two-year-old fish of both species typically forms by the first week of April, and is probably present on all individuals of these ages by the last week of the month.

It is further apparent that the time of annulus formation is related to age. In older fish the annulus becomes clearly defined somewhat later than it does in one- and two-year-old fish. All fish three years old and older, however, had begun their seasonal growth by the third week in May. The phenomenon of later annulus formation in older fish has been described by other workers. Hile (1941), in his study of the rock bass, Ambloplites rupestris, of Muskellunge Lake, Wisconsin, stated annulus formation was complete on young fish taken July 1 and 2, 1932, but incomplete in individuals older than six years taken in the same collections. A similar situation was described for herring, Clupea harengus, of the English Channel by Hodgesen (1929), who concluded that younger fish have a longer growing period within a season while older fish tend to begin growing later in the year.

There is some indication that annulus formation and the onset of spring growth may occur slightly earlier in the corbina than it does in the spotfin croaker. Based on collections made during 1951 (a warmer-than-usual spring), all one- and two-year-old corbinas collected on, and subsequent to, March 13 had complete annuli on the periphery of their scales and were actively commencing their seasonal growth. Both one- and two-year-old spotfin croakers, on the other hand, formed an annulus subsequent to April 1 and sometime prior to April 27. Thus, at least during the 1951 growth season, corbinas formed annuli two to four weeks sooner than spotfin croakers. However, even though the 1951 data are suggestive, insufficient data were available for other years to determine whether corbinas invariably commence their spring growth before spotfin croakers.

7.1. Relationship of Annulus Formation to Temperature

If, as previously demonstrated, growth throughout the year is closely related to monthly temperatures, it seems reasonable that the annulus will be formed earlier or later in the spring, depending on when temperature levels reach and exceed the minimum required for growth.

Beckman (1943) showed that for various Michigan game fishes annulus formation was directly correlated with temperature—forming earlier in years with higher spring temperatures and, in all years, becoming evident progressively later from southern to northern Michigan.

Similar indications were found that annulus formation occurs earlier in years with warmer-than-average springtime temperatures when I compared early season growth of yearling corbinas taken during 1951, 1954 and 1955. The average of combined March and April temperatures for these three years were 59.8° F in 1951, 58.6° F in 1954, and 59.0° F in 1955 (Table 6) . The combined average for the two-month period was 1.0 degrees above the 1949-1955 average in 1951, 0.2 degrees below average in 1954, and 0.2 degrees above it in 1955.

TABLE 6

Average Monthly Surface Water Temperature[1] Los Angeles Outer Harbor

	1949	1950	1951	1952	1953	1954	1955	Average 1949-1955	Average 1924-1955
January	52.3	54.1	57.6	56.9	59.2	57.0	56.6	56.2	56.4
February	53.8	55.9	57.3	58.3	58.8	58.7	56.3	57.0	56.9
March	55.4	58.5	58.5	56.8	58.1	57.8	60.2	57.9	57.9
April	58.0	60.9	61.0	61.3	59.7	59.4	57.8	59.7	59.1
May	62.4	58.0	60.6	62.9	59.5	60.6	60.0	60.6	61.0
June	65.2	63.0	63.8	63.8	63.1	65.4	62.9	63.9	63.6
July	66.1	67.4	66.8	63.5	66.9	68.7	65.0	66.3	65.7
August	66.7	66.1	66.0	66.6	66.3	68.3	64.8	66.4	66.8
September	66.1	67.6	65.2	64.1	63.6	66.8	65.7	65.6	65.4
October	62.8	66.6	66.0	63.5	63.5	64.0	61.4	64.0	63.8
November	61.4	62.8	64.4	61.4	60.9	63.3	60.8	62.1	61.0
December	57.3	61.8	59.4	59.5	57.1	60.0	57.4	58.9	58.3
Average	60.6	61.9	62.2	61.6	61.4	62.5	60.7	61.5	61.3

[1] U.S. Dept. of Commerce, Coast and Geodetic Survey. Surface Water Tempertures at Tide Stations-Pacific Coast. Spec. Pub. no. 280, 5th ed., 1956.

TABLE 6

Average Monthly Surface Water Temperature Los Angeles Outer Harbor

Not only were 1951 spring temperatures higher than those of 1954 or 1955, but in 1951, average temperatures were relatively high during March and April, with April temperatures averaging 1.5 degrees warmer than March. In contrast, although the two-month average during 1955 was 59.0° F (slightly above the 7-year average of 58.8° F), this near-average figure was attained because water temperatures were abnormally high during the last two weeks of March. April 1955 temperatures were abnormally low and, in fact, were lower than any other average April temperatures in the 7-year period.

The monthly growth curves for yearling corbinas, calculated from collections made in 1951, 1954, and 1955 (Figure 13), clearly indicate that at the termination of the full year's increment growth of the 1953 year-class during 1954 was considerably superior to the growth of the 1954 year-class in 1955. This will be discussed more fully in the section dealing with total annual growth as it relates to summer temperatures.

Although summer collections of the 1950 year-class were believed insufficient to give a reliable picture of monthly growth for the entire

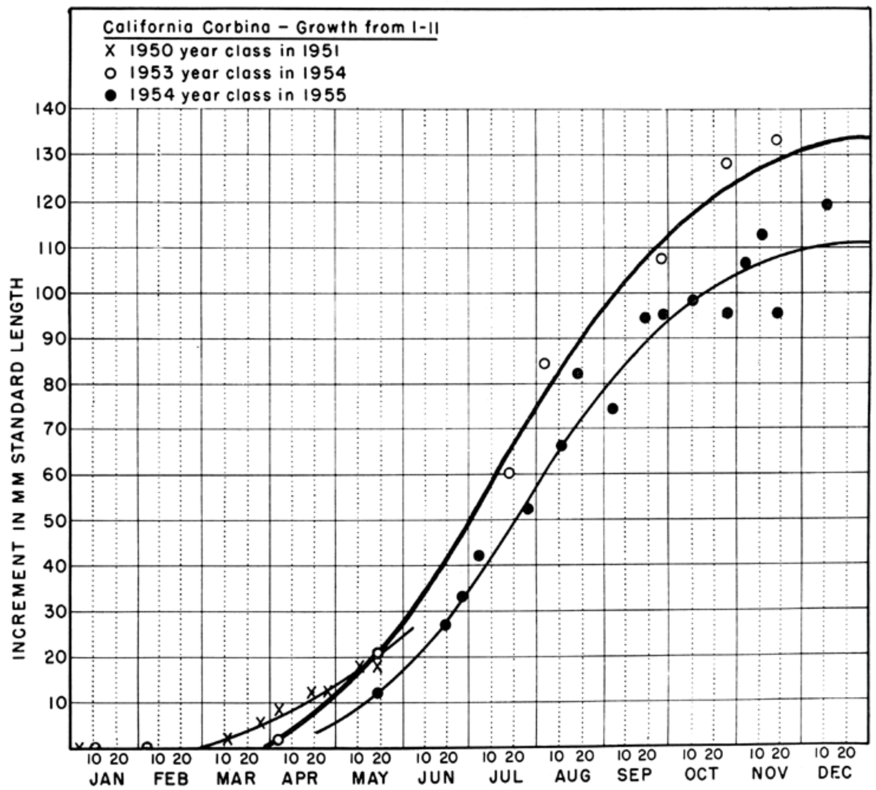

FIGURE 13. Monthly growth from age I to age II of 1950, 1953, and 1954 year-class California corbinas. The earlier onset of growth of the 1950 year-class reflects higher than average springtime temperatures in 1951. The growth of the 1953 year-class over that of the 1954 year-class is judged to be a response to higher water temperatures during the summer and fall of 1954.

FIGURE 13. Monthly growth from age I to age II of 1950, 1953, and 1954 year-class California corbinas. The earlier onset of growth of the 1950 year-class reflects higher than average springtime temperatures in 1951. The growth of the 1953 year-class over that of the 1954 year-class is judged to be a response to higher water temperatures during the summer and fall of 1954

year, 83 one-year-old fish (in 8 samples containing from 5 to 15 individuals) were taken between January 6 and May 19, 1951. Weekly growth analyses for these individuals revealed average increments ranging from almost 5 mm on March 13, to 8 mm on April 1, and 18 mm by May 19 (Table 7).

For comparing spring growth in 1954 and 1955 with that of 1951, one reliable sample (9 fish) of the 1953 year-class was available from a collection of April 1, 1954, and 15 yearling fish of the 1954 year-class were taken on May 19, 1955. The growth attained by fish of the April 1 collection in 1954 averaged less than 4 mm, approximately the same increment that had been attained over three weeks sooner by the 1950 year-class in 1951.

No valid conclusions can be drawn from the single fish collected in the third week of May 1954; however, it would appear that by the third week of May, total increments during both 1951 and 1954 may have been approximately the same.

The increment of 15, 1954 year-class fish taken May 19, 1955, averaged only 12 mm as compared to the 18 mm calculated for the 1950 year-class on the identical date in 1951.

TABLE 7

Early Season Growth of Yearling California Corbinas During 1951, 1954, and 1955

Year-Class		1950		1953		1954	
Year		1951		1954		1955	
Month	Week	mm Growth	Number Fish	mm Growth	Number Fish	mm Growth	Number Fish
January	1	0	(11)	--	--	--	--
	2	--	--	0	(11)	--	--
February	1	--	--	0	(14)	--	--
March	2	4	(11)	--	--	--	--
	4	5	(10)	--	--	--	--
April	1	8	(15)	4	(9)		
	3	12	(6)	--	--	--	--
	4	12	(15)	--	--	--	--
May	2	18	(5)	--	--	--	--
	3	18	(10)	21	(1)	12	(15)

TABLE 7

Early Season Growth of Yearling California Corbinas During 1951, 1954, and 1955

Thus, while data are drawn from unfortunately small samples, spring growth of yearling fish commenced earlier and proceeded more rapidly during 1951 than in either 1954 or 1955. Moreover, this more rapid early-season growth in 1951 was probably a result of earlier and more consistent warming of inshore waters.

The foregoing has demonstrated the relationship between water temperatures and the onset of growth and growth rate throughout the year. It is now possible to postulate rather specifically the temperature level necessary for California corbina and spotfin croaker growth.

Based on the time of annulus appearance the minimum temperature necessary for any significant growth will be that which is normally found in the Los Angeles-Long Beach Harbor between the middle of March and the first of April. If the average monthly temperature is assumed to occur at approximately the middle of the month, it can be seen in Figure 12 that, during 1924–1955, the March 15-April 1 surface water temperatures ranged between approximately 57 and 58° F.

To further support the conclusion that 57 to 58° F is probably the minimum temperature below which little or no growth occurs, all but 2 percent of the corbina's first- and second-year's growth was completed by December 15, 1955 (Figure 12), at which time water temperatures had fallen to 57.4° F.

8. RELATIONSHIP OF TOTAL ANNUAL GROWTH TO WATER TEMPERATURES

Since growth and other metabolic activities in poikilothermal (coldblooded) animals are directly correlated with temperature, it is reasonable to expect that (other factors being equal) years of high temperature should be characterized by greater growth than are years of lower than average temperatures. Such a relationship has been described in fish growth by a number of workers. Segerstrale (1932, 1933) demonstrated a very close relationship between summer temperatures and perch and cyprinid growth in Finland. Hile (1936) and Van Oosten (1944), in reviewing the causes for fluctuations in fish growth, cite other works tending to corroborate the findings of Segerstrale.

That such an obvious and expected correlation has not been found consistently in all fish-growth studies is, of course, attributable to the variety of other growth influencing factors that mask the effect of temperature or any other single factor. To some degree, failure to find a relationship may be due to imperfect knowledge of environmental temperatures to which the species has been exposed during its life.

California corbinas and spotfin croakers spend essentially all of their active growing period in shallow inshore waters. Since monthly temperature records for these inshore areas in southern California are relatively well known, it seemed both practical and desirable to determine the relationship between total annual growth and summer temperatures in the vicinity of the Los Angeles-Long Beach Harbor.

Tables 1 and 2 contain summaries of the calculated lengths attained by each year-class in the various growth years and at the several ages in which they were collected. From these two tables four sets of growth data were extracted and utilized in Figures 14 through 17 to point out the relationships between annual growth in both species and environmental temperatures during the first two years of life.

Percentage deviation from average annual growth in both species is shown in relation to the average water temperatures occurring during two time-periods each year: (1) the period of maximum temperatures from July through September and (2), the longer interval from May through September, when the overall average temperature is not quite so high.

8.1. California Corbina

In Figure 14 (upper graph), deviations between the first year's growth of corbinas (1949 through 1954 year-classes) are related to average summer water temperatures (July through September) during the calendar years of 1949 through 1954. The figure thus relates growth, from birth to formation of the first annulus, with temperatures occurring during the first summer of life prior to annulus formation the following spring. The left- and right-hand scales are arranged so the horizontal line through the center of the graph connects zero growth deviation on the right with the overall average July-September temperature on the left.

As summarized in Table 2, the average calculated lengths attained at age I by the 1949 through 1954 year-classes were: 98, 104, 98, 84, 95, and 103 mm respectively. The unweighted average standard length for these six year-classes was 97 mm and the percentage deviations of individual year-classes from this overall average were calculated to be: 1949 (+1), 1950 (+7), 1951 (+1), 1952 (-7), 1953 (-2), 1954 (+6). The average July through September temperatures were derived from the monthly temperature data in Table 6.

The lower graph of Figure 14 shows deviations from average second-year growth (from first to second annulus) of the 1948 through 1954 year-classes in relation to the average 1949 through 1955 July-September water temperature.

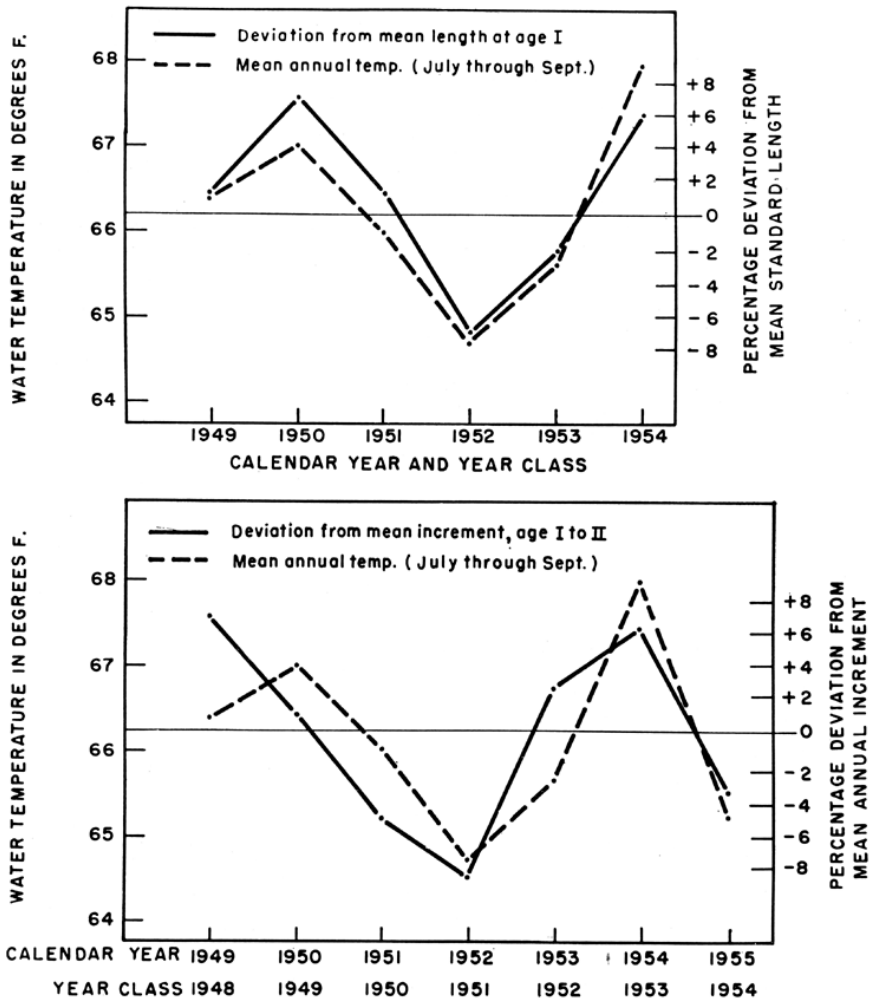

FIGURE 14. (Upper graph) First season's growth of California corbinas in relation to surface water temperatures (July through September). Percentage deviations from mean standard length attained at age I by the incoming year-classes from 1949 through 1954 are plotted against the average annual three-month temperature. (Lower graph) Percentage deviations from average second-year growth in relation to average May-September water temperatures.

FIGURE 14. (Upper graph) First season's growth of California corbinas in relation to surface water temperatures (July through September). Percentage deviations from mean standard length attained at age I by the incoming year-classes from 1949 through 1954 are plotted against the average annual three-month temperature. (Lower graph) Percentage deviations from average second-year growth in relation to average May-September water temperatures

The data of Table 2 indicated that second-year increments of the 1948 through 1954 year-classes during the growth years of 1949 through 1955 were: 122, 115, 108, 104, 117, 121, and 110 mm respectively. The unweighted average second-year's growth of the seven combined year-classes was 114 mm and the resultant percentage deviations of the 1948 through 1954 year-classes were: 1948 (+7), 1949 (+1), 1950 (-5), 1951 (-9), 1952 (+3), 1953 (+6), and 1954 (-3).

On the basis of these analyses, it appears that variations in total annual corbina growth during their first and second years, are correlated to a remarkable degree with variations in environmental temperatures during the warmest summer months.

Insofar as growth during the first year of life is concerned, Figure 14 indicates that, with the exception of 1951 when both temperature and growth were very close to the six-year average, all years that were characterized by higher (or lower) than average temperatures were correspondingly characterized by greater (or less) than average annual growth.

The positive relationship of second-year growth to July through September temperatures was similarly highly significant. Seven growth years are represented in the lower graph of Figure 14, and only one (the 1952 year-class in 1953), lacked a positive correlation between average summer temperatures and percentage deviation from mean annual growth. The slightly greater than average growth of the 1952 year-class in 1953 (in spite of lower than average summer temperatures) may be attributable to the very poor growth of the year-class in 1952, and therefore reflects a second-year growth compensation of the year-class as a whole.

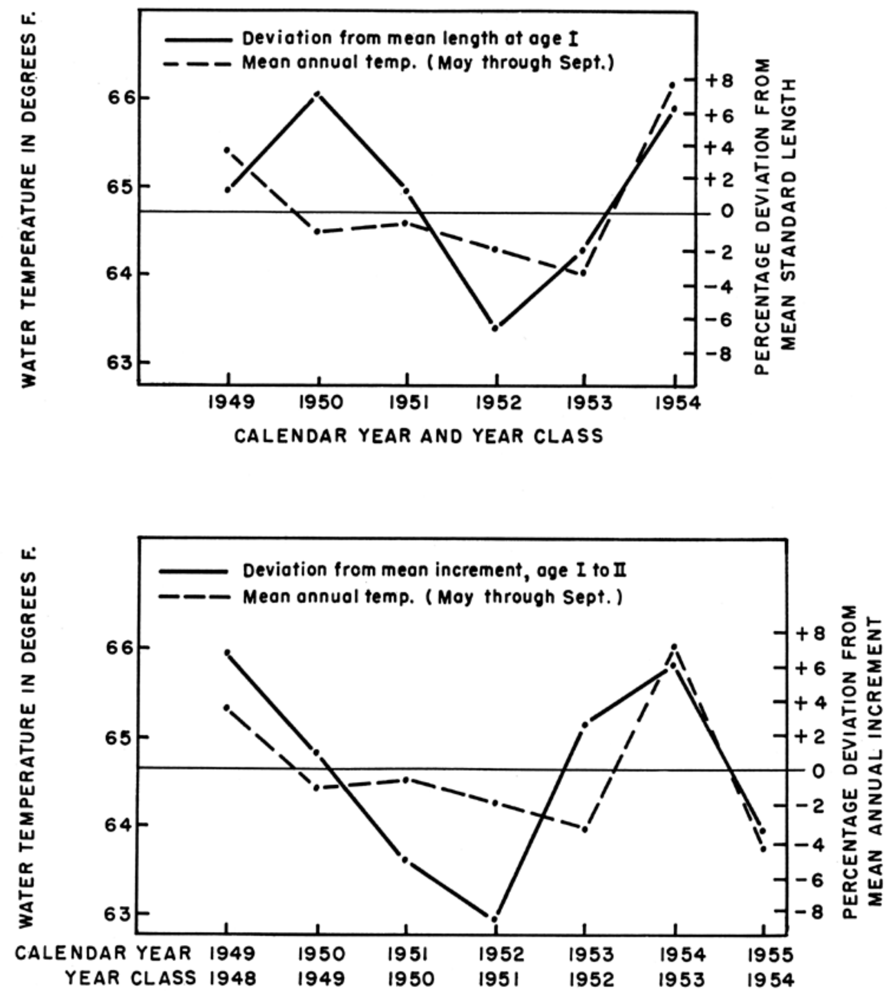

FIGURE 15. (Upper graph) Percentage deviation from average first-year growth of California corbinas in relation to July through September surface water temperatures. (Lower graph) Deviation from average second-year growth in relation to May-September water temperatures.

FIGURE 15. (Upper graph) Percentage deviation from average first-year growth of California corbinas in relation to July through September surface water temperatures. (Lower graph) Deviation from average second-year growth in relation to May-September water temperatures

The relationship of first- and second-year corbina growth to May through September water temperatures is shown in Figure 15. Although total annual growth was still relatively well-correlated with average water temperatures, the closeness of fit is somewhat less obvious than was the case with the shorter, warmer period of July through September (Figure 14). Thus, while total annual growth is directly related to overall summer temperatures, the correlation is most striking with the shorter period of maximum temperatures.

The close relationship between corbina growth and maximum summer temperatures probably is a reflection of environmental conditions in the habitat typically occupied by the species. Certainly the very shallow water, shoreward of the breaker zone, is most susceptible to the maximum effects of insolation and temperatures here may be considerably higher than offshore or in deeper coastal waters.

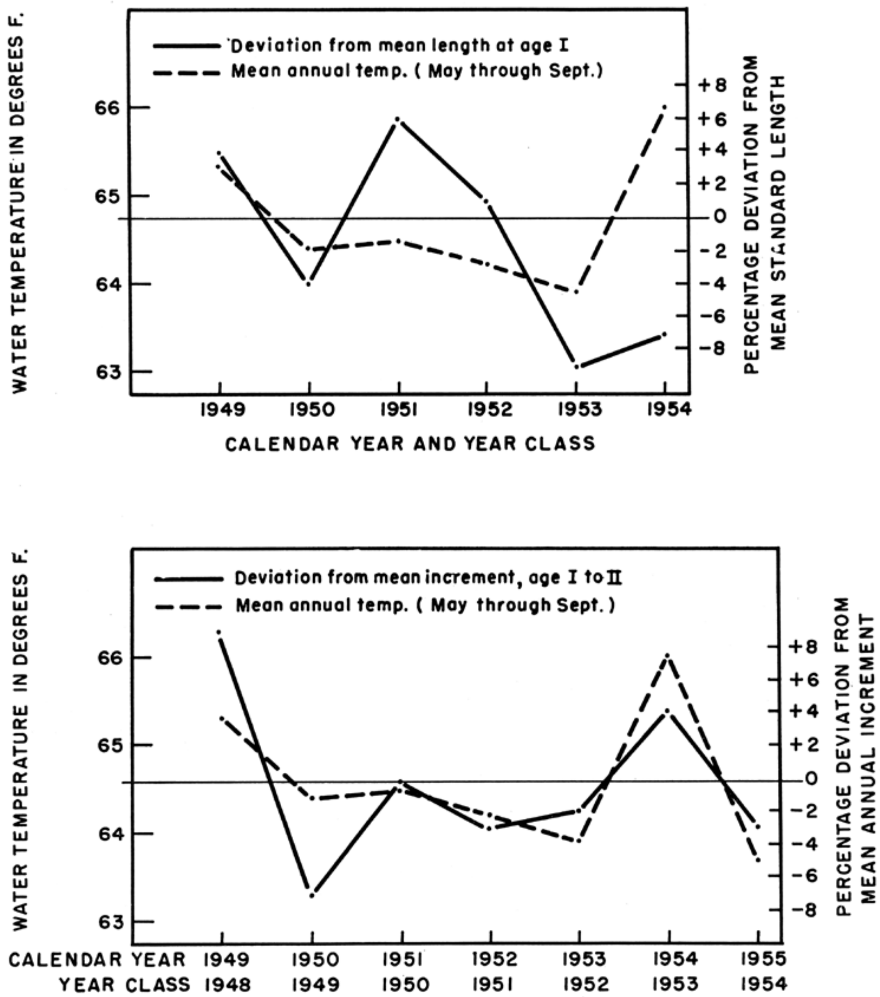

FIGURE 16. (Upper graph) First-year growth of spotfin croakers in relation to inshore water temperatures (May through September). (Lower graph) Deviations from average second-year growth in relation to average May through September water temperatures.

FIGURE 16. (Upper graph) First-year growth of spotfin croakers in relation to inshore water temperatures (May through September). (Lower graph) Deviations from average second-year growth in relation to average May through September water temperatures

The spotfin croaker data (Figures 16 and 17) were derived in the same manner described for California corbinas. Again, deviations from average first and second year's growth were plotted against average water temperatures during the two summer periods of May through September (Figure 16) and July through September (Figure 17).

Lengths attained by the 1949 through 1954 year-classes at the formation of their first annulus were (Table 1) : 101, 93, 103, 98, 86, and 90 mm respectively. The six-year unweighted average length of these year-classes was 97 mm so the percentage deviation of each from the six-year average was: 1949 (+4), 1950 (-4), 1951 (+6), 1952 (+1), 1953 (-9), and 1954 (-7). The unweighted average of second year growth increment was 100 mm and the percentage deviations of the 1948 through 1954 year-classes were: 1948 (+9), 1949 (-7), 1950 (0), 1951 (-3), 1952 (-2), 1953 (+4), and 1954 (-3).

From the configuration of values representing deviations from the average of attained lengths at the end of the first year of life (upper graphs in Figures 16 and 17), the spotfin croaker's first-year's growth is not as closely related to inshore water temperatures as was the California corbina's.

In contrast to the California corbina, there is a relatively poor relationship (upper graph of Figure 17) where the spotfin croaker's first year's growth is plotted against average water temperatures during July through September.

The relationship appears to be better during the longer summer period of May through September. Although the positive relationship of growth and May through September temperatures coincide only in 50 percent of the years (upper graph of Figure 16), the direction of change in growth from year to year is in all cases identical with the direction of change in average surface water temperatures. When the relationship of second-year spotfin croaker growth to average May through September temperatures was plotted (lower graph of Figure 16), the direction and magnitude of change was very closely correlated over the seven-year period.

The relationship of second-year's growth to July through September temperatures (Figure 17, lower graph) was very nearly the same as that shown for the May through September average temperatures (Figure 16, lower graph). The only obvious aberrancy is the relationship between temperature and growth of the 1949 year-class during 1950.

There are surely inherent dangers in attempting to correlate a biological phenomenon as complex as growth with a single environmental factor. Nevertheless, on the basis of my data I feel that the single environmental factor of temperature (along with a train of secondary effects) is of major, and perhaps primary, significance in regulating California corbina and spotfin croaker growth. The direct relationship of monthly growth increments to monthly temperature levels, the earlier onset of spring growth during years of warmer spring temperatures, and the direct relationship of total annual growth to summer temperature levels lend substance to this conviction.

Other factors, both biological or physical, admittedly could and unquestionably do, have an effect on growth. However, from my data, it may be concluded that, if factors other than temperature are of primary importance in controlling growth rates, their action must necessarily

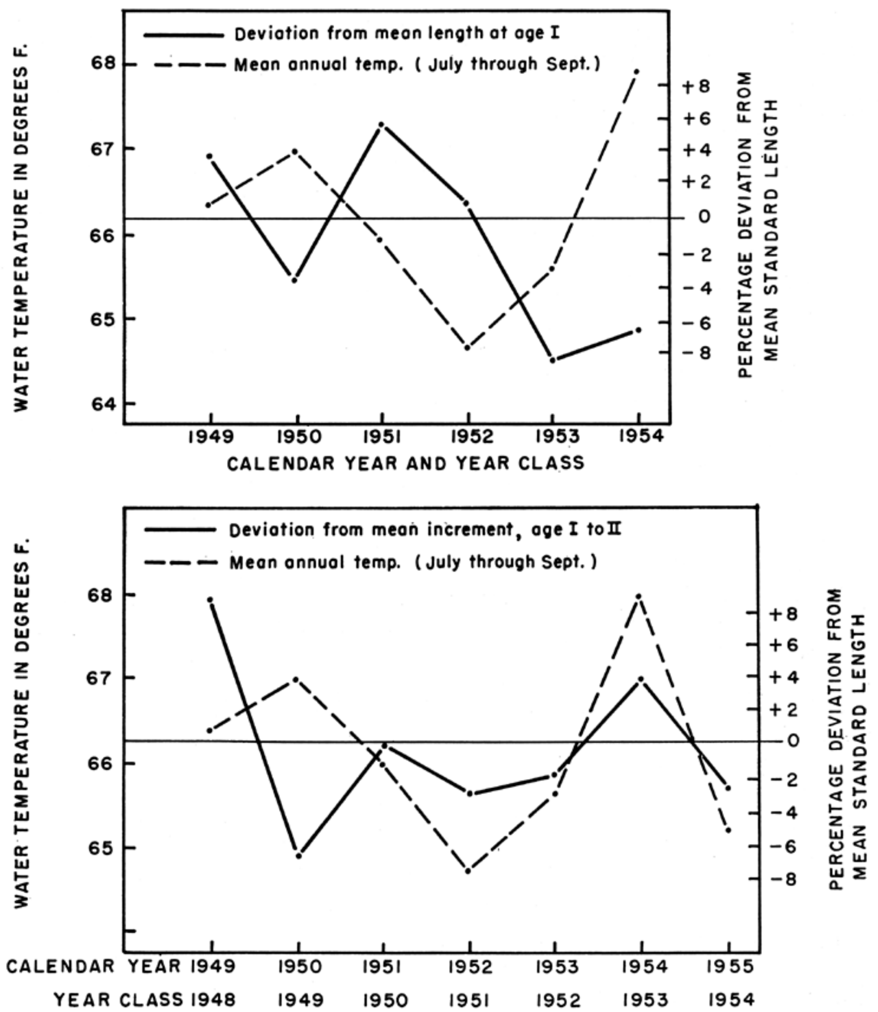

FIGURE 17. (Upper graph) First-year growth of spotfin croakers in relation to inshore water temperatures (July through September). (Lower graph) Deviations from average second-year growth in relation to average July through September water temperatures.

FIGURE 17. (Upper graph) First-year growth of spotfin croakers in relation to inshore water temperatures (July through September). (Lower graph) Deviations from average second-year growth in relation to average July through September water temperatures

have paralleled both the annual rise and fall in temperature and also have been directly correlated with differences in average annual summer temperatures.

9. FOOD HABITS

California corbina and spotfin croaker food habits were investigated in some detail in an effort to expand the fragmentary information currently available and to define more completely the relationships between these species and other forms in the inshore environment. In particular, an effort was made to correlate changes in food habits with growth and to inquire into the possibility of "key" food organisms at various life stages—the absence of which might limit the distribution or abundance of the fish species.

Except in the Salton Sea (Walker, 1961) and some details on black croaker food (Limbaugh, 1961), essentially no studies have been made to date on the food habits of Pacific Coast sciaenids, but numerous investigators have studied the food habits of the more important Atlantic Coast sciaenids. Welsh and Breder (1923) and Hildebrand and Schroeder (1928) analyzed qualitatively and quantitatively the food consumed by members of the family on the Atlantic Coast. Pearson's (1928) investigation of the food habits of six of the commercially important sciaenids of the Texas Coast have been considerably expanded by subsequent workers. Reid (1955a, 1955b) and Reid, Inglis, and Hoese (1956), studied the biology and ecology of East Bay, Texas; Breuer (1957) conducted ecological studies of Baffin and Alazan bays; and Gunter (1945) made a general survey of Texas marine fishes. Guest and Gunter (1958) have summarized results of Cynoscion nebulosus food studies in the Gulf of Mexico. In addition to the studies on marine forms, the food and feeding relationships of the freshwater drum, in Lake Erie have been investigated by Daiber (1952).

These studies have revealed that sciaenid feeding habits and food are logically correlated with the physical characteristics of the fish, the habitat occupied, and the available food. The more generalized, large-mouthed, active, midwater forms such as Cynoscion and Larimus feed primarily on fish or free-swimming invertebrates. At the other extreme in both body form and food are Micropogon, Menticirrhus, and Pogonias; these are true bottom dwellers possessing typically flattened profiles, mandibular barbels, and rather small inferior mouths. As might be expected, they feed primarily on sedentary crustaceans as well as a variety of worms and mollusks. Intermediate in anatomy, habitat, and feeding habits, are such genera as Bairdiella, Sciaenops, and Stellifer, which consume a mixture of sedentary bottom forms, active invertebrates and fish.

9.1. Southern California Sciaenids

The southern California sciaenids, while not represented by the number of species found on the Atlantic and Gulf Coasts, show a rather similar grouping of general types from the standpoints of body form, habitat, and in all probability, food.

In southern California the most generalized sciaenids are the white seabass and the queenfish. White seabass occupy essentially the same position in the food chain on our coast as do the various species of Cynoscion on the Atlantic and Gulf Coasts. Adult white seabass are primarily piscivorous, feeding on such forms as northern anchovies, sardines, Sardinops caerulea; atherinids, Atherinops affinis, and Atherinopsis californiensis; and the common squid, Loligo opalescens.

A preliminary analysis of food consumed by juvenile white seabass (Table 8) revealed that active pursuit of particulate items is established at an early age.

Queenfish, the other generalized sciaenid of southern California, seldom reach sufficient size to actively pursue even moderate-sized forage fish. Nevertheless they are primarily particulate feeders on small fish and swimming invertebrates. They are well-equipped for this mode of feeding, having large terminal mouths and numerous, very small, sharp teeth in both jaws. Juveniles up to 75 mm standard

TABLE 8

Stomach Contents of 42 Juvenile White Seabass Taken in the Long Beach-Belmont Shore Area of Los Angeles Harbor

Date	2 July 1951		28 Aug. 1951		11 Aug. 1953		Totals	
Standard Length mm	35-76		37-92		38-92			
Number of Fish	18		10		14		42	
FOOD ITEMS	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.
Mysids	89	46	100	97	100	99	95	86
Amphipods	--	--	--	--	7	1	2	<1
Crab zoea	6	1	--	--	--	--	2	<1
Pycnogonids	11	1	--	--	--	--	5	<1
Juv. queenfish	28	39	--	--	--	--	12	10
Juv. gobies	11	3	30	3	--	--	12	1
Unid.-Misc.	50	10	--	--	--	--	21	2
		100		100		100		99

TABLE 8

Stomach Contents of 42 Juvenile White Seabass Taken in the Long Beach-Belmont Shore Area of Los Angeles Harbor

length are commonly found in the Long Beach area with their stomachs completely filled with mysids, juvenile gobies, anchovies, and even smaller queenfish.

White croakers and yellowfin croakers are apparently non-discriminating feeders, eating small fish of various species as well as invertebrates of many types with the exception of heavy-shelled mollusks. These two species might appropriately be considered intermediate in food habits between the very active piscivorous Cynoscion and the true bottom feeders, the corbina and the spotfin croaker.

Black croakers spend much of their adult lives in dark, rocky caves and caverns and feed exclusively on crustaceans. Limbaugh (1961) says they are nocturnal in their feeding and eat mostly lumpy crabs, Paraxanthias taylori, young moss-covered crabs, Loxorhynchus crispatus, red-and-white shrimp, Hippolysmata californica, and amphipods.

9.1.1. California Corbina

Skogsberg (1939) briefly described the food of adult California corbinas as, "mostly sand crabs, Emerita analoga, and other crustaceans; but other invertebrates are probably also used." With the exception of this brief description, essentially nothing has been published regarding their food habits.

Welsh and Breder (1923) reported young of the Atlantic species, Menticirrhus americanus and M. saxatilis, feed primarily on mysids, amphipods, and other small crustaceans. Older fish were reported to subsist mainly on shrimp, other crustaceans, and polychaete worms.

Stomach contents were analyzed from 488 California corbinas taken at three of the six beach-seining stations occupied by the surf-fish investigation of the California Department of Fish and Game. The stations and the numbers of fish containing food were: Belmont Shore-Long Beach (410), Emerald Bay-Laguna Beach (52) and Redondo

Beach (26). The stomachs of 31 additional individuals were completely empty.

Stomach contents were placed on a watch glass and food items were separated grossly under a binocular microscope, counted where practicable, and measured volumetrically by the water displacement method. Volumes of less than 0.01 cc were recorded as a trace. Only the stomach contents were used in the analyses, since other portions of the digestive tract contained nothing significantly different.

For the purposes of analyses, the fish were divided into five size groups: 26–50, 51–100, 101–150, 151–200, and over 200 mm. These groups, although arbitrary, coincided rather closely with apparent transition points of feeding behavior.

Juvenile corbinas, up to 50 mm long, subsist almost entirely on amphipods and mysids (Table 9), in which respect they resemble M. americanus and M. saxatilis of the Atlantic Coast. The larger individuals of this size group tend to feed on clam siphon tips but not exclusively.

Corbinas 51 to 100 mm long, taken in the Long Beach area, had markedly different food habits. They ate mysids in moderate amounts, but bean clam, Donax gouldi, siphon tips were the dominant item in the diet (Table 9). These neatly clipped siphon tips were observed in 75 percent of the stomachs, and individual fish often had eaten many hundreds. The impression one gets examining these stomachs is that the fish literally had been "grazing" over extensive beds of clams.

Among individuals 101 to 150 mm long, clam siphon tips continued to be important in the diet, occurring in 52 percent of the stomachs and constituting 22 percent of the total food volume. However, small sand crabs, occurred in nearly half the fish of this size and by volume (59 percent) constituted the major item consumed. Also in this size group, clam parts other than siphons appeared in small quantities, indicating a capacity on the part of the fish to crush and manipulate at least the more delicate clam shells.

TABLE 9

Stomach Contents of 488 California Corbinas From Southern California Surf-Zone

Standard Length mm	26-50		51-100		101-150		151-200		201 and larger	
No. of Fish	32		126		114		78		129	
FOOD ITEMS	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.
Amphipods	75	24	21	1	18	<1	5	<1	3	<1
Mysids	66	52	58	13	43	2	10	<1	--	--
Clam siphons	13	18	75	76	52	22	26	12	10	2
Sand crab	--	--	6	2	43	59	45	45	74	83
Polychaetes	--	--	5	6	17	8	30	13	23	5
Clams[1]	--	--	4	<1	9	4	33	27	16	4
Grunion eggs	25	5	2	<1	--	--	--	--	--	--
Fish	--	--	1	<1	--	--	--	--	4	3
Unid. & Misc.	--	1	--	2	--	5	--	3	--	3
TOTALS		100		100		100		100		100

TABLE 9

Stomach Contents of 488 California Corbinas From Southern California Surf-Zone

Sand crabs are by far the dominant food item consumed by corbinas longer than 150 mm and, in fish larger than 200 mm, these crustaceans were in 74 percent of the stomachs examined and constituted 83 percent of the total food volume. Emerita analoga was the overwhelmingly dominant sand crab eaten but a few of the less common Lepidopa myops and Blepharapoda occidentalis were recorded.

Clam parts other than siphons were observed in 33 percent of the fish 151 to 200 mm long and contributed 27 percent to their total food volume. Clipped siphon tips were present in 26 percent of the stomachs in this size group, but contributed only 12 percent of the total volume. At this size, most of the siphons consumed were from larger clam species, although the small bean clam siphons were still evident.

Bony fish made their only significant contribution in corbinas larger than 200 mm. Two speckled sand dabs, Citharichthys stigmaeus, and one queenfish were found in a 360-mm corbina from Belmont Shore; one barred surfperch, Amphistichus argenteus, was in a 457-mm fish from Redondo Beach; and there were two barred surfperch, one each from corbinas 362 and 499 mm long taken at Emerald Bay.

While the progression of food preference among corbinas in the Long Beach area was from mysids and amphipods --> to clam siphons --> to sand crabs, in other areas, there may be considerable modification in the relative proportions of these typical foods. Very few corbinas smaller than 150 mm were taken at either the Redondo Beach or the Emerald Bay sampling stations and consequently their stomach contents had little effect on the totals in Table 9. However, in these more typically open-coast areas, clam siphons did not necessarily form a significant portion of the diet. of 16 corbinas smaller than 150 mm taken at Redondo Beach, only six had utilized this food and clam siphons or other soft clam parts constituted less than 10 percent of the total food volume.

Young fish at both Redondo Beach and Emerald Bay consumed a rather heterogeneous mixture of amphipods, mysids and shrimp until they were capable of ingesting small sand crabs. Fish larger than 150 mm, at both these open-coast stations evidently preferred sand crabs, since sand crabs constituted 95 to 100 percent of the food consumed.

Although the California corbina is primarily a surf-dwelling form, it does occur in bays and lagoons and, as would be expected, the diet in these quiet-water habitats is modified accordingly. The stomachs of 10 adult corbinas taken in Alamitos Bay (not included in Table 9) revealed that 90 percent of these fish had been feeding almost exclusively on large clam siphons; the siphons of mud piddocks, Barnea subtruncata, and gapers, Tresus nuttalli, contributing 87 percent of the total volume. Unidentified clam feet added another 9 percent, and the remainder consisted of several unidentifiable polychaetes, shrimp, and small crabs.

While not significant volumetrically, grunion eggs were of interest. During the spring and early summer, these eggs were commonly found in the stomachs and intestines of young corbinas and spotfin croakers. Most commonly, the eggs were advanced in their embryological development, indicating they had either been somewhat prematurely dislodged from the sand by wave action or were ingested by the fish during the two- or three-minute period, described by Walker (1952), following normal dislodgment and preceding hatching. None of these eggs showed any indication of digestive deterioration in the stomach or intestine of the fish. Although consumed frequently, grunion eggs apparently contribute little or nothing to either the corbina's or spotfin croaker's nutrition.

Polychaete worms were observed with moderate frequency in the diets of all sizes of corbina above the very smallest. These organisms may be significant in their diets when plentiful in environments otherwise favorable to corbinas or when the apparently more favored sand crabs and clams are absent.

In general, corbinas appeared to be strikingly clean and discriminating in their feeding habits. Their discriminatory ability appears to be aided by a mandibular barbel which presumably acts as a chemoreceptor. According to aquarium observations by C. L. Hubbs (personal communication), corbinas often can be observed cruising along the bottom of a tank with their mandibular barbel barely skimming the surface of the sand.

Nearly all food items in their stomachs were relatively intact and virtually no foreign matter such as sand, mud, debris, or shells was observed. When sand crabs or other soft-shelled crustaceans were present they generally showed little sign of having been crushed by either the jaws or the pharyngeal teeth. When an individual had been feeding on clams, only the siphon, foot or other soft parts were evident—never the shells. Either the soft parts were "picked" from the shells, or the shells were crushed by the jaws and pharyngeal teeth and rejected.

In view of the careful, discriminating manner in which corbinas select and ingest their food, it is not difficult to realize why they are considered by surf fishermen to be the most wary and difficult to hook of all the California surf-fish.

9.1.2. Spotfin Croaker

Spotfin croakers, like California corbinas, feed almost exclusively on or near the bottom throughout their juvenile and adult life. During young stages—until they are 150 mm long—the food of both species in the Long Beach area is essentially the same, consisting primarily of amphipods, mysids, and the siphon tips of small clams (most commonly Donax). However, at larger sizes corbina and spotfin croaker food habits definitely diverge.

In contrast to adult corbinas, whose major source of food is the sand crab, adult spotfin croakers in the Long Beach area fed primarily on clam siphons, entire crushed clams, and polychaete worms. often the alimentary canal, from pharynx to vent, was literally stuffed with a mixture of clams, crushed shells, polychaete setae, sand and mud.

Seven identifiable kinds of food were found in the stomachs of 173 spotfin croakers 30 to 499 mm long [(Table 10)]. These fish were all taken in the Belmont Shore area of Long Beach and, while it is a favored location of the species, it is by no means the only location in the Los Angeles area inhabited by spotfins. The food items (Table 10) should therefore be indicative of their mode of feeding, but the relative proportions of them would vary considerably depending on the habitat and locality occupied by the fish. For example, 25 adult spotfins

TABLE 10

Stomach Contents of 173 Spotfin Croakers Taken in the Surf-Zone of the Long Beach-Belmont Shore Area

Standard Length mm	30-50		51-100		101-150		151-200		201 and larger	
No. of Fish	34		27		16		31		65	
FOOD ITEMS	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.	Pct. Occur.	Pct. Vol.
Amphipods	15	10	--	--	19	2	23	3	46	3
Mysids	91	78	70	34	19	3	6	2	32	2
Isopods	3	2	--	--	6	1	25	3	26	2
Clam siphons	12	8	37	30	63	83	48	57	35	31
Clams—crushed	--	--	--	--	13	5	23	13	57	38
Polychaetes	3	2	30	11	13	4	13	1	42	12
Grunion eggs	--	--	7	13	--	--	13	15	3	8
Unid. & Misc.	--	--	--	12	--	2	--	6	--	4
TOTALS		100		100		100		100		100

TABLE 10

Stomach Contents of 173 Spotfin Croakers Taken in the Surf-Zone of the Long Beach-Belmont Shore Area

taken April 1, 1953, in the proximity of the Terminal Island sewer outfall and the fish cannery waste discharges, had gorged themselves on various pollution-tolerant polychaetes as well as on the assorted organic debris issuing from the waste discharge.

Thirteen large adult croakers taken incidentally by a purse seiner on July 27, 1953 in 50 feet of water off San Onofre, California, had a wide assortment of food organisms in their stomachs (number of occurrences in parentheses following each item):

Amphipods (12), polychaete worms (12), serpent star fragments (6), clams (6), clam siphons (2), nemertean worms (2), brachiopods (3), crabs (3), shrimp (2), scaphopods (2), sand star, *Astropecten*, (1), scallop (1).

In summary, spotfin croakers feed exclusively on or near the bottom throughout their juvenile and adult life. Young up to 50 mm long exhibit considerable agility at selecting and capturing food, eating primarily mysids and amphipods. Fish 50 to 100 mm long also feed on these small motile crustaceans, but begin to show a marked preference for sedentary bottom forms. Spotfin croakers longer than 100 mm feed predominantly on whole clams, clam siphons, and polychaete worms in the surf-zone. Adult fish in deeper waters or in bays appear to consume a variety of appropriately-sized invertebrates. Their selection of invertebrate food apparently depends upon its relative abundance and availability.

Several qualitative differences between California corbina and spotfin croaker food habits are apparent. These almost certainly reflect their rather extensive morphological differences in feeding apparatus, and also morphologically induced differences in habitat preference. Large quantities of crushed, heavy clam shells in the stomachs of spotfin croakers, for example, reflect their ability to take advantage of this abundant food supply by virtue of their heavy, crushing pharyngeal teeth. The corbina's relatively delicate pharyngeal teeth, on the other hand, are poorly suited for crushing heavy molluscan shells. As a result, although corbinas commonly utilize mollusks, they are limited to the siphons, foot, or other soft parts that either extend from the shell or can be "picked" from it.

As an example of probable habitat differences between the two species, no spotfin croaker examined in the study had eaten sand crabs even though corbinas, often taken in the same seine haul, may have been feeding exclusively on them. Since spotfin croakers are relatively non-discriminating feeders, they should be capable and not averse to feeding on sand crabs if available. Surf fishermen commonly take both spotfins and corbinas on sand crab bait.

Presumably this distinction in inshore feeding habits reflects a difference in their spatial distribution within the surf-zone: corbinas forage in the very shallow areas of active backwash occupied by sand crabs, and spotfins remain in somewhat deeper water beyond the innermost line of breakers. The ability of a corbina to maintain its equilibrium in this often violent environment is undoubtedly abetted by its flattened ventral surface, its large ventrally-placed pectoral fins and its lack of an air bladder.

Further distinction between food habits and habitat preferences of the two species, as they relate to morphological differences, is evident. For example, a corbina will avoid those organically enriched areas of the Los Angeles-Long Beach Harbor which support heavy populations of polychaete worms (Reish, 1955). Although polychaetes are commonly consumed by corbinas, and in some areas are a desirable food item, corbinas seldom, if ever, have been observed taking advantage of the vast assemblages of potential food surrounding sewage outfalls. Bait boats, hauling for anchovies in the proximity of domestic sewage and fish cannery outfalls, regularly take spotfin croakers, white croakers, yellowfin croakers and queenfish—but practically never corbinas. Experimental trawl work conducted by the Department of Fish and Game throughout most areas of the Los Angeles-Long Beach Harbor in 1957 and 1958 failed to turn up any corbinas in areas receiving heavy loads of organic wastes which often support numerous pollution-tolerant invertebrates and fish.

In general, fishes most commonly found on the bottoms of such areas are skates, rays and flatfishes—adapted to the "ooze" by both body shape and their ability to respire through dorsally-placed spiracles or opercles. More normally-shaped species presumably are successful in such environment by virtue of an air bladder, which enables the fish to remain indefinitely suspended off the bottom.

Corbinas, lacking air bladders and normally spending much of their time in close contact with the bottom, cannot or will not tolerate bottoms of very fine, easily-disturbed sediments. It is not difficult to visualize the respiration problems that would confront a resting corbina in such an environment.

10. SUMMARY

1. The primary purpose of this study was to determine typical growth rates and other growth characteristics for California corbinas and spotfin croakers by studying scales from fish taken in the vicinity of the

Los Angeles-Long Beach Harbor. Prior to this, essentially no life-history work had been conducted on any native California sciaenid.

2. Scales from 1,724 California corbinas and 1,553 spotfin croakers showing one or more annuli were examined and measured. The fish were collected during the years of 1950 through 1956.

3. All growth calculations are based on samples in which data from both sexes were combined. There were no significant differences between the growth of male and female spotfin croakers over the ages sampled in the study. Beyond the age of three, female corbinas appear to grow more rapidly than males. However, my analyses of monthly growth, total annual growth, and the relationship of growth to temperature were based on fish showing three or fewer annuli. Therefore, possible differences between the sexes probably had no effect upon the growth conclusions reached in these sections.

4. Criteria used to define annuli on the scales of both species were essentially the same as those employed by other workers using ctenoid scales. In both species each true annulus can be traced completely around the scale; it consists of one or more straightened circuli across the anterior field, broken or coalesced circuli around the central lateral fields, and typically exhibits "crossing over" of circuli on the posterolateral fields. False annuli, only rarely seen prior to the third growth year, are seldom traceable completely around the scale and are so spaced that they produce unreasonable estimates of lengths at previous ages.

5. The validity of annuli as year marks was established by the facts that: (1) fish taken in fall and winter had no annulus on the periphery of the scales (the annulus appears in the spring when peripheral growth is resumed); (2) good correlation existed between the length of the fish and the number of annuli; (3) there was close agreement between back-calculated lengths and lengths empirically determined from fish of known age.

6. Two different methods were used to determine croaker and corbina lengths at previous ages. Because the body length-scale length relationship was not established for the spotfin, I used the direct proportion method of Van Oosten (1929). This method results in reasonably accurate calculated lengths. No clear-cut evidence of "Lee's phenomenon" is seen, and calculated lengths at previous ages do not differ significantly from lengths empirically determined on younger fish at the time of annulus formation.

7. The grand average calculated spotfin croaker standard lengths at ages I through X were 97, 197, 269, 312, 345, 367, 394, 422, 442, and 453 mm respectively.

8. The spotfin croaker weight-length relationship determined from 291 fish of both sexes, is described by the exponential equation $W = 0.000032095\, L^{2.94436}$. The straight-line logarithmic expression of the relationship is: $\text{Log } W = -4.49356 + 2.94436 \text{ Log } L$. Average weight estimates at each age from I through X were: 23, 183, 458, 708, 952, 1,142, 1,408, 1,724, 1,975 and 2,124 grams respectively.

9. Determining California corbina lengths at previous ages was facilitated by a detailed determination of the body length-scale length relationship covering the range of lengths used in the study.

10. The corbina body length-scale length relationship is best described by two separate, straight regression lines. The major line, based on the body—scale relationship of all fish showing one or more annuli, is: $Y = -17.921 + 2.629X$, where Y = standard length and X = scale radius. The second line, based on the body-scale relationship of fish 32 to 100 mm S.L., is described by $Y = 10.004 + 1.994X$ and graphically intersects the major line at a standard length of 97 mm. Corrections determined by the vertical distance separating the two lines, were added to those length values calculated from the major line which fell below 97 mm S.L.

11. The grand average calculated corbina standard lengths at ages I through VIII are: 97, 210, 278, 323, 366, 386, 410, and 421 mm respectively.

12. The corbina weight-length relationship, determined from 300 fish of both sexes, is described by the exponential equation $W = 0.0000011325\, L^{3.0677}$. The straight-line logarithmic expression of the relationship is: $\text{Log } W = -4.94597 + 3.06773 \text{ Log } L$. Average weight estimates at each age from I through VIII are: 14, 151, 356, 564, 828, 975, 1,175 and 1,273 grams respectively.

13. Monthly growth during 1955 was determined for yearling and two-year-old corbinas and for yearling spotfin croakers. These analyses showed that accumulated growth increments in both species, when plotted against time, assume a typical sigmoid curve with the steepest portion occurring from July through September—typically the warmest months of the year.

14. Throughout the 1955 growing season, monthly growth increments (expressed as percent of total annual expected growth) agreed extremely closely with the progression of monthly water temperatures during 1955 and with the progression of average monthly temperatures recorded from 1924 through 1955.

15. Annuli formed in both species in the spring following a winter growth cessation. Yearling and two-year-old fish typically had begun their spring growth by April and all fish had formed an annulus by the third week in May.

16. Variations in time of annulus formation were believed directly related to spring temperatures. During 1951, a warmer than average spring, yearling corbina growth reached an average of 4 mm prior to the second week in March. An identical amount of growth was not attained during 1954 (a colder than average spring) until approximately three weeks later.

17. Based on the knowledge that annuli probably form in both species between March 15 and April 1, the minimum water temperature at which growth will normally occur is between 57 and 58° F.

18. When the relationship between summer water temperatures and the total annual growth was studied for both species during their first and second growing seasons it was found that, in the corbina, total growth attained during both growth years could be directly correlated with the average water temperature occurring from July through September, and, to a lesser degree, with the lower temperature occurring

from May through September. Similar analyses for the spotfin croaker showed that first-year's growth was directly correlated with average summer temperatures from May through September, but only poorly related to temperatures from July through September. Second-year's growth was rather well correlated with average temperatures of both time periods.

19. Stomach contents of 488 corbina revealed that fish up to 50 mm long fed primarily on mysids and amphipods; at lengths of 50 to 100 mm the diet in the Long Beach area consisted primarily of bean clam siphon tips; fish longer than 100 mm fed predominantly on sand crabs. In clean, quiet-water bays where sand crabs do not occur, adult corbinas fed primarily on the siphon tips and other soft parts of clams as well as on polychaete worms. At all stages of their life-history, corbinas are apparently particulate, discriminating feeders. The species is seldom observed in areas which, although rich in suitable food organisms, receive significant quantities of organic pollutants and are characterized by soft, easily-disturbed sediments.

20. Stomach analyses performed on 173 spotfin croakers indicated that up to a length of 50 mm, their diet consisted of mysids and amphipods, as was the case with California corbinas. Fish 50 to 100 mm long also fed on small motile crustaceans but had begun to utilize more sedentary bottom forms. Spotfin croakers longer than 100 mm, when in the surfzone, fed predominantly on whole clams, clam siphons, and polychaete worms. Adult fish in deeper waters and bays had fed on a variety of appropriately-sized invertebrates. In contrast to the corbina, spotfin croakers are relatively indiscriminate in their food preferences and feeding habits. A spotfin croaker will apparently avoid the very shallow surfzone and therefore seldom feeds on the common and abundant sand crabs. Spotfins, however, are considerably more tolerant of organically enriched environments than are California corbinas, and commonly feed on the pollution-tolerant species that abound in the vicinity of sewer outfalls in the Los Angeles-Long Beach Harbors.

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