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A Management Study of The California Barracuda Sphyraena Argentea Girard

By
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FRONTISPIECE: A near limit of California barracuda caught from a sportfishing party boat in Santa Monica Bay. *Photo courtesy Bill Beebe.*

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ACKNOWLEDGMENTS

The culmination of field and laboratory studies of the California barracuda are contained in this report. All the work was performed as part of a Federal Aid to Fish Restoration project: California Dingell-Johnson F 16 R, Barracuda-White Seabass Management Study.

Literally hundreds of people contributed to the progress of this investigation. Each contribution, whether from biologists, sportfishermen, partyboat operators, commercial fishermen, or interested conservationists, made the path a bit smoother and brought the horizon closer. The contributions of several people or groups deserve special mention. The crews of the Department's research vessels, *Alaska* and *N. B. Scofield*, were very helpful with the work at sea. Jerry West and numerous other members of the Southern California Council of Conservation Clubs gave their time and energy, particularly with the tagging program. Norman Abramson and Harold Cogswell assisted with statistical and mathematical problems. Jack Hanson, Dave Miller, Emil Smith, and James Thomas assisted in the daily routine. The arduous task of editing the manuscript was done by John E. Fitch, while Phil M. Roedel and Parke H. Young reviewed it in general. Their suggestions, both large and small, contributed materially to continuity and polish. Mrs. Janey Gonzales and Mrs. Mary Dopp deciphered my penciled draft and notes to help formulate the first typed-draft, while Miss Donna Pedersen typed the final manuscript. To all I am most grateful and extend my sincere thanks.

I would like to dedicate this paper to the memory of Warden-Captain William G. Plett of the patrol boat *Marlin* for his contributions to the conservation of California's marine resources and particularly for his keen interest in the barracuda.

Leo Pinkas
January 1966

1. INTRODUCTION

The California barracuda, Sphyraena argentea, inhabits eastern Pacific coastal waters from Magdalena Bay, Baja California, to Prince William Sound, Alaska. It has played a significant role in the growth and development of California's fishing industries. Exploited primarily between Point Conception, California, and San Quintin, Baja California, these long, slender, silvery cylinders of animated protein figured prominently in the development of the purse seine, were the object of an International Fisheries Commission Study, and are one of the mainstays of southern California's sportfishing industry.

Influenced by the economic impetus of World War I, the commercial barracuda fishery grew concurrently with the rapid development of the purse seiner. Annual deliveries of 6 to 8 million pounds by the early 1920's, were largely due to purse seiners operating in southern California and Mexican waters, (Skogsberg, 1925). From 1928 to 1962 the commercial catch from California waters averaged 1.7 million pounds annually, ranging from over 4 million in 1928 to only 50 thousand pounds in 1956. In the same period, landings of barracuda from Mexican waters fluctuated around 1 million pounds with a high of 2.1 million in 1945 and a low of 42 thousand pounds in 1959 (Table 1). The catch of Mexican fish usually declines with increased abundance in local waters and increases as local stocks become less available (Figure 1).

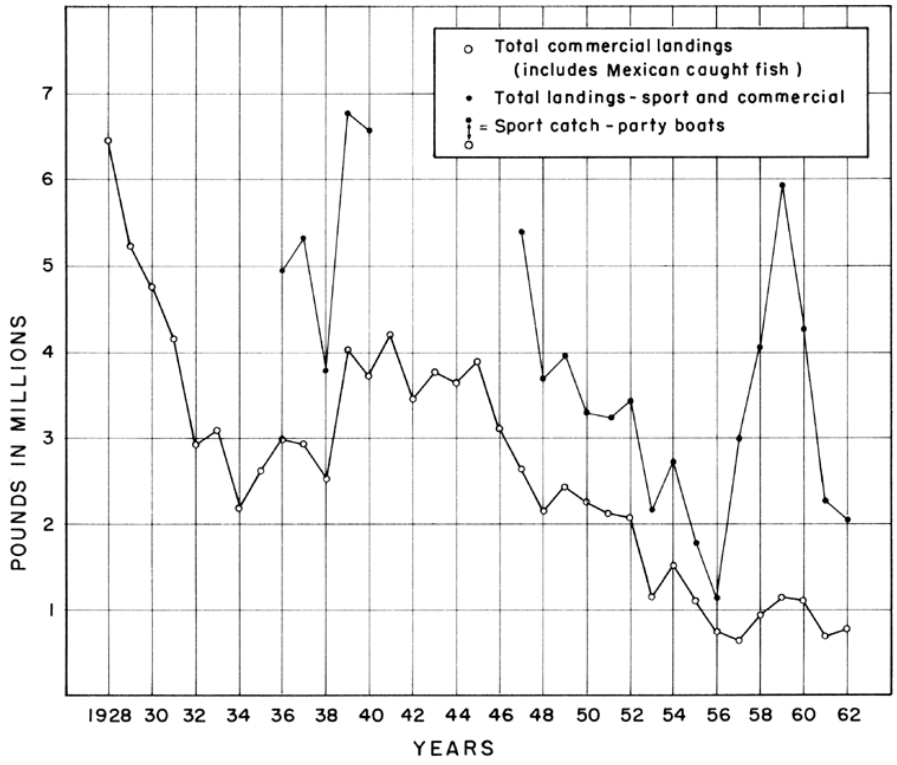

FIGURE 1. California landings of sport and commercially caught barracuda from California and Mexican waters.

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In California waters, commercial barracuda fishermen currently are limited by law to hook and line, and gill nets with a mesh size of 3 ½ inches or larger. May and June are usually the peak months of activity in areas close to market sources; i.e. San Pedro, San Diego, and Santa Barbara. Small trolling or jig boats tend to fish during daylight hours in the same general locations as the sport fleet. Gill netters operate at night, anchoring or drifting with their nets as conditions warrant.

The commercial barracuda fishery reacts negatively to such factors as its own abundance, the abundance of other species, and the numbers of fish taken by sportsmen in general. Consequently, commercial fishermen are compelled to accept a small to moderate price, which fluctuates from a low of 4 or 5 cents per pound (eviscerated, heads on) when

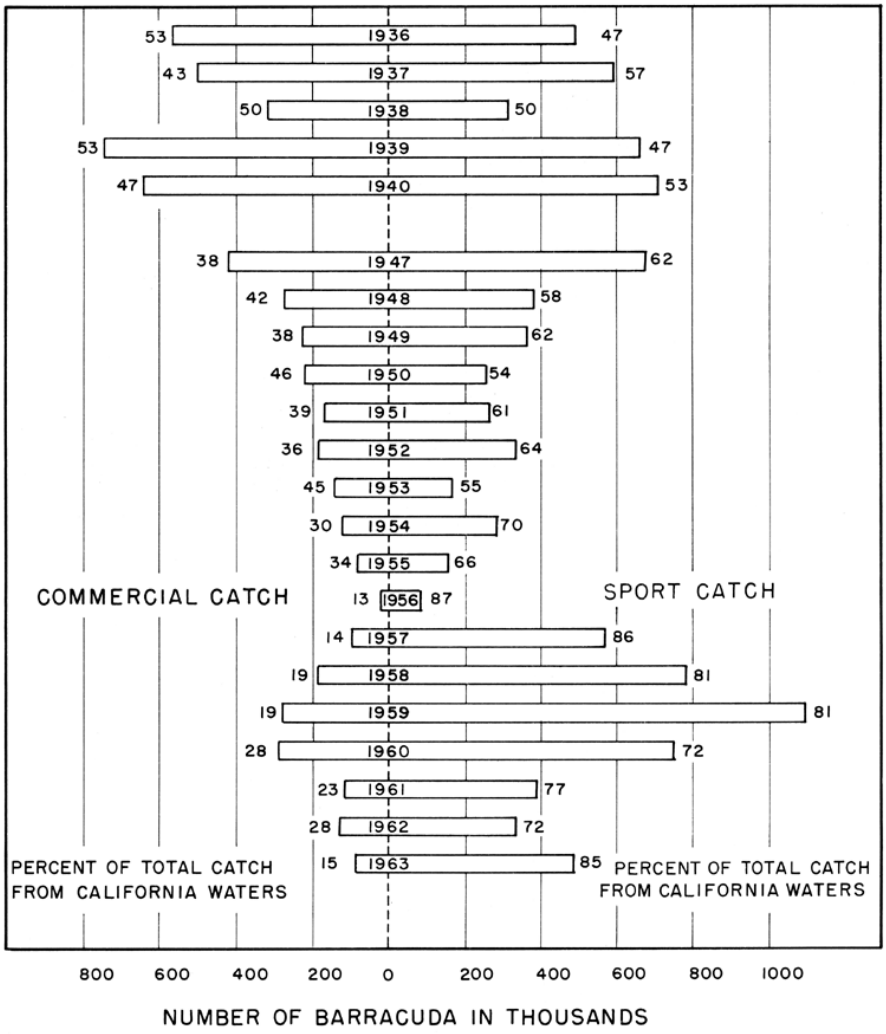

FIGURE 2. The sport and commercial barracuda catch from California waters (in numbers and percent of total).

FIGURE 2. The sport and commercial barracuda catch from California waters (in numbers and percent of total)

the fish are plentiful, to a high of 25 cents during periods of scarcity. Limited marketability, an unattractive price structure, and most significantly, increased competition from sport interests has gradually reduced commercial barracuda fishing to a minor position in the present commercial fisheries community.

Photographs and newspaper accounts of sportfishing activities in the mid-1920's and early 1930's frequently depict large catches of 'scooters'—attesting to their early popularity as a game fish. Unfortunately, during these formative years of the southern California sport fishery, records of total take were not maintained. Thus, any estimates of fishing effort or catch for this period would be subject to considerable error.

The first series of sportfishing catch records, gathered from the live-bait partyboats between 1936 and 1940, revealed two significant facts: (i) barracuda headed the list in numbers and pounds taken, and (ii) the sportsmen's take often equalled or exceeded commercial landings. As interest in marine sportfishing grew in the post World War II era, the sportsmen's portion of the total annual take increased to a level ranging between 70 and 86 percent (Figures 2 and 3).

Rod and reel sport fishermen aboard live-bait partyboats, skiffs, and yachts, pursue barracuda in the relatively shallow waters of the continental

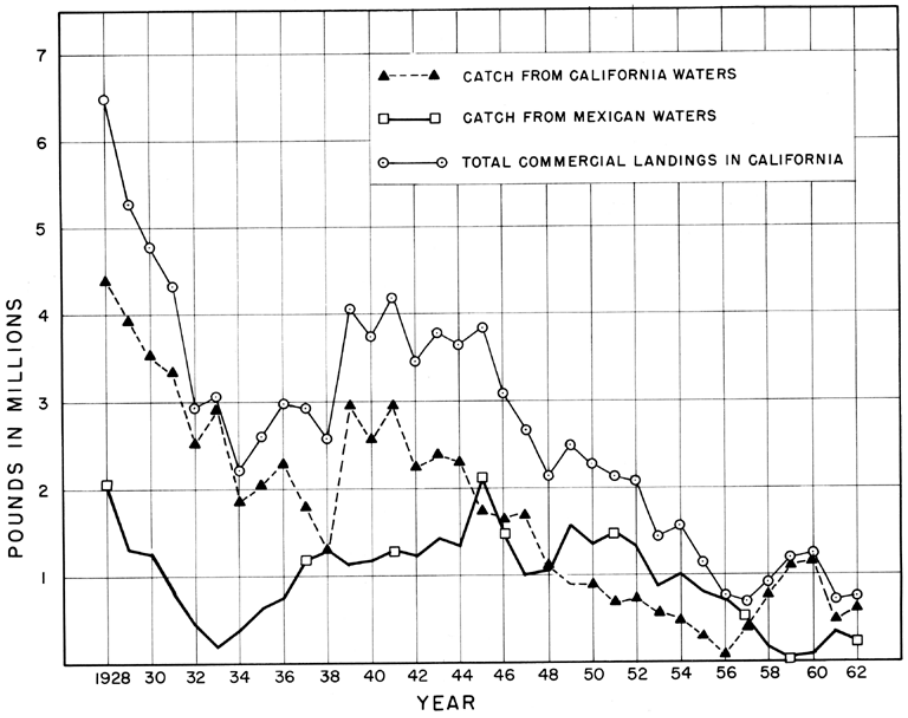

FIGURE 3. The commercial barracuda catch from California and Mexican waters.

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shelf. Occasionally pier and jetty fishermen enjoy flurries of activity as barracuda schools pass close to shore. Live anchovies and sardines are favorite baits, and are used to chum and hold schools close to a partyboat. Artificial lures of bone, metal, or plastic, in a variety of shapes and colors, are efficient and popular. Typical catch localities include the area off Point Loma, La Jolla Kelp near San Diego, Huntington Flats off Huntington Beach, Horseshoe Kelp in San Pedro Bay, Santa Monica Bay, Santa Barbara kelp area, and the offshore islands of Santa Catalina, San Clemente, and Anacapa. Most fishing occurs from May to September, at any depth from the surface down to 15 or 20 fathoms. Favorable temperatures, as measured at the surface, range between 17° and 21°C. (62° to 70°F.).

After a peak sport landing of 700,000 barracuda in 1947, there followed a 9-year period of declining catches, terminating with an all-time low of 88,000 in 1956. A marked warming of the ocean environment in 1957 set the stage for a phenomenal recovery, culminating in a record partyboat catch of 1.2 million fish in 1959. Although accurate figures are not available, additional thousands of barracuda probably were taken from private vessels during the latter period because small-boat fishing was soaring in popularity.

General concern for the barracuda resource and its economic future lead to the initiation of life history studies in 1926 by the International Fisheries Commission, United States-Mexico (U.S. Govt. Printing office, 1926). When the treaty was abrogated in 1927, the California Division of Fish and Game assumed the responsibility for continuing the research. The work was concluded with publication of Fish Bulletin 37 entitled *The California Barracuda* (Walford, 1932).

Walford (1932) studied only those facets of the barracuda's life history that were applicable to management. Thus, he concentrated on age, growth, and reproductive capacity or potential. Earlier, as well as later, biological work involved description and taxonomy (Girard, 1854; Walford, 1932; Barnhart, 1936; Clemens and Wilby, 1946; Clothier, 1950; and Roedel, 1953). Barnhart (1927) and Orton (1955) described the barracuda egg and its early developmental stages. Ecological observations centered primarily on range and catch localities (Craig, 1927; Van Cleve and Thompson, 1938; Roedel, 1953; and Limbaugh, 1955). Fitch (1958) summarized some of the pertinent life history factors.

Although it was not the objective of this study to investigate all aspects of the barracuda's life history, a synthesis of previous findings was deemed vital and proved helpful throughout our work.

Sphyraena argentea is the only barracuda (family Sphyraenidae) known to inhabit California's coastal waters. Three smaller species (S. lucasana, S. ensis, and S. idiastes) are found in the temperate and tropical waters of the eastern Pacific Ocean south of California.

California barracuda are normally found from Point Conception, California, to Punta Canoas, Baja California. During some years they have been caught as far north as central Alaska and south to Magdalena Bay, Baja California. They are a schooling fish, prefering the continental shelf, close to shore, including near-shore islands. Young barracuda will also enter coastal lagoons and bays, including man-made harbors.

All 3-year-old barracuda are sexually mature, but only 75 percent of the 2-year-old fish are capable of reproduction. The spawning season in California may encompass the months of April through September, but principal activity occurs in May, June, and July. Ovarian development indicates that several spawnings occur each season. The number of eggs released increases with age and size, ranging from an estimated 42,000 for a first spawning to over 484,000 for older fish.

The pelagic eggs, when first released, are 1.2 to 1.6 mm in diameter. In early embryonic stages, the egg is slightly lopsided. Recently-hatched prolarvae are about 2.5 mm long. In 4 days, the larva begins to assume the morphological characteristics of the adult, particularly the protruding lower jaw, and is capable of feeding.

The average 1-year-old barracuda is about 13.8 inches long and weighs one-third of a pound. A 28-inch barracuda weighs about 3 pounds, and is 4 to 5 years old. Annuli or growth rings on the scales of a large barracuda, 10 pounds in weight and 41 inches in total length, revealed it was 11 years old. Recent landings of fish measuring 44 and 46.5 inches in total length indicate a probable longer maximum life span. Unfortunately, these large fish were not examined by a biologist.

A voracious feeder, the barracuda consumes anchovies, sardines, and other pelagic fishes. Squid are readily taken when offered as bait, but have not been confirmed as a natural food. In turn, barracuda fall prey to giant sea bass (Stereolepis gigas) , seals, sealions, and porpoises. They are often heavily infested with several species of parasitic worms.

Barracuda respond readily to changes in the marine environment, the most obvious being temperature.

An assortment of efforts have been made to manage the barracuda resource. A minimum size limit of 18 inches, enacted in 1915, was changed to 3 pounds in 1918. Walford recommended a 30-inch minimum total length in 1932, but it was never adopted. The current 28-inch limitation, equivalent to 3 pounds, was imposed in 1949. The use of purse seines and other round-haul nets to take barracuda was prohibited from 1925 to 1927. Seining was again permitted between 1927 and 1940, except during the peak spawning months (May and June). The opening and closing dates frequently were juggled during this 12-year period. The presently-enforced total prohibition of seines was imposed in 1940; however, purse seine gear can be used in Mexico and the resulting catch can be delivered legally in California on declaration and inspection. Sportfishing regulations have included bag limits as well as size limitations; currently the bag limit is 10 fish per day, two of which may be under the minimum legal size of 28 inches total length.

Routine surveillance of marine sport and commercial fishing activities revealed, in the mid-1950's, that the total barracuda catch had been steadily declining since 1947. The extremely poor yields to all segments of the fishery during 1956 re-emphasized the need for investigating the current status of the resource and the fishery. of prime concern was the need to learn the cause of the decline. Closely associated questions were those relating to migratory behavior and environmental relationships of which we had little or no knowledge.

Other significant questions also needed answers: e.g. how did the shift from a commercial to a sport-oriented fishery affect the resource,

TABLE 1

Sport and Commercial Barracuda Landings

Year	Commercial						Sport		Total California		Grand totals	
	California		Mexico		Total		California		Sport and commercial		Sport and commercial	
	Pounds	Numbers[1]	Pounds	Numbers[1]	Pounds	Numbers	Pounds[1]	Numbers	Pounds	Numbers	Pounds	Numbers
1928	4,385,214	1,096,304	2,067,242	516,811	6,452,456	1,613,115						
1929	3,925,899	981,475	1,302,711	325,678	5,228,610	1,307,153						
1930	3,513,608	878,402	1,250,158	312,540	4,763,766	1,190,942						
1931	3,336,065	834,016	841,473	210,368	4,177,538	1,044,384						
1932	2,505,101	626,275	421,674	105,419	2,926,775	731,694						
1933	2,912,152	728,038	160,810	40,203	3,072,962	768,241						
1934	1,801,264	450,316	381,558	95,390	2,182,822	545,706						
1935	2,003,947	500,987	613,877	153,469	2,617,824	654,456						
1936	2,247,858	561,965	729,984	182,496	2,977,842	744,461	1,970,144	492,536	4,218,002	1,054,501	4,947,986	1,236,997
1937	1,799,045	449,761	1,139,445	284,861	2,938,490	734,622	2,393,816	598,454	4,192,861	1,048,215	5,332,306	1,333,076
1938	1,260,790	315,198	1,269,022	317,256	2,529,812	632,454	1,257,024	314,256	2,517,814	629,454	3,786,836	946,710
1939	2,969,250	743,313	1,122,804	280,701	4,092,054	1,023,014	2,653,992	663,498	5,623,242	1,406,811	6,746,046	1,686,512
1940	2,545,380	636,345	1,151,903	287,976	3,697,286	924,321	2,818,080	704,520	5,363,460	1,340,865	6,515,363	1,628,841
1941	2,971,349	742,837	1,230,579	307,645	4,201,928	1,050,482						
1942	2,243,163	560,791	1,211,374	302,844	3,454,537	863,635						
1943	2,382,824	595,706	1,392,504	348,126	3,775,328	943,832						
1944	2,317,299	579,325	1,330,878	332,720	3,648,177	912,045						
1945	1,744,560	436,140	2,110,697	527,674	3,855,257	963,814						
1946	1,636,135	409,034	1,470,380	367,595	3,106,515	776,629						
1947	1,695,867	423,967	969,878	242,470	2,665,745	666,437	2,709,796	677,449	4,405,663	1,101,416	5,375,541	1,343,886
1948	1,100,081	275,020	1,025,656	256,414	2,125,737	531,434	1,536,224	384,056	2,636,305	659,076	3,661,961	915,490
1949	903,574	225,894	1,570,327	392,582	2,473,901	618,476	1,465,692	366,423	2,369,266	592,317	3,939,593	984,899
1950	890,435	222,609	1,367,980	341,995	2,258,415	564,604	1,025,468	256,367	1,915,903	478,976	3,283,883	820,971
1951	669,823	167,456	1,465,120	366,280	2,134,943	533,736	1,078,180	269,545	1,748,003	437,001	3,213,123	803,281
1952	747,667	186,917	1,346,539	336,635	2,094,206	523,552	1,347,448	336,862	2,095,115	523,779	3,441,654	860,414
1953	565,942	141,486	877,756	219,439	1,443,698	360,925	682,200	170,550	1,248,142	312,036	2,125,898	531,475
1954	485,946	121,487	1,102,665	275,666	1,588,611	397,153	1,130,208	282,552	1,616,154	404,039	2,718,819	679,705
1955	322,831	80,708	818,128	204,532	1,140,959	285,240	619,848	154,962	942,679	235,670	1,760,807	440,201
1956	50,153	12,538	702,374	175,594	752,527	188,132	350,412	87,603	400,565	100,141	1,102,939	275,735
1957	387,043	96,760	296,070	74,018	683,113	170,778	2,308,736	577,184	2,695,779	673,944	2,991,849	747,962
1958	753,266	188,317	161,993	40,498	915,259	228,815	3,130,892	782,723	3,884,158	971,040	4,046,151	1,011,538
1959	1,110,409	277,602	42,192	10,548	1,152,601	288,150	4,782,340	1,195,585	5,892,749	1,473,187	5,934,941	1,483,735
1960	1,147,831	286,957	81,837	20,459	1,229,668	307,416	3,021,632	755,408	4,169,463	1,042,365	4,251,300	1,062,824
1961	478,362	119,591	231,017	57,754	709,379	177,345	1,567,536	391,884	2,045,898	511,475	2,276,915	569,229
1962	521,769	130,442	224,707	56,177	746,476	186,619	1,342,028	335,507	1,863,797	465,949	2,088,504	522,126
1963	347,776	86,944	30,938	7,735	378,714	94,697	1,934,796	483,699	2,282,572	570,643	2,313,510	578,378

[1] Computed value, conversion factor four pounds per fish.

TABLE 1
Sport and Commercial Barracuda Landings

and what was the effect of the various sportfishing bag and possession limits.

To answer these questions an active program was implemented in the spring of 1958 in the form of a Federal Aid to Fish Restoration project known as "Barracuda-White Seabass Management Study, Dingell-Johnson F 16 R, California." Specific project objectives and approaches were:

1) To analyse sport and commercial catch statistics to determine relative changes in abundance, location and seasons of past catches, success by gear types, and measures of catch-effort relationships.

2) To determine the length and age composition of the sport and commercial catch by sampling at wholesale fresh-fish markets and aboard the sportfishing partyboats. In conjunction with the sampling activities, to gather additional information on current fishing practices, areas of catch, and effort expended.

3) To initiate a tagging program to elucidate migratory behavior, provide data for an independent estimate of population size, and estimate rates of exploitation by various segments of the fishery.

4) To study the dynamics of the barracuda population, primarily from data gathered by the project, to provide background knowledge for management considerations.

2. LENGTH FREQUENCIES AND AGE COMPOSITION

The catches of the sport and commercial barracuda fisheries were sampled for length and age composition to determine the effect of the minimum size law and to obtain estimates of the relative strength of the contributing year-classes.

The commercial catch was sampled primarily at the Los Angeles Harbor wholesale fresh-fish markets since it was the major port of landing; deliveries there were fairly consistent throughout the season, and although limited manpower made sampling at ports with sporadic landings inefficient, occasional samples were obtained at other ports as opportunities arose.

Sport catches were sampled aboard partyboats as the fish were cleaned during their return to port. Our field men moved frequently from port to port to obtain samples from as many areas as possible. They usually sampled at a different port each day, but when the numbers of barracuda in the bag were low they would remain in an area for several days to assure an adequate sample. This sampling method was chosen because samples of adequate size could be obtained and it caused the least disruption to fishermen and partyboat routine. The loss in efficiency in obtaining only one (from an all-day boat), or at most two (from half-day boats), samples per day per man was partially offset by the fact that samples of white seabass, which also were desired, could be obtained.

Our sampling routine was similar for sport and commercial catches. Pertinent catch data were recorded for each individual sample: date, area of catch, gear used, and type of fishing. Total lengths of up to

100 barracuda were obtained by the measuring board technique described by Fry and Hughes (1952).

Scales were collected from under the pectoral fin (Walford, 1932), and placed in a small envelope on which the associated catch data were

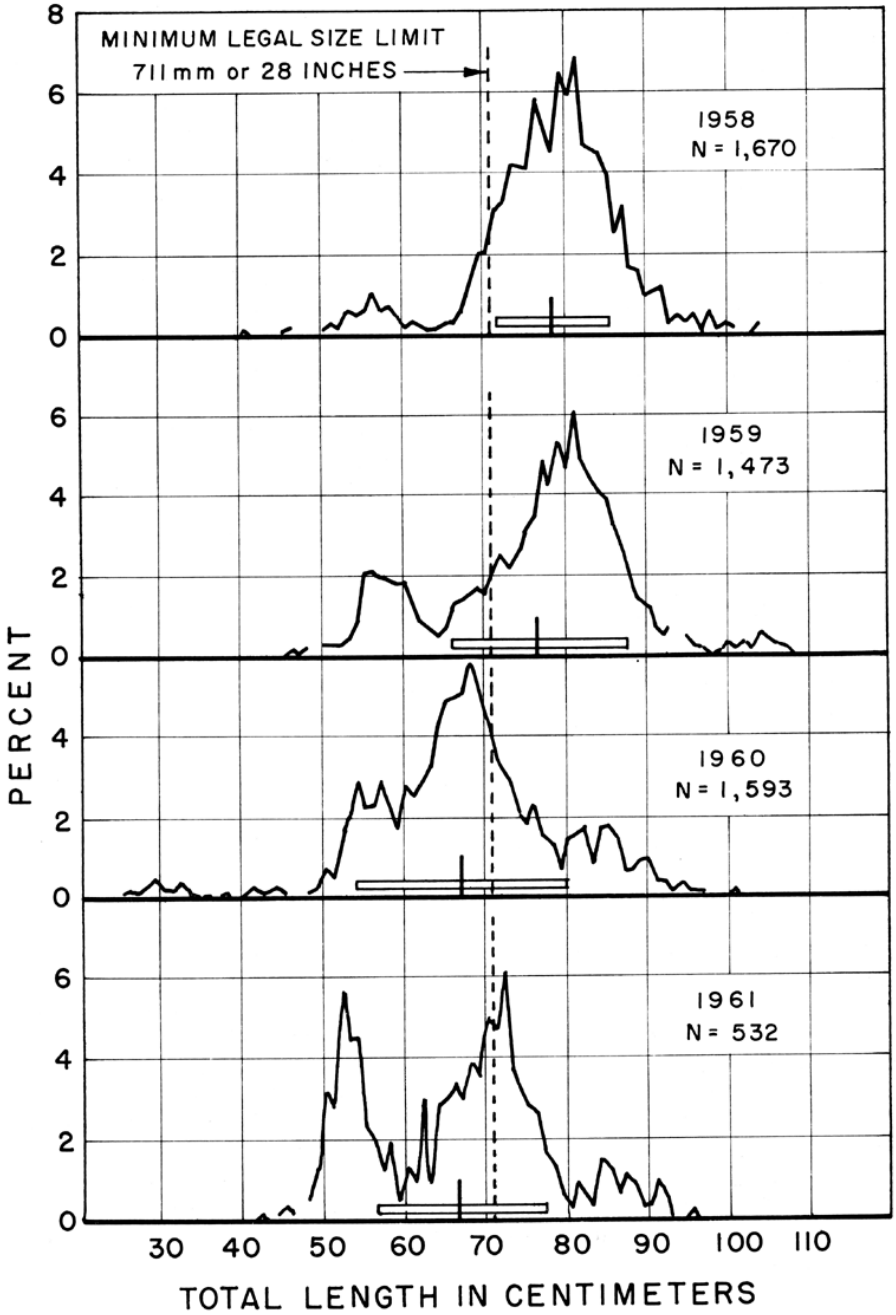

FIGURE 4. Length frequency curves of sport-caught barracuda. The horizontal bar represents one standard deviation on either side of the mean length indicated by the vertical bar.

FIGURE 4. Length frequency curves of sport-caught barracuda. The horizontal bar represents one standard deviation on either side of the mean length indicated by the vertical bar

recorded. In 1958, scales were taken from all fish measured. In 1959, 1960, and 1961, scales were taken from a 10-fish subsample.

The scales were processed for reading by soaking over-night in water containing a trace of carbolic acid, then cleaned manually with the

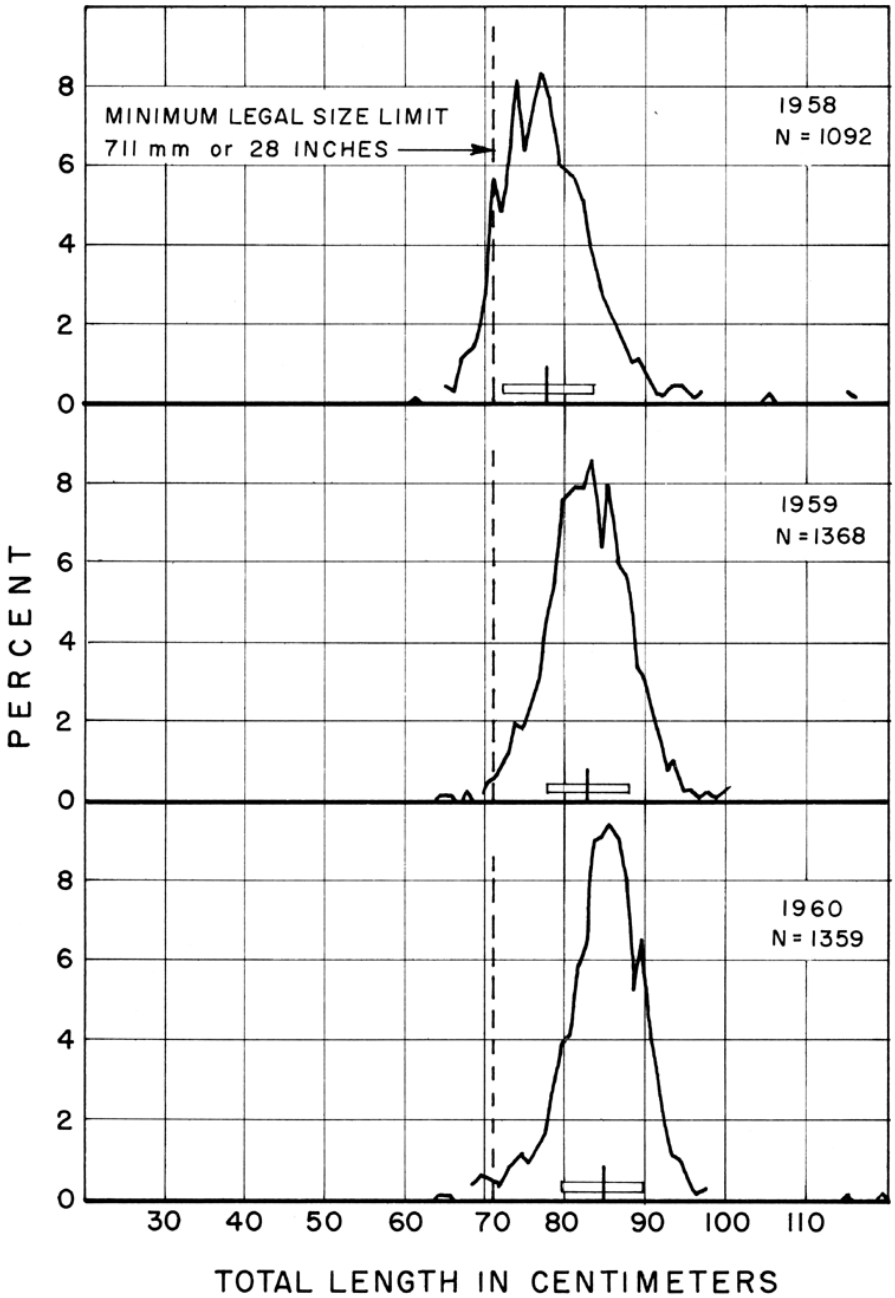

FIGURE 5. Length frequency curves of commercially caught barracuda. The horizontal bar represents one standard deviation on either side of the mean length indicated by the vertical bar.

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stub of a trimmed camel's hair brush. Six cleaned, non-regenerated scales from each fish were mounted on a glass slide in a medium of glycerin-jelly and covered with a glass cover slip. Each slide was numerically coded to mask identity.

Our age determination process was, with a few exceptions, similar to the method used by the California sardine program (Felin and Phillips, 1948; Miller, 1955; and Mosher, 1950). A 500-watt, 35 mm slide projector (Bell and Howell, Streamliner 500, Model 151 Duo) was used to project the scale image instead of a microscope. The projector was modified to accommodate (i) a mechanical stage to manipulate the slide holder, and (ii) an Exacta wide-angle lens (P. Angenieux, Paris, F. 35, 1:2.5, Retrofocus Type R 1). The 12- by 12-inch, aluminized, first-surface mirror was constructed of plate glass to minimize distortion and to maximize light transmission. Gross magnification of 40X was attained by the combined effects of the lens and projection distance.

Each scale sample was read independently by two people, and disagreements were resolved in joint session. Back calculations were not made, although the annuli of each scale were noted on a millimeter card.

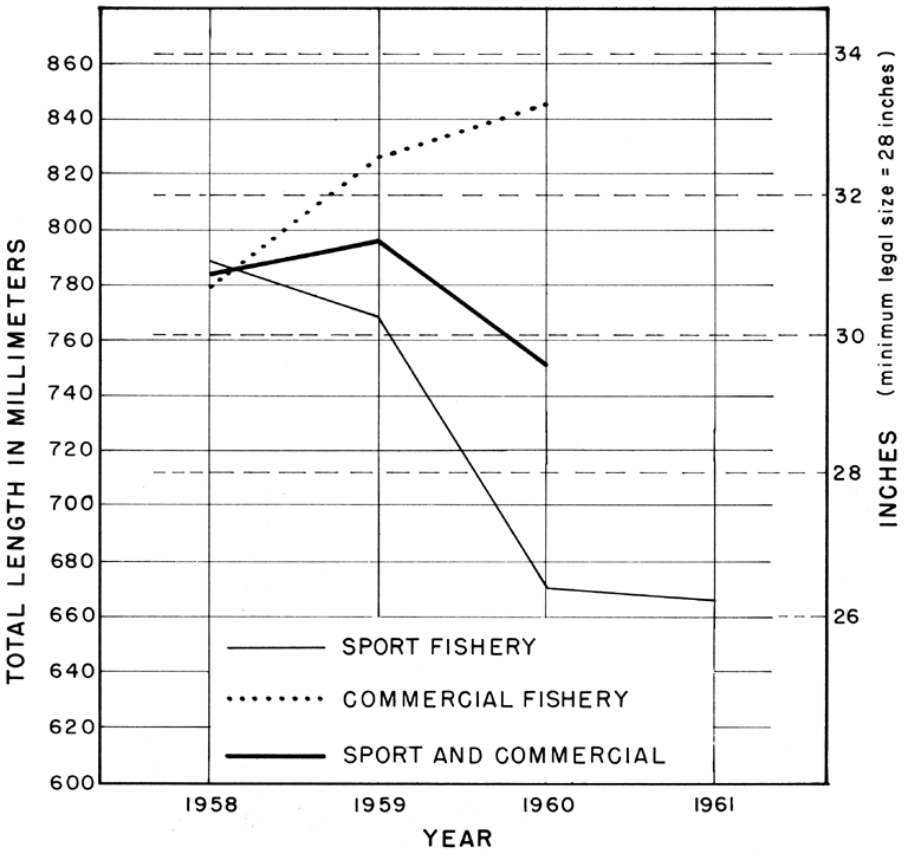

FIGURE 6. Annual mean length of barracuda caught by the sport and commercial fleets in California waters.

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2.1. Length Composition

Lengths were grouped by centimeter intervals, summed, and percent frequencies calculated for the sport and commercial fisheries, separately and combined, by monthly and yearly periods (Table 2).

The yearly grouping revealed pertinent parameters and trends without reflecting the maze of detail and incompleteness of the shorter periods (Figures 4 and 5).

The average size of the sport-caught barracuda dropped markedly, from 787.4 mm (31.0 inches) in 1958 to 666.6 mm (26.25 inches) in 1961. The most significant change occurred in 1960 when the average size fell to 671.5 mm (26.4 inches), substantially below the legal minimum of 711 mm (28 inches).

The relative degree of change is illustrated by the percent of fish above and below the minimum size. In 1958, approximately 85 percent of the sport catch was above 711 mm. This ratio declined slightly in 1959 to 74 percent. In 1960, only 31 percent of the total take exceeded 28 inches. There was little improvement in 1961 when the ratio rose to 37 percent (Figure 6).

The commercial fleet, in sharp contrast to the recreational fishermen, delivered increasingly larger fish, ranging from 779.4 mm (30.7 inches) in 1958 to 845.8 mm (33.3 inches) in 1960.

TABLE 2

Barracuda Length Frequency Sampling Statistics

	1958	1959	1960	1961
Sportfishing:				
Number of samples	53	40	52	20
Number of fish in samples	1,670	1,473	1,593	532
Number of fish caught by partyboats only	782,723	1,195,585	755,408	391,884
Sampled fish as percent of total catch	0.213	0.132	0.211	0.136
Size range of fish in samples (mm)	405–1,190	455–1,085	255–1,000	445–955
Mean length of fish in samples (mm)	787.4	768.0	671.5	666.6
Mean length of fish in samples (inches)	31.0	30.2	26.4	26.2
Standard Deviation	87.1	111.3	113.4	109.8
Standard Error	2.13	2.13	2.90	4.76
Percent of fish in sample larger than 710 mm.	87.38	74.65	31.32	37.59
Percent of fish in sample shorter than 710 mm.	12.66	25.58	68.67	62.22
Commercial Fishing:				
Number of samples	19	32	31	
Number of fish in samples	1,092	1,368	1,359	
Number of fish caught by commercialmen (California waters only)	125,544	277,602	286,957	119,591
Sampled fish as percent of total catch	0.870	0.493	0.474	
Size range of fish in samples (mm)	615–1,045	645–1,005	645–1,095	
Mean length of fish in samples (mm)	779.4	826.5	845.8	
Mean length of fish in samples (inches)	30.7	32.5	33.3	
Standard Deviation	56.34	50.32	50.30	
Standard Error	1.71	1.36	1.36	
Percent of fish in sample larger than 710 mm.	92.03	98.97	98.35	
Percent of fish in sample shorter than 710 mm.	7.96	1.02	1.61	

TABLE 2
Barracuda Length Frequency Sampling Statistics

2.2. Age Composition

The age composition of the sport and commercial barracuda catches reflected patterns similar to those exhibited by the length frequencies. Associated with each change in average length were parallel shifts in the relative strength of the various age groups (Table 3).

TABLE 3

Age Composition of the Barracuda Caught off California by the Sport and Commercial Fleets

	Age Group									
	I	II	III	IV	V	VI	VII	VIII	IX	Totals
Sport Fishery										
1958										
Year-class	1957	1956	1955	1954	1953	1952	1951	1950	1949	
Number in sample		47	55	148	470	579	196	49	5	1,549
Percent		3.0342	3.5507	9.5546	30.3422	37.3790	12.6533	3.1633	.3228	100.0001
Estimated number in catch		23,749	27,792	74,786	237,495	292,574	99,040	24,760	2,527	782,723
Catch-per-unit-of-effort of age group		.0583	.0682	.1837	.5835	.7188	.2433	.0608	.0062	
1959										
Year-class	1958	1957	1956	1955	1954	1953	1952	1951	1950	
Number in sample		13	56	63	86	125	49	7	2	401
Percent		3.2419	13.9651	15.7107	21.4464	31.1721	12.2195	1.7456	.4988	100.0001
Estimated number in catch		38,760	166,965	187,835	256,410	372,689	146,095	20,870	5,964	1,195,588
Catch-per-unit-of-effort of age group		.1002	.4319	.4859	.6633	.9641	.3779	.0539	.0154	
1960										
Year-class	1959	1958	1957	1956	1955	1954	1953	1952		
Number in sample	10	74	68	111	41	34	22	6		366
Percent	2.7322	20.2186	18.5792	30.3279	11.2022	9.2896	6.0109	1.6393		99.9999
Estimated number in catch	20,639	152,733	140,349	229,099	84,622	70,174	45,407	12,383		755,406
Catch-per-unit-of-effort of age group	.0512	.3790	.3483	.5685	.2100	.1741	.1126	.0307		
Commercial Fishery[1]										
1958										
Year-class				1954	1953	1952	1951	1950	1949	
Number in sample				99	392	394	89	9	1	984
Percent				10.0610	39.8374	40.0407	9.0447	.9146	.1016	100.0000
Estimated number in catch				27,261	78,350	66,729	13,102	1,180	102	186,724
1959										
Year-class				1955	1954	1953	1952	1951	1950	
Number in sample				6	52	154	102	21	2	337
Percent				1.7804	15.4303	45.6973	30.2671	6.2315	.5935	100.0001
Estimated number in catch				7,112	44,736	112,263	64,632	11,849	881	241,473

TABLE 3
Age Composition of the Barracuda Caught off California by the Sport and Commercial Fleets

TABLE 3—Continued

Age Composition of the Barracuda Caught off California by the Sport and Commercial Fleets

1960										
Year-class				1956	1955	1954	1953	1952		
Number in sample				8	47	123	85	16		279
Percent				2.8674	16.8459	44.0860	30.4659	5.7348		100.0279
Estimated number in catch				11,839	50,486	111,954	67,249	11,272		252,800
Sport and Commercial Fisheries Combined										
1958										
Year-class		1956	1955	1954	1953	1952	1951	1950	1949	
Estimated number in catch		23,749	27,792	102,047	315,845	359,303	112,142	25,940	2,629	969,447
Percent		2.4497	2.8668	10.5263	32.5799	37.0627	11.5676	2.6758	.2712	100.0000
1959										
Year-class		1957	1956	1955	1954	1953	1952	1951	1950	
Estimated number in catch		38,760	166,965	194,947	301,146	484,952	210,727	32,719	6,845	1,437,061
Percent		2.6972	11.6185	13.5657	20.9557	33.7461	14.6637	2.2768	.4763	100.0000
1960										
Year-class	1959	1958	1957	1956	1955	1954	1953	1952		
Estimated numer in catch	20,639	152,733	140,349	240,938	135,108	182,128	112,656	23,655		1,008,206
Percent	2.0471	15.1490	13.9206	23.8976	13.4008	18.0645	11.1739	2.3462		99.9997

[1] The estimated number of barracuda in the commercial catch was computed by converting pounds to numbers by the following formula:

$$\frac{\text{percent at age (total weight)}}{\text{average weight of fish at age}}$$

Age IV = 2.78 pounds per fish
V = 3.83 pounds per fish
VI = 4.52 pounds per fish
VII = 5.20 pounds per fish
VIII = 5.84 pounds per fish
IX = 7.48 pounds per fish

TABLE 3
Age Composition of the Barracuda Caught off California by the Sport and Commercial Fleets

In 1958 and 1959, the sport fishery cropped primarily 5- and 6-year-old fish (1952, 1953, and 1954 year-classes). In 1960, the 1956 year-class also due to the strong showing of 2- and 3-year-olds, comprising the 1957 and 1958 year-classes.

The wide range of ages (2 to 9) taken by the sport fleet provided some insight into the relative strength of the contributing year-classes. The 1954 year-class, at peak vulnerability during our study, was not as strong as the 1953 year-class, but yielded more than the 1955 group. The 1952 year-class was undoubtedly a strong one, as was indicated by its prominence at age 6, as well as its material contribution at age 7 in 1959 (Table 3).

The smaller spread of ages (4 to 9) in the commercial fishery did not reveal trends as distinctly as the sport fishery, but the strong 1953 and weaker 1954 year-classes were evident. The increases in average length noted in the commercial catches of 1959 and 1960 were due to the dominant 1953 year-class.

The wide disparities in the composition of the sport and commercial barracuda catches can be attributed to the interaction of several factors, especially a gear change which occurred within the commercial fleet during the course of study. Weak prices in 1959 and 1960 caused the number of troll fishermen, whose catches were derived from schools fished by sportsmen, to decrease. Thus, the increasing average size of fish delivered by the commercial fleet during those two years reflected the selective action of gill nets, whereas the slightly smaller fish in 1958 had reflected the larger role played by the troll fleet. Also involved in

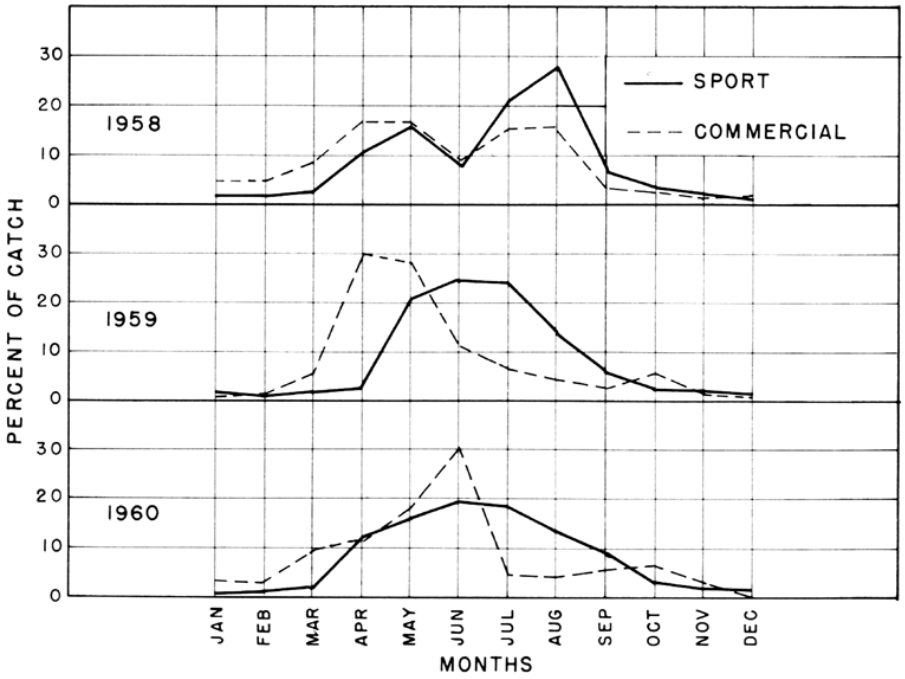

FIGURE 7. Comparison of monthly sport and commercial barracuda landings expressed in percent of total catch for each fishery.

FIGURE 7. Comparison of monthly sport and commercial barracuda landings expressed in percent of total catch for each fishery

the differential size composition is the fact that small barracuda may be retained by sport fishermen (i.e., two barracuda smaller than the legal minimum of 28 inches total length may be possessed). In 1959 and 1960, increasing numbers of small barracuda were retained by sportsmen, thus materially reducing the average size and age of their catch. These young fish were the result of local spawning in 1957 and 1958. They apparently were more available to the sport fleet than the larger and older barracuda.

A third potentially significant factor was that the two fisheries operated on distinctly different sub-groups of the barracuda population. In 1958, when age and length composition was similar, peak activity of both the commercial and sport fisheries coincided. In 1959 and 1960 commercial activity peaked a month or two ahead of the sport-fishery (Figure 7).

3. TAGGING

A tagging program was initiated to elucidate general migratory behavior, to determine what movement took place between and within the most populous barracuda areas off northern Baja California and southern California, and to gather data from which estimates of population size could be calculated.

In the fall of 1958 and the spring of 1959, three cruises were made aboard the Department's research vessel *Alaska* to resolve the basic problems of finding a suitable tag and appropriate tagging techniques. Groups of barracuda were caught with rod and reel, tagged and placed in the live-bait wells aboard ship for observation.

The tests revealed that barracuda could survive moderate handling: e.g. being captured with hook and line, being held on a measuring board while a tag was affixed, and being returned to the water. These experiments also disproved a commonly held notion that barracuda would die of fungal infections after handling. When we held fish captive infections did develop wherever the skin had been touched (in fact hand-shaped fungal infections appeared within 24 hours), but they healed rapidly and had no apparent ill effects on the fish which were observed for as long as 21 days.

The California spaghetti tag, type G, without a jacket (Blunt and Messersmith, 1960) proved superior to the Floy dart tag (Yamashita and Waldron, 1958) in our tests. Dart tags were prone to fall out, either while the fish were being held in the tanks or during handling on recovery. Similar experiences were noted in field trials on great barracuda, Sphyraena barracuda, of Florida (Springer and McErlean, 1961), and on striped bass, Roccus saxatilis, of the Sacramento-San Joaquin River system (Chadwick, 1963). Dissection of our animals at the termination of the experiment revealed less internal or muscular damage had resulted from the type G tag—possibly because of the barracuda's soft flesh and the difficulty of inserting the dart with precision and uniform pressure.

Our initial tagging program called for simultaneous releases in Mexican and California waters during May 1959. Accordingly, 2,299 tagged barracuda were released from the Department's research vessel *N. B. Scofield,* off northern Baja California while tagged fish were released

from a chartered commercial barracuda troller, the *Poacher*, admirably skippered by Joseph H. Caruthers, in areas within a day's cruising from Los Angeles Harbor (Figure 8). During the last 2 days of the *Scofield* cruise, May 23 and 24, project personnel released 150 tagged barracuda off "The Barn," a favorite sportfishing area between the cities of San Clemente and Oceanside.

Tagging techniques aboard the two vessels varied markedly because of diverse physical construction. For example, the *Poacher*, a 22-foot decked-over skiff-type boat, powered by an inboard gasoline engine, did not have the range of the 100-foot *N. B. Scofield*, nor did it have live-bait tanks or working space for more than one tagging crew.

Six additional opportunities arose to augment our initial release of 3,449 barracuda (Table 4). Three California sportsmens' clubs, Holly-dale

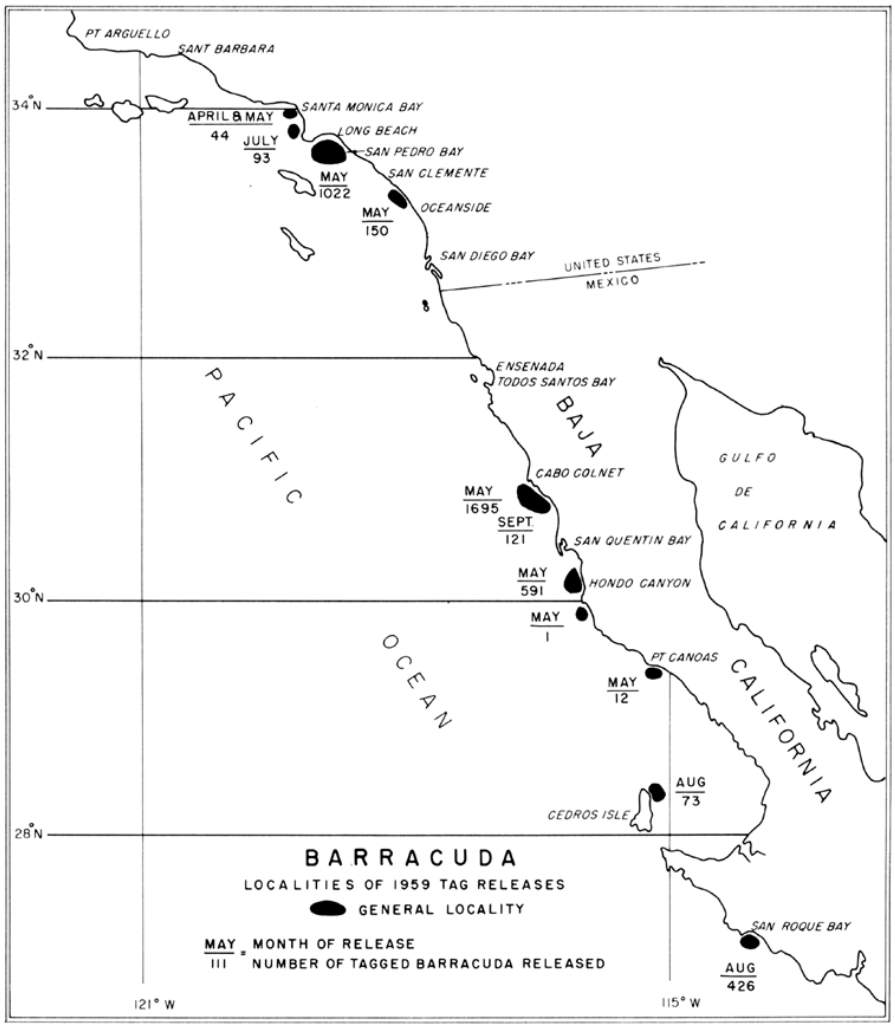

FIGURE 8. Outline chart of portions of southern California and Baja California indicating the general localities where tagged barracuda were released during May, July, August, and September 1959.

FIGURE 8. ***Outline chart of portions of southern California and Baja California indicating the general localities where tagged barracuda were released during May, July, August, and September 1959.***

Rod and Gun Club, Maywood Rod and Gun Club, and Western Conservation Club, Inc., generously provided the opportunity to tag barracuda caught aboard their chartered vessels. On several occasions Fish and Game personnel, notably the crew of the *Alaska* and members of the Department's Pelagic Fish Investigation, contributed to the program by tagging and releasing barracuda in areas off central Baja California. In the early stages of our tagging program, a few barracuda were tagged and released from a 16-foot Glasspar skiff in waters contiguous to Los Angeles-Long Beach Harbors. The techniques cmployed during these cruises were similar to or slightly modified from those used aboard the *N. B. Scofield* or the *Poacher*.

3.1. Techniques and Equipment

3.1.1. Aboard the N. B. Scofield—May 1959

Schools of barracuda were located by trolling four lines through areas where the fish were most likely to be found. The lines, attached to outriggers, were "fished" at various depths, and several types of bone and metal lures were used. Barracuda were captured by "still-fishing" with hook and line and by "pole-trolling." Both methods involved the use of 18-foot bamboo jack-poles. For still-fishing, a small feather lure was attached to a wire leader and moved back and forth at the water's surface along the sides of the boat. When pole-trolling, a metal or bone lure was employed in place of the feather. The pole was held by hand from the stern of the vessel while moving at a speed of 2 to 4 knots.

When a great number of barracuda could be lured to the boat by chumming with live bait, they were still-fished. When fish were scattered, a condition apparently associated with the presence of large amounts of natural food in the water, the pole-trolling method was used.

As each fish was captured, it was placed in the vessel's live wells and held there until fishing stopped, or until the wells were filled to capacity. The largest of the three wells contained 3,000 gallons of sea water and held almost 300 barracuda. Two smaller wells, each with a capacity of about 2,500 gallons, held between 200 and 250 barracuda. Mortality in these tanks was between 1.0 and 1.5 percent. During the early part of the cruise, only the 3,000-gallon tank was available, but as our live bait was used, the two smaller wells were also used for holding barracuda. The advantages of holding rather than tagging the fish as they were caught were: (i) no fishing time was lost while waiting for the fish to be tagged, (ii) the fish could be handled with more care at all stages, (iii) weak fish died in the tanks, and (iv) the chance that fleeing tagged fish would "pull" the rest of the school away from the boat was eliminated. Tagging was usually accomplished in a different location from where the fish were caught—either en route to the night anchorage or at it.

During tagging operations two men tagged, two held fish, one recorded, and one man brailed fish from the live wells. Approximately 20 seconds were required to tag each barracuda.

TABLE 4

Tagged Barracuda: Releases and Recoveries

	Release Data			Recovery Data								
									Miles moved			
Date	Lat. N.	Long. W.	No. rele'd	No. recov'd	Percent of no. rele'd	Date	Lat. N.	Long. W.	N	S	nil[1]	Days at liberty
California Releases												
4-30-59	33° 54.8′	118° 28.0′	5	0								
5- 7-59	33° 41.3′	118° 07.0′	12	1	8.33	5-19-59	33° 39.2′	118° 03.5′			x	13
5- 8-59	33° 42.0′	118° 08.0′	16	1	6.25	6-20-59	33° 40.5′	118° 13.3′			3	44
5-13-59	33° 41.0′	118° 07.6′	105	1	.95	7- 7-59	33° 41.0′	118° 07.6′			1	56
5-14-59	33° 39.0′	118° 04.0′	311	29	9.32	5-17-59	33° 40.5′	118° 07.5′			3	4
						5-20-59	33° 39.2′	118° 03.5′			4	7
						5-24-59	34° 00.0′	118° 47.5′	50			10
						5-30-59	33° 42.6′	118° 07.5′			x	17
						6- 7-59	33° 59.2′	118° 29.8′	32			25
						6- 9-59	33° 35.8′	117° 56.9′		10		27
						6-10-59	32° 50.0′	117° 18.5′		66		28
						6-12-59	33° 18.8′	117° 31.6′		39		30
						6-12-59	33° 03.5′	117° 18.9′		58		30
						6-13-59	33° 27.3′	117° 43.3′		29		31
						6-13-59	32° 23.3′	117° 14.5′		94		31
						6-20-59	33° 40.5′	118° 13.3′			7	38
						6-20-59	33° 46.0′	118° 25.8′	12 est.			38
						6-23-59	33° 59.2′	118° 29.8′	32			41
						6-26-59	33° 40.5′	118° 13.3′			6	44
						6-27-59	33° 15.0′	117° 28.0′		44		45
						6-29-59	33° 40.5′	118° 13.3′			6	47
						7- 5-59	34° 02.0′	118° 34.0′	38			53
						7-12-59	33° 40.5′	118° 13.3′			6	60
						7-13-59	34° 02.0′	119° 22.5′	64			61
						7-14-59	33° 40.5′	118° 13.3′			6	62
						8- 2-59	33° 39.2′	118° 03.5′			4	81

TABLE 4

Tagged Barracuda: Releases and Recoveries

						9- 1-59	32° 38.2′	117° 15.4′		80		116
						11-10-59	32° 38.0′	117° 14.5′		80		181
						12- 3-59	34° 01.8′	118° 53.0′	45			204
						7- 5-60	33° 39.2′	118° 03.5′			x	419
						9- 8-60	34° 01.5′	118° 31.5′	37			484
						Return no. 136 no data						
						Return no. 165 no data						
5-18-59	33° 38.5′	118° 00.0′	160	13	8.13	6-11-59	33° 40.7′	118° 04.2′			x x	25
						6-11-59	33° 42.1′	118° 06.8′			x	25
						6-14-59	33° 39.2′	118° 03.8′				28
						6-24-59	33° 18.2′	117° 30.2′		32		38
						6-28-59	33° 59.2′	118° 29.8′	38			42
						6-28-59	33° 22.7′	117° 36.0′		27		42
						7- 4-59	34° 01.5′	118° 41.0′	44			48
						7-11-59	33° 40.5′	118° 13.3′			6	55
						7-11-59	33° 46.8′	118° 26.3′	24			55
						7-13-59	33° 45.4′	118° 00.9′			4	57
						11- 1-59	35° 07.0′	120° 43.0′	180			168
						7- 7-60	33° 54.0′	118° 26.0′	30			417
						7-14-60	33° 38.5′	118° 00.0′			x	424
5-19-59	33° 38.5′	118° 00.0′	60	5	8.33	5-30-59	33° 38.3′	118° 01.3′			1	12
						6- 7-59	33° 39.2′	118° 03.5′			4	20
						6-24-59	33° 59.2′	118° 29.8′	36		x	37
						6-28-59	33° 38.5′	118° 00.0′				41
						7-12-59	34° 01.5′	118° 35.5′	43			55
5-20-59	33° 54.8′	118° 28.0′	39	4	10.26	5-23-59	33° 47.8′	118° 25.5′		11		4
						6- 4-59	34° 01.2′	118° 45.8′	17			16
						5-20-60	33° 53.5′	118° 27.0′			4	367
						6-29-60	33° 42.0′	118° 12.0′		28		407
5-20-59	33° 47.6′	118° 25.2′	7	1	14.29	9- 6-59	32° 37.5′	117° 15.0′		100		110

TABLE 4—Cont'd.

TABLE 4—Continued

Tagged Barracuda: Releases and Recoveries

Date	Release Data			Recovery Data								
	Lat. N.	Long. W.	No. rele'd	No. recov'd	Percent of no. rele'd	Date	Lat. N.	Long. W.	Miles moved N	Miles moved S	Miles moved nil[1]	Days at liberty
5-21-59	33° 40.5′	118° 13.3′	120	6	5.00	6- 7-59	33° 39.2′	118° 03.5′		10		18
						6-12-59	33° 40.7′	118° 05.2′			8	23
						6-14-59	33° 28.5′	117° 43.5′		27		25
						7-11-59	34° 24.5′	119° 57.0′	98			52
						7-13-59	33° 40.5′	118° 13.3′			x	54
						11- 1-59	35° 07.0′	120° 43.0′	180			165
5-23-59	33° 18.2′	117° 30.2′	132	15	11.36	6- 8-59	33° 40.5′	118° 13.3′	43			17
						6-10-59	33° 46.5′	118° 26.3′	55			19
						6-12-59	33° 27.3′	117° 43.3′	15			21
						6-23-59	33° 02.8′	117° 18.3′		20		32
						7- 5-59	33° 38.5′	118° 00.0′	32			44
						8- 1-59	33° 59.0′	118° 48.5′	77			71
						8- 1-59	33° 22.0′	117° 33.0′			3	71
						8- 1-59	Santa Mon	ica Bay	67 est.			71 est.
						8-17-59	33° 15.0′	117° 28.0′			4	87
						8-28-59	31° 48.5′	116° 47.2′		98		98
						8- 7-59	San Diego	area				75 est.
						10- 6-59	36° 18.0′	121° 57.0′	280			136
						11- 6-59	31° 33.0′	116° 44.0′		110		167
						3-10-60	33° 42.0′	118° 20.0′	50			291
						6- 6-60	33° 39.0′	118° 03.0′	32			380
5-24-59	33° 18.2′	117° 30.2′	18	1	5.56	6-18-60	33° 02.0′	117° 17.5′		20		392
5-26-59	33° 43.0′	118° 09.3′	123	13	10.57	6- 7-59	33° 39.2′	118° 03.5′			6	13
						6- 8-59	33° 39.2′	118° 01.5′			7	14

TABLE 4

Tagged Barracuda: Releases and Recoveries

						6– ?–59	32° 38.0′	117° 14.5′		83		20 est.
						7– 1–59	33° 46.5′	118° 26.3′	17			37
						7– 6–59	33° 42.8′	118° 15.0′			x	42
						7–12–59	32° 50.0′	117° 18.5′		70		48
						7–13–59	34° 01.5′	118° 35.5′	40			49
						7–23–59	No data					61
						8–28–59	33° 45.4′	118° 09.0′			3	95
						9–10–59	34° 02.0′	118° 32.0′	33			108
						9–26–59	33° 43.3′	118° 07.4′			x	124
						11– 1–59	35° 07.0′	120° 43.0′	180			160
						12–28–59	33° 43.0′	118° 19.5′			9	217
5–27–59	33° 40.5′	118° 13.3′	75	8	10.67	6– 1–59	33° 41.8′	118° 05.3′			8	19
						6–16–59	33° 40.5′	118° 11.3′			x	21
						6–22–59	33° 15.0′	117° 28.0′		47		27
						6–28–59	33° 39.2′	118° 03.8′			4	33
						6–29–59	33° 59.2′	118° 29.8′	30			34
						6– ?–59	33° 37.6′	117° 58.0′		13		19 est.
						7–18–59	33° 46.5′	118° 26.3′	16			72
						10–22–59	34° 02.0′	118° 32.5′	33			149
7–19–59	33° 50.0′	118° 26.3′	86	5	5.81	10–15–59	34° 01.5′	118° 35.5′	14			89
						10–23–59	34° 01.5′	118° 32.5′	13			97
						11–14–59	34° 01.5′	118° 35.5′	14			119
						12– 8–59	34° 01.5′	118° 32.5′	13			143
						3– 5–60	33° 59.7′	118° 48.5′	21			230
8–23–59	33° 40.5′	118° 13.3′	40	4	10.00	9– 1–59	33° 59.2′	118° 29.8′	26			10
						9– 3–59	33° 40.5′	118° 13.3′			x	12
						12–16–59	34° 01.5′	118° 46.0′				116
						4– 6–60	33° 18.2′	117° 30.2′		43		227
Totals California			1,309	107	8.17							

TABLE 4—Cont'd.

TABLE 4—Continued

Tagged Barracuda: Releases and Recoveries

Date	Release Data			Recovery Data								
	Lat. N.	Long. W.	No. rele'd	No. recov'd	Percent of no. rele'd.	Date	Lat. N.	Long. W.	Miles moved N	Miles moved S	Miles moved nil[1]	Days at liberty
Mexican Releases												
5- 8-59	29° 24.7′	115° 08.3′	12	0	0							
5-10-59	29° 56.9′	115° 48.0′	1	0	0							
5-11-59	30° 18.8′	115° 53.2′	537	4	.74	8-11-59	31° 48.5′	116° 47.2′	105			93
						8-16-59	31° 51.0′	116° 48.0′	113			98
						8-16-59	31° 51.0′	116° 48.0′	113			98
						8-29-59	32° 56.5′	117° 16.0′	180			111
5-12-59	30° 14.1′	115° 50.3′	48	2	4.17	8- 2-59	34° 24.0′	119° 47.0′	340			83
						8-31-59	32° 37.0′	117° 14.5′	160			112
5-13-59	30° 14.1′	115° 50.3′	6	0	0							
5-16-59	30° 46.6′	116° 08.0′	226	0	0							
5-17-59	30° 46.6′	116° 08.0′	149	3	2.01	8-21-59	33° 32.5′	117° 48.5′	190			97
						8-22-59	32° 38.0′	117° 14.5′	125			98
						6-15-60	32° 50.0′	117° 18.5′	130			394
5-17-59	30° 55.0′	116° 17.1′	39	1	2.56	8-23-59	33° 47.5′	118° 09.0′	195			99
5-18-59	30° 57.4′	116° 19.5′	278	14	5.04	6-13-59	32° 16.0′	117° 02.2′	90			27
						6-13-59	31° 48.5′	116° 47.2′	60			27
						6-15-59	31° 48.6′	116° 43.3′	60			29
						7-18-59	32° 23.0′	117° 14.0′	100			62
						7-29-59	31° 48.0′	116° 50.0′	43			73
						8- 3-59	33° 40.5′	118° 13.3′	195			78
						8- 4-59	33° 39.2′	118° 03.5′	190			79

TABLE 4

Tagged Barracuda: Releases and Recoveries

						8- 4-59	31° 33.0′	116° 14.0′	42			79
						8-16-59	33° 40.5′	118° 13.3′	195			91
						8-27-59	32° 51.8′	117° 16.0′	130			102
						9- 2-59	31° 48.5′	116° 47.2′	60			108
						9- 5-59	34° 02.0′	118° 52.0′	235			111
						9-23-59	33° 46.5′	118° 26.3′	205			129
						1-20-60	32° 50.0′	117° 18.5′	127			248
5-19-59	30° 57.4′	116° 19.5′	374	16	4.28	6-13-59	31° 48.5′	116° 47.2′	60			26
						7- 2-59	34° 02.0′	118° 52.0′	230			45
						7- 3-59	33° 40.5′	118° 13.3′	195			46
						7-27-59	32° 02.3′	117° 14.0′	100			70
						8- 5-59	32° 47.0′	117° 16.0′	125			79
						8- 9-59	33° 43.6′	118° 11.2′	200			83
						8-15-59	32° 35.0′	117° 05.0′	100			89
						8-17-59	33° 49.2′	118° 25.0′	210			91
						9- 3-59	30° 29.0′	116° 06.0′		30		108
						9- 3-59	30° 29.0′	116° 06.0′		30		108
						9- 6-59	31° 48.5′	116° 47.2′	60			111
						9-13-59	33° 21.0′	117° 33.5′	160			118
						9-18-59	33° 42.5′	118° 09.0′	195			123
						11-12-59	32° 28.0′	117° 08.0′	100			178
						11-23-59	33° 42.0′	118° 20.0′	200			189
						1- 5-60	33° 43.0′	118° 20.0′	200			232
5-20-59	30° 57.4′	116° 19.5′	629	26	4.13	6-27-59	33° 28.4′	117° 44.3′	170			39
						7- 1-59	33° 40.5′	118° 13.3′	200			43
						7- 4-59	33° 59.2′	118° 29.8′	220			46
						7-29-59	31° 48.0′	116° 50.0′	60			71
						8- 2-59	33° 28.5′	117° 44.0′	173			75
						8- 5-59	32° 50.0′	117° 18.5′	127			78
						8- 6-59	32° 51.3′	117° 16.0′	128			79
						8- 9-59	33° 40.5′	118° 13.3′	194			82
						8- 9-59	31° 51.0′	116° 38.0′	60			82
						8-11-59	33° 18.2′	117° 30.2′	158			84
						8-14-59	33° 43.0′	118° 09.3′	87			87
						8-17-59	32° 50.5′	117° 18.2′	128			90

TABLE 4—Cont'd.

TABLE 4—Continued

Tagged Barracuda: Releases and Recoveries

Date	Release Data					Recovery Data						
	Lat. N.	Long. W.	No. rele'd	No. recov'd	Percent of no. rele'd.	Date	Lat. N.	Long. W.	Miles moved N	Miles moved S	Miles moved nil[1]	Days at liberty
						8–18–59	33° 47.5′	118° 09.0′	195			91
						8–20–59	33° 18.2′	117° 30.2′	158			93
						8–22–59	32° 23.0′	117° 14.0′	109			95
						8–22–59	32° 38.0′	117° 14.5′	117			95
						8–23–59	33° 23.5′	117° 36.5′	163			96
						8–30–59	33° 59.2′	118° 29.8′	220			103
						9– 2–59	31° 48.5′	116° 47.2′	60			106
						9– 5–59	34° 02.2′	118° 52.0′	230			109
						9– 7–59	32° 16.0′	117° 02.0′	90			111
						9–12–59	33° 46.5′	118° 26.3′	205			116
						9–13–59	33° 46.5′	118° 26.3′	205			117
						9–25–59	31° 48.6′	116° 47.2′	60			129
						11– 7–59	32° 50.0′	117° 18.5′	127			172
						9– 7–60	31° 51.0′	116° 48.5′	61			476
8–3–59	27° 06.8′	114° 17.0′	426	0	0							
8–9–59	28° 21.0′	115° 11.4′	73	0	0							
9–3–59	30° 52.0′	116° 12.0′	42	0	0							
9–4–59	30° 56.0′	116° 15.0′	32	0	0							
9–5–59	30° 56.0′	116° 16.0′	47	0	0							
Totals Mexico			2,919	66	2.26							
Grand Totals			4,228	173	4.09							

[1] Small but unknown value or direction undetermined.

TABLE 4

Tagged Barracuda: Releases and Recoveries

3.1.2. Aboard the Poacher

Bone and metal lures were trolled at various depths through concentrations of barracuda. As each fish was captured, it was placed in a padded box, measured, tagged, and released. In addition to a fisherman, two project personnel participated in these tagging operations: one man tagged while the other held the fish and recorded data. In all tagging operations, the fish's head was covered with and held by a wet rag which quieted the animal and provided a better grip.

3.1.3. Tag-type and Application

The tag used by the barracuda program and our method of applying it were sufficiently different from other tagging endeavors to warrant a brief description.

The white, single strand, plastic tubing (spaghetti) used to form the loop tag was made of Resinite X270I, size 19, inside diameter .038 inches, wall thickness .016 inches, manufactured by Borden Company of Santa Barbara, California. The legend, "Return Fish and Game San Pedro Cal.," was inscribed three or four times to the foot with a hot stamp-carbon ribbon technique by Teletronic Laboratories, Gardena, California. Individual tags were cut to 12-inch lengths and inscribed in at least two places with an identifying number with vinyl ink (California Ink Co., formula 104N5A4).

The needles we used to thread the tag through the fish's musculature were of two types. One was identical to the stainless steel tubing with a solid, conically-shaped point used on tuna (Blunt and Messersmith, 1960). The second needle was made of a piece of solid stainless steel rod about 127 mm long and 2.4 mm in diameter. A point was formed by grinding one end into a long, tapering, triangular shape, similar to a sail-maker's needle. About 8 millimeters of the blunt end was reduced to approximately 1.3 mm diameter, with a slight convexity, so the tag would fit snugly over it (Figure 9).

No tests were conducted to determine if one needle was superior to the other. Both were used interchangeably with apparently equal results, but the solid needle functioned better during moments of adversity, such as sudden violent movements by the barracuda. The friction-fit between the plastic tubing and solid needle was sufficiently strong to keep the two intact; whereas, the tube needle would part company with its loosely-held tag. The points of both needles required frequent resharpening for best performance.

We applied the tag by inserting the needle through the dorsal musculature just posterior to the second dorsal fin, from one-fourth to one-half inch below the dorsal surface. The two ends of the tag were brought together and tied to form a small loop. The surplus ends were then trimmed close to the knot.

Since we did not offer a monetary reward for returned tags, the success of our program was dependent upon: (i) conditioning of fishermen by previous tagging programs; (ii) constant word-of-mouth reminders, and inquiries among sport and commercial fishermen, partyboat operators, bait and tackle shops, wholesale fish markets, conservation clubs, etc.; (iii) mailing of a "flyer" describing the tagging program and its objectives to partyboat operators and commercial fishermen; and (iv) prompt reply to cooperating fishermen with a letter of

TABLE 5

Barracuda Tag Recoveries by Type of Fishery and Area of Release

	Sport fishery						Commercial fishery				
	Party boats	Private boats	Piers, jetties, barges	In Mexican waters	Undetermined	Totals	Gill net	Troll	Other	Totals	Grand totals
California releases											
1959											
May	3	2				5	2			2	7
June	30	5	1		2	38	2			2	40
July	12	2	2		2	18			1	1	19
August	4		2	1	1	8					8
September	2	4				6					6
October	3				1	4			1	1	5
November	2			1		3	3			3	6
December	2	1				3			1	1	4
Totals	58	14	5	2	6	85	7		3	10	95
1960											
January											
February											
March	2					2					2
April	1					1					1
May	1				1	2					2
June	2					2	1			1	3
July	3					3					3
August											
September	1					1					1
Totals	10				1	11	1			1	12
California totals	68	14	5	2	7	96	8		3	11	107
Mexican releases											
1959											
May											
June	2			3		5					5
July	6			2		8					8

TABLE 5

Barracuda Tag Recoveries by Type of Fishery and Area of Release

TABLE 5—Continued

Barracuda Tag Recoveries by Type of Fishery and Area of Release

	Sport fishery						Commercial fishery				Grand totals
	Party boats	Private boats	Piers, jetties, barges	In Mexican waters	Undetermined	Totals	Gill net	Troll	Other	Totals	
August	17	4		5	2	28	1	3	2	4	32
September	7			4	1	12				2	14
October											
November	3					3					3
December											
Totals	35	4		14	3	56	1	3	2	6	62
1960											
January	1					1		1		1	2
February											
March											
April											
May											
June	1					1					1
July											
August											
September				1		1					1
Totals	2			1		3		1		1	4
Mexican totals	37	4		15	3	59	1	4	2	7	66
Grand totals	105	18	5	17	10	155	9	4	5	18	173

TABLE 5

Barracuda Tag Recoveries by Type of Fishery and Area of Release

thanks and a commendation card reviewing the history of the recaptured fish.

An additional stimulus was applied by our retrieving tags and fish promptly when advised of their whereabouts. Invaluable assistance was also provided by many Fish and Game wardens and by personnel of the Department's Pelagic Fish Investigation, who, in their daily field contacts, helped carry the message, and picked up tagged barracuda at every opportunity.

3.2. General Tagging Results

The 173 tagged barracuda returned to us during the course of the marking program came from a surprising number and variety of fisheries. The expected sources returned tags about as anticipated: sport-fishing partyboats, 105; private boats, 18; and commercial fishermen, 13. Unexpected sources included pier, jetty, and surf fishermen, live-bait fishermen; sardine fishermen; and the Department's research vessel (Table 5).

In reviewing our tagging results, it is well to keep in mind certain deficiencies, some of which were recognized at the inception of the program. The most glaring weakness was the lack of commercial and sportfishing effort south of Ensenada where a significant portion of the barracuda population was known to reside, and where southern California summer fish probably migrate in winter. Thus, in the absence of a fishery, we could expect no returns and no varification of our hypothesis regarding migration patterns south of Todos Santos Bay.

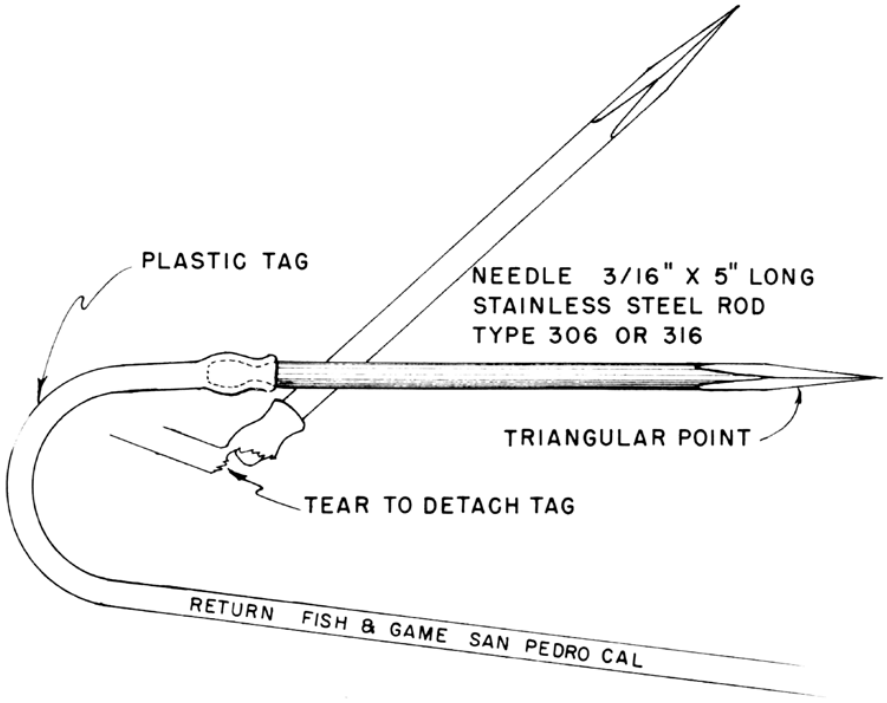

FIGURE 9. "Sailmakers" tagging needle used in applying the spaghetti tag to barracuda.

*FIGURE 9. **"Sailmakers" tagging needle used in applying the spaghetti tag to barracuda.***

Limited investigational resources prevented our releasing tagged barracuda in some essential areas, such as the offshore islands of San Clemente and Santa Catalina.

The unmistakable evidence of substantial but unmeasured tag loss, which manifested itself 3 to 4 months after liberation, was disheartening. Throughout the recovery phase of the program, every effort was made to examine the fish with tag intact. Particular attention was paid to the condition of the tag wound. During the period of greatest returns, June, July, and August, 1959, reports repeatedly indicated that the wound was well healed, with no evidence of adverse effects from the tag. Most of the 51 fish returned to the laboratory verified these observations, although a few wounds were irritated.

The fall months, however, presented another picture. The tag wounds were large and ulcerated, and there were indications of tags being sloughed off or pulled through the flesh. In addition, scales were missing and there were skin ulcers on the dorsal surface of the caudal peduncle. Several barracuda were returned with only a thin section of skin holding the tag in place. In almost all instances there were relatively large masses of marine growth (hydroids) on all exposed portions of the plastic loop. One tag bore a barnacle, Balanus tintinnabulum, 20 mm high and 19 mm wide, attached to the knot. Hydroid and barnacle problems were observed in the tag returns from kelp bass, Paralabrax clathratus (attached to Peterson disks); yellowtail, Seriola dorsalis (attached to plastic loops); and yellowfin tuna, Thunnus albacares (also on plastic loops). Springer and McErlean (1961) reported algal growths on dart tags returned from great barracuda of Florida, while Chadwick (1963) noted hydroids and barnacles on the tags used on striped bass in the Delta area of the Sacramento-San Joaquin River system.

It was obvious that the loop tag was subject to increased losses by the heavy drag of undesirable marine growths. The same growths also caused the tag to ride on the caudal peduncle, resulting in skin lesions and general irritation. In light of the frequent occurrence of these growths it is perhaps remarkable that tags were continuously received through the spring and summer of 1960. Because tag losses were extensive we did not attempt to make detailed analyses of the results beyond the winter of 1959–60. Late returns, however, did yield general information.

Sportfishing from partyboats, private boats, and from piers yielded the greatest number of tag returns, 89.6 percent. The low rate of return by the commercial fleet, 10.4 percent, probably was because tag releases were not completed until after commercial activity peaked (Figure 7). The "other" category, which I have listed under commercial returns, includes recoveries by fishermen who pursued other species primarily, and barracuda were incidental to their catch, e.g. live-bait fishermen.

The movement of barracuda in time and space is also illustrated by the number of recoveries from each of the two major tag lots in relation to the total partyboat catch off southern California (Figure 10).

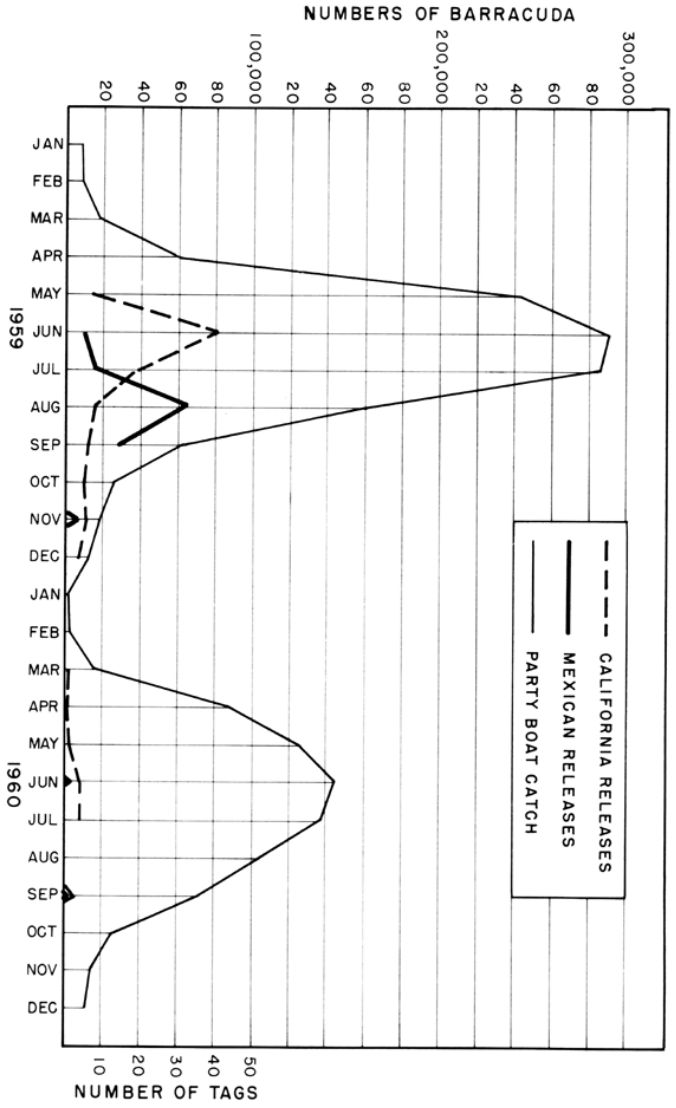

FIGURE 10. Number of barracuda caught per month by sportsmen aboard partyboats, and the number of tagged barracuda recaptured by the area of release in 1959 and 1960.

FIGURE 10. ***Number of barracuda caught per month by sportsmen aboard partyboats, and the number of tagged barracuda recaptured by the area of release in 1959 and 1960.***

Recoveries of California releases peaked in June as did barracuda landings by partyboats. Recoveries of Mexican releases gradually increased from south to north and from June to August, when they attained their maximum rate. In July 1959, the sport fleet caught 285,695 barracuda, almost as many as in June, yet the total number of returns declined by 40 percent. The August recapture rate returned to the June level (45 per month) even though there was a sharp drop in total landings to 159,351 barracuda. This indicated the presence of a large unmarked group of fish. Catch records confirmed this assumption by revealing that large numbers of barracuda had been taken off San Diego in May, an area missed by our tagging crews.

Apparently the fish off San Diego in May had moved northward by July, replacing the San Pedro Bay group, which in turn, was showing up in Santa Monica Bay. Northward-moving Mexican fish first appeared at scattered points in June and July, arriving en masse off Ensenada and southern California in August. It is a moot point whether one group forced the other to move northward, or whether they simply replaced each other. One fact appears clear, some co-mingling of groups took place at all times and in most areas.

The number of tag returns per-unit-area, was compared with the total barracuda catch from the same areas (California Department of Fish and Game, 1952) on a monthly basis and for the entire season. In general, tagged barracuda were recaptured in areas of highly concentrated fish. The trend, however, was weak and did not hold for many heavily fished regions with large aggregations of barracuda such as Santa Catalina Island. No tags were recovered from this area although a partyboat skipper reported sighting one on a fish in the water. This fish responded to live chum but refused lures and capture.

The returns of California releases were grouped by total length and distance traveled to determine whether or not there was differential migratory behavior by size or age. No relationship was apparent for length categories ranging between 500 and 1000 mm. Small as well as large barracuda either moved equal distances or remained in the area of release for like periods of time.

A rough idea of the rate of movement can be gleaned from the elapsed number of days at liberty and the straight line distances between points of release and recapture. These calculations indicate rates ranging from 0 to 5.1 miles per day. The latter figure is based on relatively short time intervals and minimum distances. Only two fish, one each from California and Mexican release lots, attained this estimated maximum rate. Supporting the 5 miles per day figure were five additional barracuda that moved between 4 and 5 miles per day. The bulk of the recaptures migrated at indicated rates of only 1 to 2 miles per day. Probably barracuda which are on the move travel at slightly faster rates than our tag returns indicated, perhaps between 6 to 10 miles per day.

Little can be said regarding the 620 tagged barracuda released in Mexico by the *Alaska* in August and September 1959 because there were no returns, probably due to the lack of fishing in the area.

3.3. Results of 1959 Tagging

3.3.1. May:

The seven May recoveries from California releases the same month, were typical first returns, being of short duration and exhibiting little movement. One exception was a barracuda that traversed 50 straight-line miles from Horseshoe Kelp north to Point Dume in 10 days. Its 5-mile-per-day rate was one of the fastest migrations of all barracuda recovered in our tagging study (Figure 11).

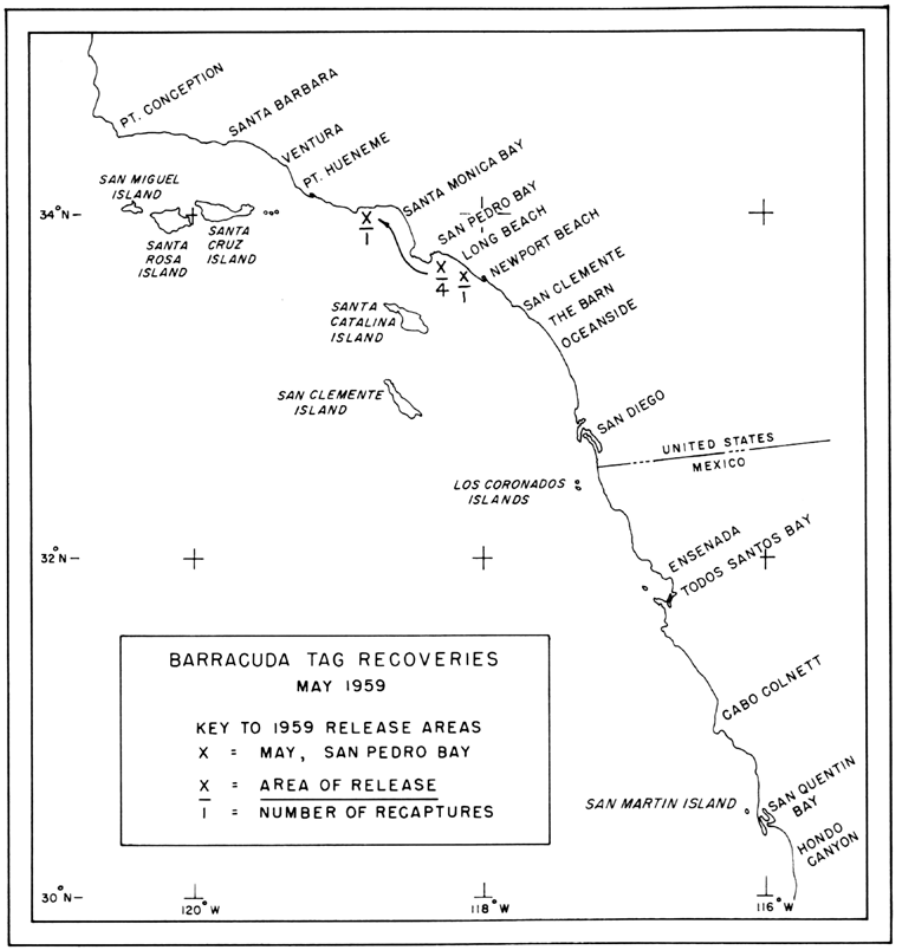

FIGURE 11. Recovery locations of tagged barracuda released in May and recaptured in May 1959.

FIGURE 11. ***Recovery locations of tagged barracuda released in May and recaptured in May 1959.***

3.3.2. June:

By the end of June the barracuda released in the Horseshoe Kelp-Huntington Flats area had begun to disperse along the coast. Seven fish (0.7 percent of the tag lot) had migrated northward into Santa Monica Bay while 12 (1.2 percent) were retaken at scattered points as far south as Los Coronados Islands. Many fish remained in the area of release as evidenced by 17 barracuda (1.7 percent) recaptured there.

One barracuda, tagged and released in the central portion of Santa Monica Bay in May, was recovered in June about 16 miles to the northwest.

Four barracuda from 150 released off the Barn in May, were recaptured in June. Three of these had moved northward, but one migrated south.

Our Mexican releases began showing up in June, first in the Ensenada area, then as far north as Dana Point (Figure 12).

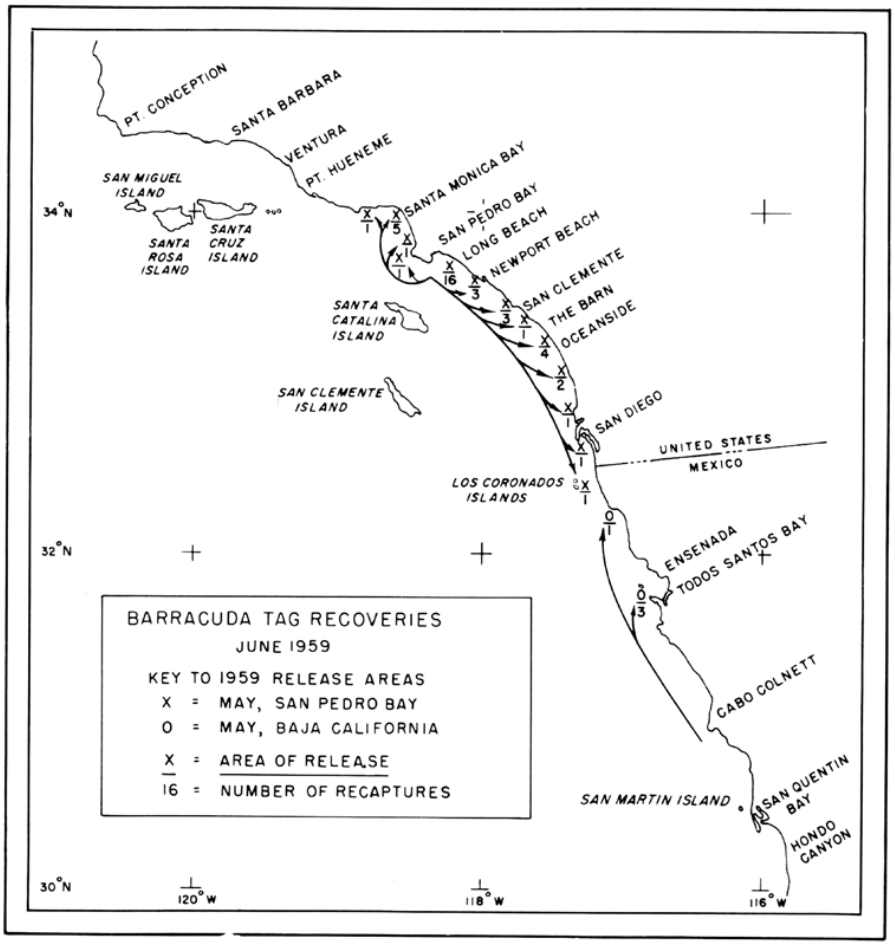

FIGURE 12. Recovery locations of tagged barracuda released in May and recaptured in June 1959.

FIGURE 12. ***Recovery locations of tagged barracuda released in May and recaptured in June 1959.***

3.3.3. July:

July recoveries revealed a strong northward movement from our three major tagging areas: San Pedro Bay, the Barn, and Mexico. The tag lot from San Pedro Bay continued moving into and beyond Santa Monica Bay, showing up as far north as Santa Barbara and westward to Anacapa Island. The only barracuda recovered in July from the Barn group was captured off Huntington Beach.

Cape Colnett (Mexico) fish were taken at four widely separated points along the coast: Todos Santos Bay, the Los Coronados Islands, San Pedro Bay and Santa Monica Bay. These northward migrations support the trend revealed by the June recoveries (Figure 13).

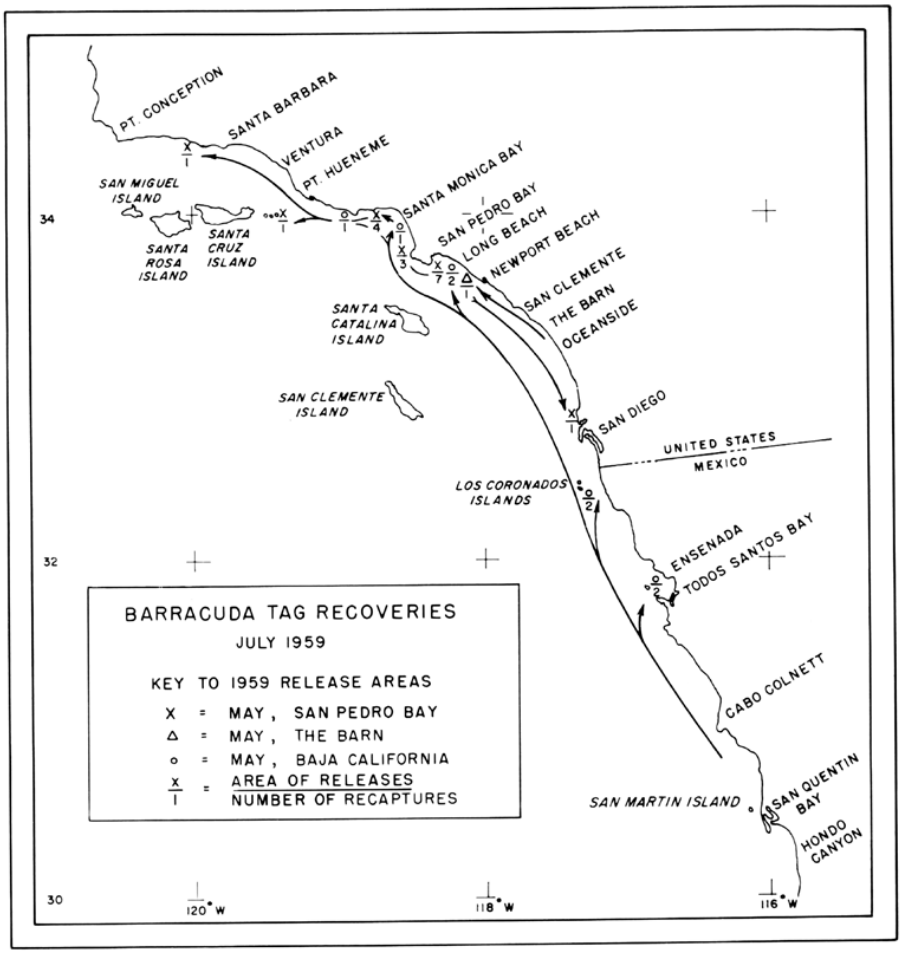

FIGURE 13. Recovery locations of tagged barracuda released in May and recaptured in July 1959.

FIGURE 13. ***Recovery locations of tagged barracuda released in May and recaptured in July 1959.***

3.3.4. August:

A dominant feature of the August recoveries was the widespread occurrence of the Mexican tag lot in southern California waters. of equal significance was the north-south dispersal of the Barn releases, and the absence of the San Pedro Bay tag group, except for two fish which did not move (Figure 14). A plausible explanation for the disappearance of the latter group would be that they had continued migrating northward and were generally unavailable to the sportfishing fleet. Subsequent recoveries of this tag lot off Point Sur in October and Pismo Beach in November support this conclusion.

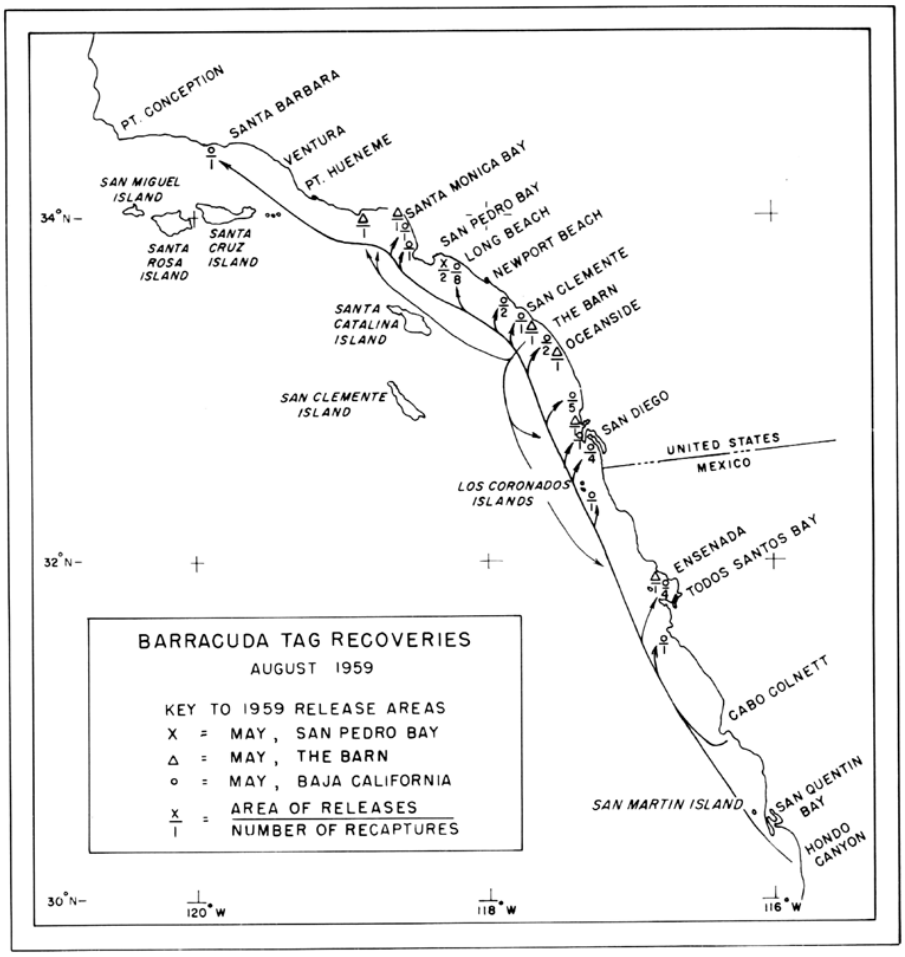

FIGURE 14. Recovery locations of tagged barracuda released in May and recaptured in August 1959.

FIGURE 14. ***Recovery locations of tagged barracuda released in May and recaptured in August 1959.***

3.3.5. September:

A decline in September recoveries did not result from reduced fishing effort, because total angler days dropped only 5.06 percent compared to a 59.95 percent drop in barracuda catch. Thus the reduced number of tag returns appears to have reflected the size of the barracuda population available off southern California.

Tags were recovered from Point Dume to Ensenada, with the Mexican tag lot predominating and repeating their distributional pattern of August.

September also saw the first returns from our July and August tag releases. These fish were taken relatively close to the points of release in Santa Monica Bay and San Pedro Bay (Figure 15).

The crew of the *Alaska* recovered two tagged barracuda on September 3, 1959, off San Martin Island, Baja California, while fishing for barracuda to tag. These fish were from the May 19, 1959, releases off

Cape Colnett, about 30 miles to the north. Since these were the only recoveries in this area, their migratory patterns are not clear.

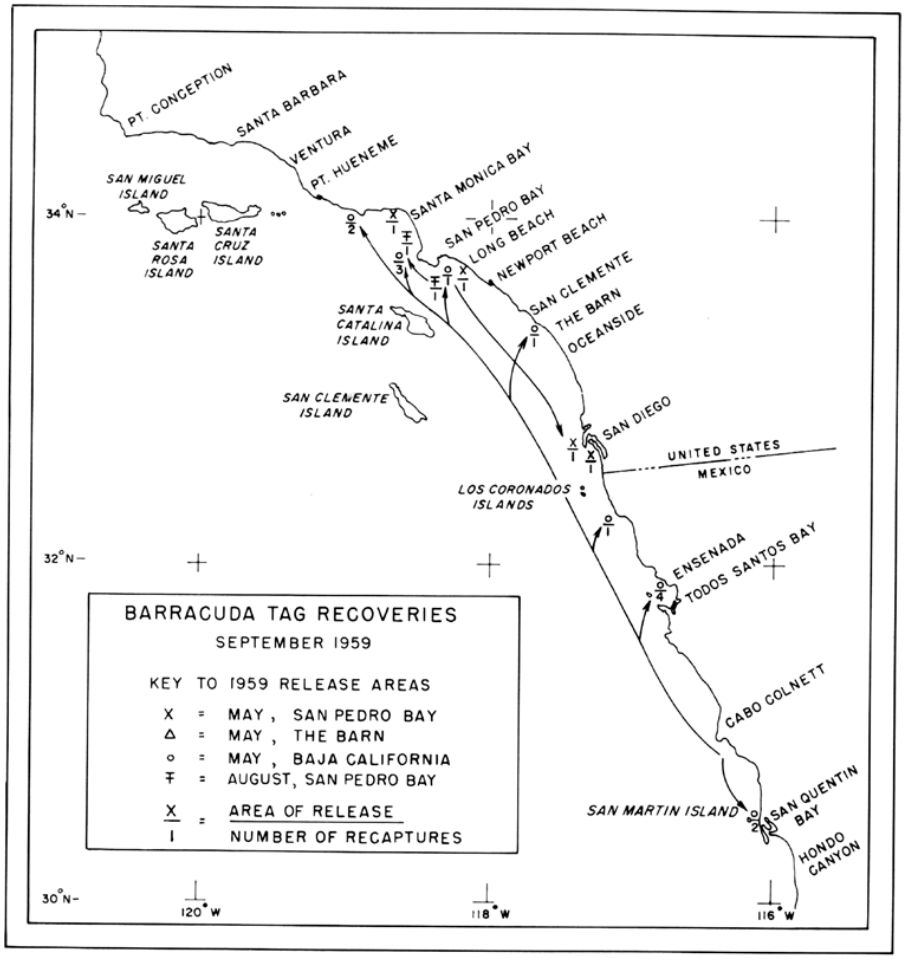

FIGURE 15. Recovery locations of tagged barracuda released in May and August and recaptured in September 1959.

FIGURE 15. ***Recovery locations of tagged barracuda released in May and August and recaptured in September 1959.***

3.3.6. Fall Months:

Only five barracuda were recaptured in October. A Point Sur return, by a commercial fisherman, represented the northernmost recovery (it had been released off the Barn). Two of three recoveries made in northern Santa Monica Bay had been released there in July and August; the third fish was from our May releases in San Pedro Bay. We did not receive recovery information on one tag.

November returns (9) were widespread, ranging from Pismo Beach, California, to Santo Tomas Point, Baja California. The returns from the extreme ends of the range were from fish tagged off the Barn.

Four December tag returns were all from California releases made in May, July, and August. These recaptures were close to their points of release, indicating that a fair portion of the spring barracuda population was still in California waters.

3.4. Recoveries During 1960

The 15 tagged barracuda recovered during 1960 by sport and commercial fishermen were scattered from northern Santa Monica Bay to Todos Santos Bay during January through September. Four winter and early spring returns provided evidence of a wintering population off southern California. The 1960 sport fishery peaked in June and July, and there was a corresponding increase in tag returns (four and three respectively). Recoveries during these two months were from approximately the same area of release.

The final two recoveries of tagged fish were taken early in September 1960, within a day of each other, but 157 miles apart. One, recaptured in Santa Monica Bay, had been released 484 days previously in San Pedro Bay; the second recaptured in Todos Santos Bay, was released off Cape Colnett 476 days earlier.

3.5. Tagging Conclusions

The 173 barracuda tag returns during 1959 and 1960 indicated that:

1) Fish off northern Baja California and off southern California intermingle and are essentially one population. Conditions that were beyond the scope and control of our investigation left unanswered the nature of the relationship between the groups of barracuda off southern California with those off central and southern Baja California (from Cedros Island south).

2) There was a decided northward movement of barracuda in the summer of 1959 and a possible southward migration in the fall.

3) Part of the barracuda population moved about during the summer months, ranging up to 100 miles north or south from points of release. Other portions of the population remained in the original areas of release and showed a tendency to remain through the winter.

4. CATCH-PER-UNIT-OF-EFFORT

We found it was desirable to obtain representative catch-per-unit-of-effort values for the barracuda fishery, so they could be used as an index of relative abundance and as an aid in estimating other population parameters.

Catch records of the commercial barracuda fishery were searched for boats that could be used as a standard or base in calculating catch-per-unit-of-effort values. The attempt was unsuccessful because diverse fishing gear and practices such as gill netting, trolling, and aerial scouting made inconsistencies which could not be compensated for. In addition numerous part-time fishermen were involved in the fishery, and frequent shifting by "regular" fishermen to more lucrative fisheries, such as albacore and white seabass, even at the peak of the barracuda season. In fact, only one vessel fished consistently for a 10-year period. Although four or five boats operated a minimum of 5 consecutive years, their catches were unsuitable for analysis

because the groups of years differed, and there were several changes of ownership.

The catch-effort data of the sportfishing fleet did not at first appear promising, due to the relatively short span of annual records available and the large number of species involved. For example, during any one day barracuda and four or five other species of fish may be actively pursued; under these circumstances it is not possible to assign correct effort values to each. However, preliminary catch-per-unit-of-effort computations for a few randomly chosen areas, made without a division of effort, appeared promising. An investigation into sportfishing practices revealed several factors favoring use of uncorrected data. It was found, for example, that barracuda are highly desirable as a game fish thus insuring constant pursuit by almost all segments of the southern California sport fleet. Even special albacore cruises take fair numbers. This fact permitted two assumptions of basic importance: (i) enough effort was directed at barracuda for us to assume that total effort was, and (ii) records of effort wherein no barracuda were caught could be considered as indicating there were no barracuda in the area, particularly when the effort represented more than one cruise and was distributed over a broad area for a long period of time.

Only sport-catch records originating south of Point Conception were used, since they encompassed the primary range of the fish and its fishery in California waters (Tables 6 and 7). In recent years, the catch of barracuda north of Point Conception has been insignificant, although indicative of environmental changes (Radovich, 1961).

The calculated catch-per-unit-of-effort values, expressed in numbers of barracuda-per-angler-day, appear to be a good index of relative abundance of the exploitable population within the range of the southern California fleet. Monthly averages, which ranged from 0 to 5.78 barracuda-per-day-per-angler, varied more than the annual values, 0.24 to 3.09. In general, the magnitude of the monthly values of any given year were consistent with its annual figure, i.e. when an annual value was low all its monthly values were low and vice versa (Table 8). These figures are not applicable to the entire population in the eastern Pacific Ocean because the barracuda fishery operates in only a portion of the barracuda's primary range, and never exploits the entire population simultaneously.

Catch-per-unit-of-effort values also provides another dimension in the description and analysis of an exploited resource. The common base incorporated in yield figures permits direct comparisons in time and by areas. The values also help reveal situations not readily apparent in gross catch or effort data. Contrasting examples of the latter are evident in the data gathered during the course of our study. In 1958, sport and commercial barracuda landings paralleled each other, peaking in a bimodal fashion: March-April, and July-August (Figure 7). The catch of barracuda per angler day indicated an abundance of fish during the same two periods: 2.66 in April, and 2.58 in August. The June level of 1.28 fish per day corresponds to a similar drop in the commercial catch. The monthly index of abundance, however, reveals a different picture for 1960 when the two fisheries again paralleled each other. Landings peaked in June of 1960, but the barracuda

TABLE 6

Numbers of Barracuda Caught by the Partyboat Fleet in Southern California Waters [1]

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Totals
1947			2,721	18,776	98,792	233,020	216,617	81,630	12,688	10,209	2,996		677,499
1948	767	1,068	1,583	9,370	35,072	109,949	151,699	46,856	20,385	6,021	983	4	383,757
1949			1,047	2,954	19,128	182,293	98,536	43,340	12,868	2,717	3,540		366,423
1950	1,314	1,243	436	3,209	11,398	51,543	107,307	45,007	9,436	8,235	3,210	42	242,380
1951		33	155	3,761	18,037	77,786	67,218	33,527	24,979	30,614	13,280	28	269,418
1952	1	42	3,641	9,324	44,516	82,155	72,435	90,185	31,185	2,488	578	12	336,562
1953			1,387	8,213	20,374	29,137	63,863	27,908	17,616	1,703	54		166,478
1954		1,044	2,003	15,268	26,999	63,199	98,283	56,515	15,590	2,078	70		281,049
1955			3,059	7,215	15,534	69,862	31,364	19,482	7,501	922			154,939
1956		166	503	2,590	9,744	17,103	24,154	24,121	7,150	1,446	241		87,218
1957		244	271	3,120	19,867	86,516	53,443	133,110	195,352	50,480	22,168	12,489	577,060
1958	12,080	14,041	22,792	81,072	112,179	61,446	159,787	208,941	61,092	27,497	10,835	10,464	782,226
1959	9,177	9,116	17,103	59,080	242,892	290,031	285,695	159,351	63,817	26,299	18,857	13,561	1,195,579
1960	4,379	7,549	16,241	87,736	125,432	144,103	137,868	104,749	72,520	27,882	15,075	11,826	755,360
1961	7,784	5,111	13,725	23,474	68,716	99,599	66,308	65,872	28,060	7,865	4,386	953	391,853

[1] Point Conception south to the Los Coronados Islands, Baja California.

TABLE 6
Numbers of Barracuda Caught by the Partyboat Fleet in Southern California Waters

TABLE 7

Number of Angler Days Expended Aboard the Partyboat Fleet in Southern California Waters [1]

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Totals
1947	1,774	2,404	11,096	24,934	43,864	60,587	64,621	64,316	29,922	10,521	3,140	966	318,175
1948	1,317	3,009	7,103	20,635	46,307	60,389	83,602	75,468	33,491	11,661	5,224	2,099	351,035
1949	1,841	3,261	8,021	26,411	56,756	74,357	91,353	73,107	36,693	13,192	8,204	2,275	395,830
1950	3,360	5,340	10,437	34,560	45,089	69,124	112,492	86,938	37,644	19,406	9,102	6,695	440,187
1951	3,215	3,933	9,630	27,570	41,435	73,163	96,709	85,447	54,774	28,340	13,120	2,545	439,881
1952	2,259	4,360	6,832	28,008	65,429	75,060	103,333	109,120	41,484	15,105	4,166	1,749	410,887
1953	2,327	3,623	7,808	21,921	52,401	62,251	92,833	81,521	30,964	11,359	5,352	3,019	375,379
1954	3,057	6,133	7,658	27,484	46,947	65,998	89,113	77,527	37,174	17,112	5,859	4,775	388,837
1955	3,964	5,506	11,746	22,954	43,257	57,004	69,884	80,400	31,072	13,747	7,495	3,476	349,605
1956	4,229	5,773	12,210	19,526	33,427	55,264	79,518	84,725	42,205	15,990	7,815	4,918	365,600
1957	3,251	6,403	17,223	31,916	40,102	64,297	75,550	79,182	59,627	29,286	15,329	7,658	429,815
1958	9,396	7,875	10,815	30,522	51,250	48,000	71,591	81,085	49,561	27,474	10,332	9,077	406,978
1959	9,687	8,804	21,080	35,336	44,349	50,190	61,415	55,825	53,000	23,322	14,464	8,175	386,547
1960	7,213	8,811	16,229	34,331	51,167	62,759	69,437	66,342	47,000	24,798	7,981	6,352	402,920
1961	9,937	9,132	10,958	23,131	37,353	51,396	96,662	72,126	39,025	19,889	6,477	5,555	381,644

[1] Point Conception south to the Los Coronados Islands, Baja California.

TABLE 7
Number of Angler Days Expended Aboard the Partyboat Fleet in Southern California Waters

TABLE 8

Numbers of Barracuda Caught Per Angler Day from the Partyboat Fleet in Southern California Waters [1]

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
1947			.25	.75	2.25	3.85	3.35	1.27	.42	.97	.95		2.13
1948	.58	.36	.22	.46	.76	1.82	1.81	.62	.61	.52	.19		1.09
1949			.13	.11	.34	2.45	1.08	.59	.35	.21	.43		.93
1950	.39	.23	.04	.09	.25	.75	.95	.52	.25	.42	.35	.01	.55
1951		.01	.02	.14	.44	1.06	.70	.39	.46	1.08	1.01	.01	.82
1952		.01	.53	.33	.68	1.09	.70	.82	.75	.16	.14	.01	.82
1953			.18	.37	.39	.47	.69	.34	.57	.15	.01		.44
1954		.17	.26	.56	.58	.96	1.11	.73	.42	.12	.01		.72
1955			.26	.31	.36	1.23	.45	.24	.24	.07			.44
1956		.03	.04	.13	.29	.31	.30	.28	.17	.09	.03		.24
1957		.04	.02	.10	.50	1.35	.71	1.68	3.28	1.72	1.45	1.63	1.34
1958	1.29	1.78	2.11	2.66	2.19	1.28	2.23	2.58	1.23	1.00	1.05	1.15	1.92
1959	.95	1.04	.78	1.69	5.48	5.78	4.65	2.85	1.20	1.28	1.30	1.66	3.09
1960	.61	.86	1.00	2.56	2.43	2.30	1.99	1.58	1.54	1.12	1.89	1.86	1.88
1961	.78	.56	1.25	1.01	1.84	1.94	.69	.91	.72	.40	.68	.17	1.03

[1] Point Conception south to the Los Coronados Islands, Baja California.

TABLE 8
Numbers of Barracuda Caught Per Angler Day from the Partyboat Fleet in Southern California Waters

per angler day computations indicate they were more abundant in April: 2.56 in April, 2.30 in June.

During the 15-year period 1947–1961, barracuda abundance showed distinct and consistent trends strongly associated with environmental conditions. During the warm-water years 1958–1960, barracuda were at a significantly higher level of abundance, 1.34 to 3.09 per day, than during the long cool period from 1949 to 1956, when their abundance steadily declined from 1.09 to 0.24.

A positive relationship was demonstrated between the catch-per-angler-day of the sport fleet, the total sport and commercial catch, and the average (annual) daily sea surface temperature off Scripps pier (Figure 16). In general, all three factors paralleled each other, giving a strong indication that barracuda are motivated by or respond to temperature changes of even the slightest magnitude.

An interesting variation of the temperature-catch relationships is seen by comparing the average daily winter (December, January, and February) temperature off Scripps pier and the subsequent seasons' total barracuda catch (Figure 17). The positive correlation is not precise enough for pinpoint catch predictions, but general trends and rough estimates of potential catch can be calculated using the formula derived

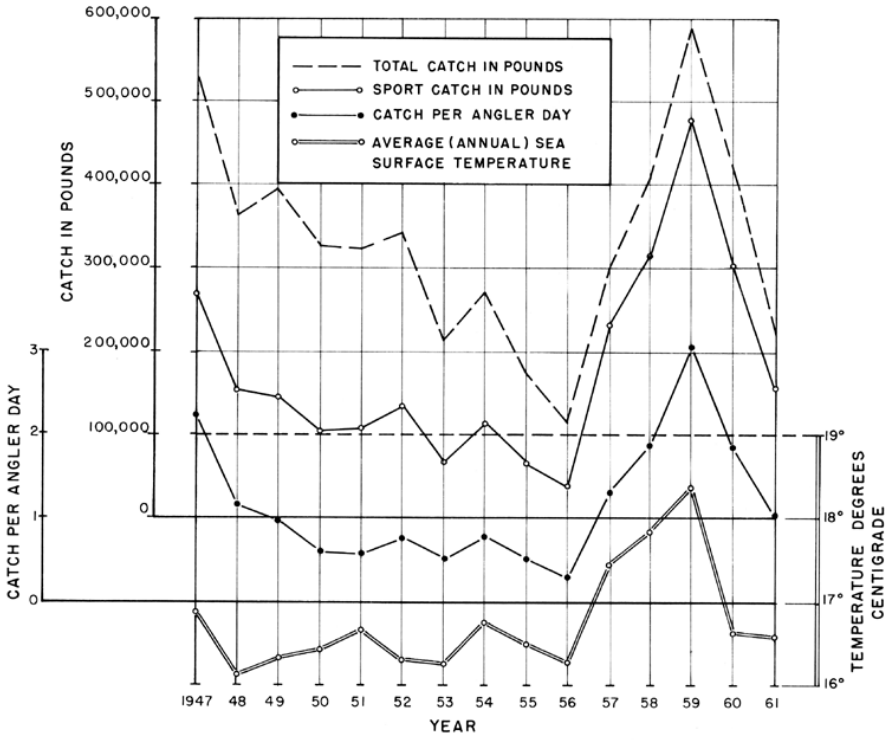

FIGURE 16. The occurrence of barracuda in southern California (as indicated by the total catch in pounds, the sport catch in pounds, or the catch-per-angler-day aboard the sportfishing partyboats) is closely associated with environmental conditions as indicated by the average daily sea surface temperature at Scripps pier, La Jolla, California.

FIGURE 16. The occurrence of barracuda in southern California (as indicated by the total catch in pounds, the sport catch in pounds, or the catch-per-angler-day aboard the sportfishing partyboats) is closely associated with environmental conditions as indicated by the average daily sea surface temperature at Scripps pier, La Jolla, California

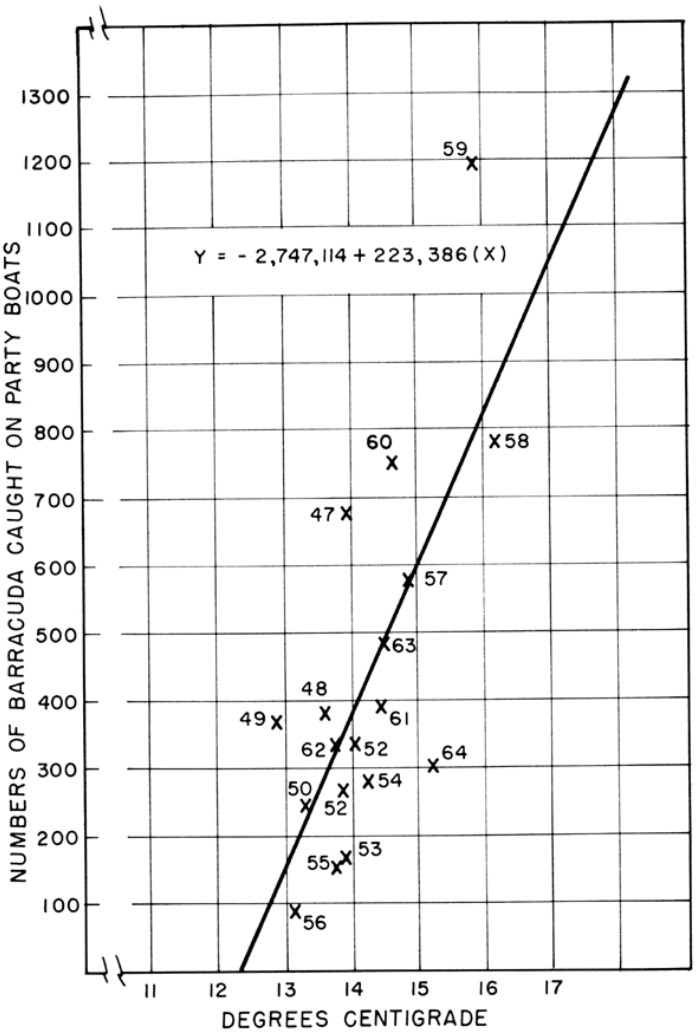

FIGURE 17. The least squares regression line formed by plotting the average daily sea surface temperature for December, January, and February, and the number of sport-caught barracuda the following season indicates a positive correlation between the two factors. The formula of the line Y = −2, 747, 114 + 223, 386 X plus the average winter temperature at Scripps pier (the X factor), can be used to predict the sportfisherman's catch the following season.

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from the linear regression of the data (computed by least squares) for the years 1947 through 1964: $Y = a + b(X)$ Y = estimated sport (partyboat) catch in numbers of barracuda. X = average daily sea surface temperature for December, January, and February at Scripps Institution of Oceanography pier. a = -2,747,114 b = 223,386

The above relationships, as well as others discussed recently by Radovich (1961), will hold true only as long as fishing pressure remains light and sporadic in Baja California. Any sustained or marked changes in exploitation rates in this area should be accompanied by additional studies and re-evaluations of regulations.

5. POPULATION PARAMETERS

Estimates of the various parameters describing the barracuda population off southern California must be of a conditional nature, since the resource is not exploited throughout its range. Further limitations on the values result as a consequence of the variance between barracuda behavior and the restrictions of the mathematical models used in analysis. This type of problem is recognized and faced by all marine fisheries investigators, and is one which has yet to be resolved. Its solution is beyond the intent of this paper. The best available estimates, however, assist in describing and evaluating the resource and in analyzing the effects of existing regulations or any proposed changes.

5.1. Growth

Walford (1932) adequately described and discussed the growth of barracuda in terms of weight at length, and length at age. For the usual allometric weight-length formula, $W = aL^b$, he derived the following values, $W = .003962\ L$ 2.983. Mean lengths at age, however, were presented only through the 6th year.

The von Bertalanffy growth equation, developed after Walford's work, expresses the length at age parameter in concise mathematical terms and imparts physiological meaning (Beverton & Holt, 1957 and 1959). This equation was fitted[1] to our 1960 age length data (it had the smallest estimated variance) with the following results,

$$l_t = L_\infty [1 - e^{-k(t-t_o)}]$$

L_∞	= 1022.54	Standard Error	17.07
k	= .24924	Standard Error	.013636
t_o	= −.7689	Standard Error	.094127

EQUATION

Standard error of the estimate 45.3354

[1] Programmed by Norman J. Abramson and run on the I. B. M. 7090 computer at Western Data Processing Center, University of California at Los Angeles.

5.2. Survival Rates

Annual survival rates for fully recruited barracuda, age 5 and older, in the sport fishery, in the commercial fishery, and in the two combined, were calculated by the method of Robson and Chapman (1961). The computations are based on the number of fish by age in each fishery as determined by the percent composition from routine sampling (Table 3). This approach to estimating survival rates was chosen over several alternative techniques because the sport and commercial results could be compared directly and the two coalesced into one estimate (Table 9).

The basic importance of survival rate figures is in their use in computing mortality rates and in analyzing potential yield in relation to various management proposals (discussed in the following sections).

Without a base for comparison, it is difficult to evaluate the survival rate computations properly. Survival rates for barracuda 5 years old and older for the combined sport and commercial fisheries were: 1958, .45163; 1959, .49893; and 1960, .51334. The values for the sport fishery alone had a smaller range than the commercial fishery, or the two combined: 1958, .46697; 1959, .48369; and 1960, .48241. The range for the commercial fishery was much wider than for the sport fishery, or the two combined: 1958, .37794; 1959, .54490; and 1960, .53771.

The low value of .37794 for the commercial fishery in 1958 appears to be out of line with the other values. It would be gross speculation to attempt to elucidate this phenomenon in light of the sketchy data, but some of the pertinent factors influencing this estimate, as well as all the others, are sampling error, availability, environmental changes, and variations in year-class strength.

TABLE 9

Estimated Rates of Survival and Mortality Based on Numbers of Barracuda Age Five and Older in the Catch

	Survival rate[2] s	Standard error of s	Instantaneous total mortality coefficient[3] Z	Beverton and Holt's method[1]		
				Instantaneous total mortality coefficient Z	Fishing mortality coefficient F	Natural mortality coefficient M
Sport fishery						
1958	.46697	.000448	.76357	.75107	.56769	.18338
1959	.48369	.000126	.72567	.72257	.53919	.18338
1960	.48241	.000780	.72981	.74541	.56203	.18338
Commercial fishery[4]						
1958	.37794	.000958	.97551			
1959	.54490	.000696	.60697			
1960	.53771	.000689	.61990			
Sport and commercial fisheries						
1958	.45163	.000409	.79407			
1959	.49893	.000353	.69515		(.5111)[5]	(.18405)[5]
1960	.51334	.000517	.66748			

[1] Calculated from catch, effort, and age composition data; method of Beverton and Holt (1957), (as described by Ricker, 1958).
[2] Method of Robson and Chapman (1961).
[3] From tables of Natural or Naperian logarithms.
[4] Fishing and natural mortality coefficients for the commercial fishery were not calculated because the units of effort were ill-defined and poorly recorded. There were insufficient tag returns from this fishery to compute a meaningful value.
[5] Calculated from tag return data, method of Beverton and Holt (1957). All the tag returns from all sources in California waters yielded a fishing mortality coefficent of .5786.

TABLE 9

Estimated Rates of Survival and Mortality Based on Numbers of Barracuda Age Five and Older in the Catch

5.3. Mortality Rates

Instantaneous total mortality coefficients (Z)[2] for the years 1958, 1959, and 1960 were derived from formulae describing the general relationships between survival and mortality (Ricker, 1958: 24–25).

Survival rate = $s = N_1/N_o = e^{-z}$ Instantaneous total mortality coefficient = $Z = (F + M)$ =exponent ($-z$) with sign changed N_o, N_1, ..., N_r = number of fish in year-class. F = instantaneous fishing mortality coefficient M = instantaneous natural mortality coefficient

Since the estimates of Z are derived directly from the survival rate figures (table of Natural or Naperian logarithms) similar patterns and trends are evident. The sport fishery values are all close to each other: 1958, .76357; 1959, .72567; and 1960, .72981. In the commercial fishery, the 1958 estimate again appears to be an anomaly, .97551, compared with .60697 for 1959, and .61990 for 1960. The combined sport and commercial fishery estimates vary less than the commercial alone, but more than the sportfishery: 1958, .79407; 1959, .69515; and 1960, .66748.

Components of the instantaneous total mortality coefficient, namely the result of fishing (F) and from natural causes (M), were estimated by two different methods using independent data.

5.3.1. *Mortality Estimates from Catch, Effort, and Age Data*

Beverton and Holt's (1957) iterative method of fitting a linear equation to successive estimates of total mortality (derived from age composition data) and effort was used to calculate estimates of instantaneous coefficients of total mortality, of fishing mortality, and of natural mortality. Detailed catch and effort statistics gathered routinely for the sport fishery (Baxter and Young, 1953), plus the results of sampling the catch for length and age composition in 1958, 1959, and 1960 supplied the required basic data. Step by step computations followed Ricker's (1958) description of the method with one exception: survival rates for 5-year-old and older fish were calculated by the Robson and Chapman (1961) technique instead of linking the year-classes from year to year.

The computations yielded a natural mortality coefficient of .18338, which is assumed to be constant from year to year, and fishing mortalities of .56769 for 1958; .53919 for 1959; and .56203 for 1960. Here again, patterns of small changes or differences are evident.

I was unable to calculate estimates of fishing and natural mortality for the commercial fishery and for sportfishing from private boats by the Beverton and Holt (1957) method, because basic catch and effort data were not in our records, and we were unable to gather them during our limited investigation.

[2] The standard notations and definitions recommended by Holt, Gulland, Taylor, and Kurita (1959) are used in this paper.

5.3.2. Mortality Estimates from Tagging Data

The second approach to estimating instantaneous coefficients of fishing and natural mortality was based on mark and recapture data, a well-established technique discussed at length by Beverton and Holt (1957), Ricker (1958) and others.

The results of the 1959 tagging experiment were used in Beverton and Holt's formulae for calculating the instantaneous coefficient of fishing mortality (*F*), and for natural mortality plus the other loss factors (*M*).

$$F = \frac{\frac{n_1}{t} \log_e \left(\frac{n_1}{n_2}\right)}{N_o \left(1 - \frac{n_2}{n_1}\right)}$$

$$M = \frac{1}{t}\left[\log_e \frac{n_1}{n_2}\right]\left[1 - \frac{n_1}{N_o\left(1 - \frac{n_2}{n_1}\right)}\right]$$

EQUATION

Where: n_1, n_2 = number of marked fish recaptured in a given period N_0 = number of marked fish liberated at time zero t = recapture period

Only June and July 1959 returns from California releases were used in the calculations because they were made before the mass of migrating fish from Mexico appeared in southern California waters. The returns from Mexican releases were not used because we could not determine, with precision, the number of tagged barracuda that emigrated or that were captured in Mexico.

A sportfishing mortality value of .5161 was derived for the 1959 partyboat fleet. There were insufficient tag returns from the commercial barracuda fishery to compute a meaningful value for this group alone. The sport and commercial fisheries yielded a combined fishing mortality value of .5111, and a natural mortality of .18405. The returns from all fishing activity (partyboats, private boats, commercial fisheries, piers, etc.) yielded a value of .5789.

The mortality estimates computed by the two methods are remarkably close, particularly the natural mortality coefficients: .18338 and .18405. Since they were derived from independent sets of data, it seems reasonable to assume that they are close to the true values.

5.4. Yield

Beverton and Holt (1957) have synthesized the parameters of recruitment, growth, and natural and fishing mortality into a theoretical population model applicable to marine fish. Their mathematical statement of yield (in weight) per recruit is particularly useful in the analysis of a fishery, because it provides a concise description of current situations and it can be manipulated for predictive purposes.

Yield-per-recruit computations for the barracuda resource and its fisheries indicate that an optimum harvest in weight could be obtained if cropping were to start at age 4, or at a total length of 27 inches (Figure 18). The current legal minimum size of 28 inches, in effect since 1940, represents fish in their 5th year of life (between 4 and 5 years old) and in terms of yield is near optimum.

The commercial barracuda catch, at least during our investigative period, was composed predominantly of 5- and 6-year-old fish. Indications

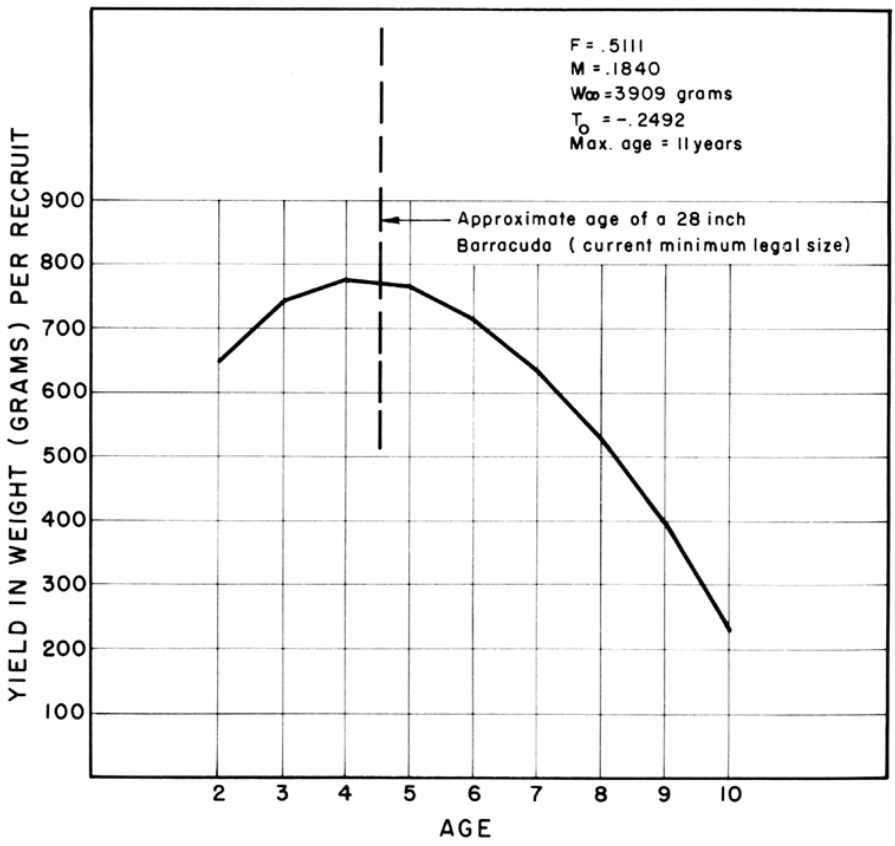

FIGURE 18. Yield-per-recruit of barracuda as a function of age at first entry into the fishery.

FIGURE 18. Yield-per-recruit of barracuda as a function of age at first entry into the fishery

are that current practices, including legal and trade requirements, are in harmony with conservation and full utilization objectives. One possible source of variance, which unfortunately was not measured, was the California landings of barracuda caught in Mexican waters. Landings from this source during the period of study were the lowest on record.

Sportfishermen, in contrast to commercial operators, may possess two barracuda shorter than legal minimum size. Our data indicate that undersized fish, or "pencils" as they are commonly called, are not kept in quantity when large fish are abundant. This was the situation in 1958 and 1959 when the barracuda population was composed primarily of 5- and 6-year-old fish. In 1960, the age composition of the barracuda population changed markedly as recruits from the successful 1957 and 1958 local spawning became available. Thus, the relative abundance of older fish declined, and 2- and 3-year-old "pencils" dominated the catch.

The regulation permitting sportsmen to possess two barracuda shorter than the legal minimum size is at variance with true conservation, and maximum utilization objectives, since these young fish (predominantly age 2 and 3) are still in a period of rapid growth, not only in weight and length, but in reproductive capacity.

5.5. Population Size

An estimate of the size of the barracuda population off southern Californa is largely of academic interest. We are looking at an unknown portion of the total resource, and numbers of fish in this portion are strongly influenced by environmental factors. However, population estimates do provide additional background information for management considerations and also provide a reference base for the more indicative index of abundance (catch-per-unit-of-effort).

The annual mean number of barracuda in southern California waters was estimated for 1958, 1959, and 1960 by using the catch formula listed by Ricker (1958: 28, formula 1.12).

$C = F N$ Where: C = Catch F = Instantaneous coefficient of fishing mortality N = Annual mean number of fish in population

Substituting into the formula the instantaneous coefficient of fishing mortality with the appropriate total sport and commercial catch in numbers yielded the following estimates:

Year	*Estimated number of barracuda off California*
1958	1,591,817
1959	2,888,239
1960	2,156,186

The estimated numbers are minimal because: (i) actual catches were higher than recorded (no measurements from private boats, barges, or piers), and (ii) age groups 1 through 4 were incompletely represented in our data.

6. RECOMMENDATIONS

1) The 28-inch minimum size limit should be retained for both the sport and commercial fisheries.

2) No barracuda under the legal minimum size of 28 inches should be permitted in either the sport or commercial bag.

3) Ultimate conservation of the barracuda resource (as well as a number of other vital species) in the eastern north Pacific Ocean will depend upon the cooperative action of the United States and Mexico. Although the current level of exploitation constitutes a significant drain on the resource, it does not appear critical. Additional pressure can be expected with the growth of the human population, not only within the confines of the United States but also Mexico. Since most of the habitat occupied by the barracuda in Mexico functions as a haven or preserve, increased fishing in these areas could rapidly reduce the resource to significantly low levels. From a biological perspective, the time appears ripe to formulate a mutually beneficial agreement between the two countries with the objective to conserve and use wisely the jointly owned barracuda resource.

7. SUMMARY

1) The California barracuda has, for over 70 years, been important to the commercial and sportfishing industries of California and Baja California.

2) From 1958 through 1960, the barracuda sportfishery cropped 10 different year-classes (1949 through 1958) ranging in age from 2 to 9 years. Five- and 6-year-old fish dominated the catches in 1958 and 1959, while in 1960, there was a dramatic change to 3- and 4-year-old fish.

In the same period, the commercial fishery took 4- to 9-year-old barracuda, but ages 5 and 6 predominated.

3) Barracuda off northern Baja California and off southern California intermix and are essentially one population. Conditions beyond the scope and control of our investigation left questions unanswered as to the nature of the relationship between the groups of barracuda off southern California and those off central and southern Baja California (from Cedros Island south).

4) Results of our 1959 marking program revealed a decided northward movement of barracuda in the summer, strongly associated with rising water temperatures, and a probable southward migration in the fall.

5) The number of barracuda caught per-angler-day from the sport-fishing partyboats ranged from a low of 0.24 in 1956 to a high of 3.08 in 1959. These catch-per-unit-of-effort values appear to be indicative of the abundance of barracuda off southern California during those years but not necessarily of the entire population in the eastern north Pacific Ocean.

6) There has been a positive correlation between the abundance of barracuda off southern California in any given year and the average daily sea surface temperatures at Scripps pier in the same year. The relationship was demonstrated for averages calculated annually, the first 6 months of the year (Radovich, 1961), and for the 3 winter months of December, January, and February, preceding the fishing season.

7) A rough estimate of the potential barracuda catch can be obtained from the formula $Y = -2{,}747{,}114 + 223{,}386X$: where Y = estimated catch in numbers and X = the average daily sea surface temperature at Scripps Institution of Oceanography pier during December, January, and February.

8) Age-length data for 1960 were used in fitting a von Bertalanffy growth equation, with the following results: $l_t = 1022.54\,(1 - e^{-.24924\,(t-(-.76891))})$

9) Annual survival rates for fully available barracuda, age 5 and older, were computed from age composition data. The values for the combined sport and commercial fisheries were: 1958, .45163; 1959, .49893; and

values for the commercial fishery alone were: 1958, .37794; 1959, .54490; and 1960, .53771.

10) Instantaneous fishing and natural mortality coefficients, *(F* and *M)*, were calculated by the Beverton and Holt (1957) method using catch, effort, and age composition of the catch for the sport fishery only. The instantaneous fishing mortalities for barracuda age 5 and older were estimated to be: .56769 for 1958, .53919 for 1959, and .56203 for 1960. The instantaneous natural mortality coefficient, assumed to be constant from year to year, was estimated to be .18338.

11) Instantaneous fishing and natural mortality coefficients *(F* and *M)*, were calculated from tage returns for various segments of the 1959 barracuda fishery. The instantaneous fishing mortality coefficient for the sport fishery was .5161; for sport and commercial fisheries combined, .5111; and for all types of fishing, .5786. There were insufficient returns from the commercial fishery to compute a meaningful value.

12) Yield-per-recruit computations utilizing Beverton and Holt's (1957) formula indicates that an optimum yield would be obtained if cropping were to begin at age 4. The current minimum size limit of 28 inches represents a fish about 4 ½ years old, which on the yield curve is very close to the theoretical cropping optimum.

13) The annual mean number of barracuda in southern·California waters was estimated to be 1.59 million in 1958, 2.89 million in 1959, and 2.16 million in 1960.

8. REFERENCES

Barnhart, Percy Spencer. 1927. Pelagic fish eggs off La Jolla, California. Univ. of Calif., Bull., Scripps Instit. Ocean., Tech. Ser. 1(8) :91–92.

Barnhart, Percy Spencer. 1936. Marine fishes of southern California. Berkeley. Univ. of Calif. Press, 209 p.

Baxter, John L. and Parke H. Young. 1953. An evaluation of the marine sport fishing record system in California. Calif. Fish and Game, 39(3) :343-353.

Beverton, R. J. H. and S. J. HOlt. 1957. On the dynamics of exploited fish populations. London. Her Majesty's Stationery office, 533 p.

Beverton, R. J. H. 1959. A review of the life spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. *In:* The life span of animals, CIBA Foundation Colloquia on Aging, 5:1–324.

Blunt, C. E. and James D. Messersmith. 1960. Tuna tagging in the eastern tropical Pacific, 1952-1959. Calif. Fish and Game, 46(3) :301–369.

Chadwick, Harold K. 1963. An evaluation of five tag types used in a striped bass mortality rate and migration study. Calif. Fish and Game, 49(2) :64–83.

Clemens, W. A. and G. V. Wilby. 1946. Fishes of the Pacific coast of Canada. Fish. Res. Bd. of Canada, Bull. (68) :368 p.

Clothier, Charles R. 1950. A key to some southern California fishes based on vertebral characters. Calif. Dept. Fish and Game, Fish Bull. (79) :83 p.

Craig, J. A. 1927. Effect of the recent law prohibiting the taking of barracuda in California waters with purse seine and round haul nets. Calif. Fish and Game, 13(1) :18–25.

Felin, Frances and Julius Phillips. 1948. Age and length composition of the sardine catch off the Pacific coast of the United States and Canada 1941–42 through 1946–47. Calif. Dept. Fish and Game, Fish Bull. (69) :122.

Fitch, John E. 1958. offshore fishes of California. Sacramento. Calif. Dept. Fish and Game, 80 p.

Fry, Donald H. and Eldon P. Hughes. 1952. A sampling program for recovery of marked king and silver salmon. Calif. Fish and Game, 38(4) :535–540.

Girard, Charles. 1854. Observation upon a collection of fishes made on the Pacific coast of U.S. by Lieut. W. P. Trowbridge for the museum of the Smithsonian Institution. Acad. of Nat. Sci. Phila., Proc. 7 :144.

Holt, S. J., A. Gulland, C. Taylor, and S. Kurita. 1959. A standard terminology and notation for fishing dynamics. Jour. Cons. Perm. Expl. Mer, 24(2) :239-242.

Limbaugh, Conrad. 1955. Fish life in the kelp beds and the effects of kelp harvesting. Univ. of Calif., Instit. of Marine Res., (55–9) :74.

Miller, Daniel J. 1955. Studies relating to the validity of the scale method for age determination of the northern anchovy: *In* Age Determination of the Northern anchovy Engraulis mordax. Calif. Dept. Fish and Game, Fish Bull. (101) :1–66.

Mosher, Kenneth H. 1950. Description of a projection device for use in age determination from fish scales. U.S. Fish Wild. Serv., Fish Bull. 51(54) :405–407.

Orton, Grace L. 1955. Early developmental stages of the California barracuda, Sphyraena argentea Girard. Calif. Fish and Game, 41(2) :167–176.

Radovich, John. 1961. Relationships of some marine organisms of the northeast Pacific to water temperatures, particularly during 1957 through 1959. Calif. Dept. Fish and Game, Fish Bull. (112) :40–45.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. (119) :300 p.

Robson, D. S. and D. G. Chapman. 1961. Catch curves and mortality rates. Trans. Amer. Fish. Soc., 90(2) :181– 189.

Roedel, Phil M. 1953. Common ocean fishes of the California coast. Calif. Dept. Fish and Game, Fish Bull. (91) :184 p.

Skogsberg, Tage. 1925. Preliminary investigation of the purse seine industry of southern California. Calif. Fish and Game Comm. Fish Bull. (9) :95.

Springer, Victor G. and Andrew J. McErlean. 1961. Tagging of great barracuda Sphyraena barracuda (Walbaum). Trans. Amer. Fish Soc. 90(4) :497–500.

U. S. Government Printing office. 1926. Convention between the United States and Mexico to prevent smuggling and for certain other objects. Washington, D.C. U.S. Govt. Print. off., Treaty Series (732) :10 p.

Van Cleve, Richard and W. F. Thompson. 1938. A record of the pomfret and barracuda from Alaska. Copeia (1) :45–46.
Walford, Lionel A. 1932. The California barracuda (Sphyraena argentea) . Calif. Div. Fish and Game, Fish Bull. (37) :120 p.
Yamashita, Daniel T. and Kenneth D. Waldron. 1958. An all-plastic dart-type fish tag. Calif. Fish and Game, 44(4) :311–317.

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