State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME



# AN EVALUATION OF THE CALIFORNIA BARRACUDA RESOURCE AND ITS MANAGEMENT

by

Donald L. Schultze

MARINE RESOURCES

Administrative Report No. 80-6

April 1981

# AN EVALUATION OF THE CALIFORNIA BARRACUDA RESOURCE AND ITS MANAGEMENT[1/]

by

Donald L. Schultze[2/]

## ABSTRACT

Despite efforts to manage it, the California barracuda, *Sphyraena argentea,* resource has exhibited a marked decline in abundance from levels exhibited prior to 1950. This paper presents a history of the California barracuda fisheries, a summary of its life history and population dynamics; and an evaluation of the resource under current management practices and recommendations for improvements in current management.

Evaluation of the current status of the resource indicates its abundance off southern California is low but slowly improving with a marked improvement in size composition. Management recommendations, when adopted, should help increase the rate of recovery of the California barracuda resource.

---

1/ Marine Resources Region, Administrative Report No. 80-6, April 1981.

2/ Marine Resources Branch, California State Fisheries Laboratory, 350 Golden Shore, Long Beach, CA 90802

# I. INTRODUCTION

The status of the California barracuda, *Sphyraena argentea* Girard (1854), has been of concern to commercial and recreational fishermen, and to fishery managers, since early in the twentieth century. This paper presents a summary of the California barracuda fisheries, life history, and population dynamics; and management recommendations resulting from assessment of fisheries data and monitoring activities during 1972 through 1978.

Early studies were conducted to determine: effects of purse seining on barracuda (Skogsberg, 1925); length-weight and age-length relationships, maturity, fecundity, spawning season, and method of capture (Walford, 1932); length and age composition of the catches, migration, catch per effort, survival rates, yield, and population size (Pinkas, 1966); and historical trends in the fishery (MacCall, Stauffer, and Troadec, 1976).

Landings by sport and commercial fishermen have declined despite a variety of regulations enacted over the years to conserve and manage this resource. A long continuous decline in commercial landings has occurred since the late 1920's. Two periods of major decline in landings by sport anglers occurred from 1948 through 1956 and from 1968 through the present. Concern over declining sport catches during the 1948-1956 period resulted in a management study conducted during 1958 through 1961 (Pinkas, 1966). It was conducted during portions of a period of extremely warm ocean waters accompanied by large increases in barracuda landings (Radovich, 1961). With increased landings the previous concerns were forgotten until the late 1960's when landings again declined and only small barracuda

could be found. This revived interest, in 1969 and 1970, in the strict 28 in. (71.1 cm) size limit proposed by Pinkas in 1966 following a detailed management study. From 1957 until 1971 each sport fisherman could keep two barracuda per day less than 28 in. total length. In March of 1971 for the first time a strict 28 in. size limit became effective and no barracuda less than 28 in. long could be retained in the daily bag limit of fish.

Assessments of the California barracuda resource during the period 1971 through 1973 identified areas needing further investigation and suggested areas for future management (Schultze, 1973, MacCall, Stauffer and Troadec, 1976). Monitoring of catches and size composition of California barracuda proceeded from 1972 through 1978 with the purpose of evaluating effects of the 1971 regulation change on the barracuda population.

## II. Stocks

The California barracuda is the only member of the barracuda family reported from California. It ranges from Cape San Lucas, Baja California, Mexico (Berdegue', 1956) to Prince William Sound, Alaska (Pinkas, 1966). However, in recent years barracuda have seldom been observed north of Pt. Conception, California. Two other species, the Mexican barracuda, *Sphyraena ensis*, and the Gulf barracuda, *S. lucasana*, occur as far north as southern Baja California, Mexico (Berdegue', 1956). The California barracuda is a pelagic schooling predator generally found within a few miles of the mainland and islands. Many undertake annual south-north migrations along the coast in the spring and summer, and the strength of these migrations is correlated with changes in ocean temperature (Radovich, 1961). Results of a study conducted during the late 1950's indicate that the portion of the California barracuda population located south of Pt. Eugenia, B.C., Mexico during the

winter months, does not enter southern California waters during the spring-summer migration. Thus, California fishermen may exploit only the northern portion of the stock in California waters (Pinkas, 1966.

## III. Fisheries

### A. U.S. Commercial Fisheries

Landings: Published records indicate California barracuda have been fished commercially since at least the 1800's (Table 1). Landings increased from 227 metric tons (0.5 million lbs) in 1889 to 1,135 to 1,589 metric tons (2.5-3.5 million lbs) by 1917, then rose dramatically to more than 3,632 metric tons (8.0 million lbs) following World War I when purse seine vessels became active in the fishery (Figure 1). In the 1920's barracuda landings averaged about 3,000 metric tons (6.7 million lbs).

Feelings against the use of nets grew during the 1920's and regulations affecting fishing gear as well as seasonal closures were enacted and then changed at almost every session of the legislature from 1925 to 1935. The decline in barracuda landings that occurred from 1926 to 1935 was attributed to the effects of these regulations, and to the combined results of unfavorable economic conditicns, increased competition from other species of fish, and a possible decrease in the barracuda supply (Janssen, 1937). During the 1930's annual landings averaged 1,464 metric tons (3.2 million lbs), less than half of the average for the 1920's.

An increase in the number of barracuda off southern California due to unusually warm ocean waters during the last half of 1939 through 1941 and wartime demands for protein resulted in an increase in commercial landings through 1945. The increase in the proportion of barracuda landed from Mexico during the 1940's was largely due to a ban effective

TABLE 1. Yearly Commercial Landings of California Barracuda in Pounds.

| Year | California waters | South of state | Total pounds |
|---|---|---|---|
| 1889 | -- | -- | 500,714 |
| 1890 | -- | -- | 511,078 |
| 1891 | -- | -- | 694,793 |
| 1892 | -- | -- | 326,804 |
| 1895 | -- | -- | 979,674 |
| 1899 | -- | -- | 1,191,505 |
| 1904 | -- | -- | 2,159,282 |
| 1908 | -- | -- | 3,205,000 |
| 1915 | -- | -- | 3,592,616 |
| 1916 | 2,226,993 | 460,360 | 2,687,362 |
| 1917 | 2,965,368 | 94,944 | 3,060,323 |
| 1918 | 3,885,691 | 951,593 | 4,837,284 |
| 1919 | 4,038,852 | 1,786,105 | 5,824,957 |
| 1920 | 4,585,388 | 3,615,947 | 8,201,335 |
| 1921 | 4,588,900 | 3,036,262 | 7,625,162 |
| 1922 | 4,721,448 | 1,528,770 | 6,250,218 |
| 1923 | 5,135,824 | 2,064,751 | 7,200,575 |
| 1924 | 4,733,779 | 2,394,744 | 7,128,523 |
| 1925 | 5,976,453 | 2,059,996 | 8,036,449 |
| 1926 | 2,945,169 | 2,077,295 | 5,022,464 |
| 1927 | 4,355,583 | 1,844,156 | 6,199,739 |
| 1928 | 4,385,214 | 2,067,242 | 6,452,456 |
| 1929 | 3,925,899 | 1,302,711 | 5,228,610 |
| 1930 | 3,513,608 | 1,250,158 | 4,763,766 |
| 1931 | 3,336,065 | 841,473 | 4,177,538 |
| 1932 | 2,505,101 | 421,674 | 2,926,775 |
| 1933 | 2,912,152 | 160,810 | 3,072,962 |
| 1934 | 1,801,264 | 381,558 | 2,182,822 |
| 1935 | 2,003,947 | 613,877 | 2,617,824 |
| 1936 | 2,247,858 | 729,984 | 2,977,842 |
| 1937 | 1,799,045 | 1,139,445 | 2,938,490 |
| 1938 | 1,260,790 | 1,269,022 | 2,529,812 |
| 1939 | 2,967,780 | 1,124,274 | 4,092,054 |
| 1940 | 2,545,661 | 1,169,171 | 3,714,832 |
| 1941 | 2,971,349 | 1,230,579 | 4,201,928 |
| 1942 | 2,243,163 | 1,211,374 | 3,454,537 |
| 1943 | 2,382,884 | 1,392,454 | 3,775,338 |
| 1944 | 2,317,430 | 1,330,878 | 3,648,308 |
| 1945 | 1,744,560 | 2,128,697 | 3,873,247 |
| 1946 | 1,637,346 | 1,469,678 | 3,107,024 |
| 1947 | 1,695,867 | 969,878 | 2,665,745 |
| 1948 | 1,100,081 | 1,025,656 | 2,125,737 |
| 1949 | 903,574 | 1,554,110 | 2,457,684 |
| 1950 | 890,435 | 1,367,980 | 2,258,415 |
| 1951 | 670,015 | 1,436,913 | 2,106,928 |
| 1952 | 747,667 | 1,346,539 | 2,094,206 |
| 1953 | 565,942 | 872,904 | 1,438,846 |
| 1954 | 485,946 | 1,076,793 | 1,562,739 |
| 1955 | 322,831 | 818,128 | 1,140,959 |
| 1956 | 50,153 | 702,374 | 752,527 |
| 1957 | 387,143 | 295,523 | 682,666 |
| 1958 | 753,266 | 161,993 | 915,259 |
| 1959 | 1,110,409 | 42,192 | 1,152,601 |
| 1960 | 1,147,831 | 81,837 | 1,229,668 |
| 1961 | 478,362 | 231,017 | 709,379 |
| 1962 | 521,769 | 224,707 | 746,476 |
| 1963 | 347,354 | 31,360 | 378,714 |
| 1964 | 251,025 | 83,115 | 334,140 |
| 1965 | 273,003 | 89,055 | 362,058 |
| 1966 | 233,319 | 85,797 | 319,116 |
| 1967 | 281,224 | 31,960 | 313,184 |
| 1968 | 114,534 | 25,966 | 140,500 |
| 1969 | 70,833 | 3,760 | 74,593 |
| 1970 | 22,508 | 2,080 | 24,588 |
| 1971 | 17,256 | 40 | 17,296 |
| 1972 | 13,915 | 0 | 13,915 |
| 1973 | 37,547 | 58 | 37,605 |
| 1974 | 36,476 | 22 | 36,498 |
| 1975 | 58,458 | 139 | 58,597 |
| 1976 | 161,738 | 353 | 162,091 |
| *1977 | | | 75,802 |

*Preliminary

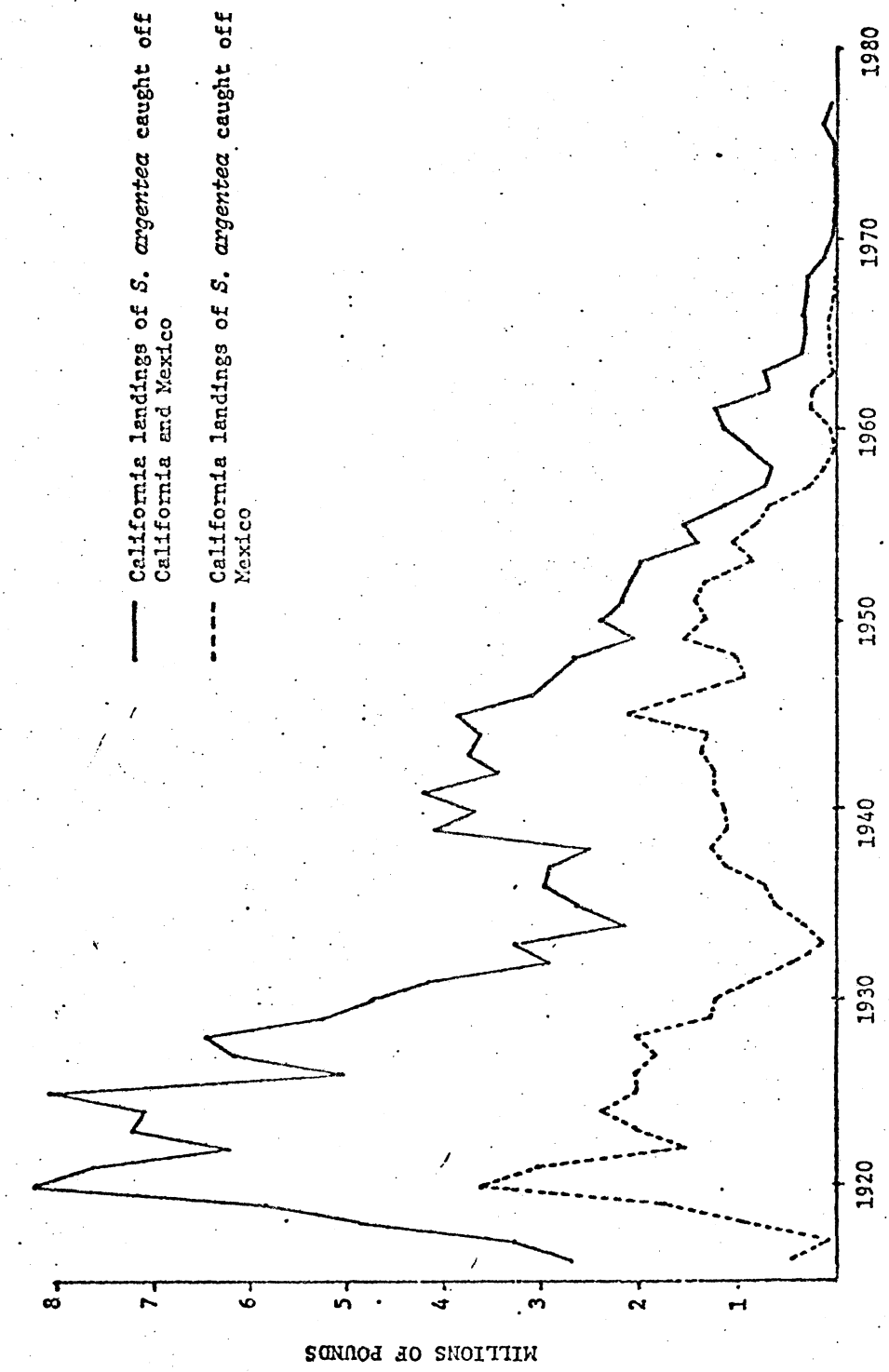


FIGURE 1. California commercial landings of California barracuda from California and Mexico and just Mexico.

in 1940 on purse seine and roundhaul nets in California waters. Catches declined following the war and landings of barracuda averaged 1,498 metric tons (3.3 million lbs) for the 1940-1949 period.

Total commercial landings and the number of boats landing barracuda declined sharply from 1950 through 1956 (Figure 2). By 1956, the four or five remaining purse seiners which had been fishing in Mexican waters as far south as Punta Abreojos dropped out of the fishery leaving the boats using gill nets, trolling gear, and lampara nets to fish commercially. Marked warming of the ocean off California during 1957 through 1959 resulted in a dramatic increase in barracuda availability off southern California, and many boats rushed to enter the commercial fishery increasing the fleet to 315 boats by 1958. During this series of warm water years, landings from Mexico declined due to good local availability of barracuda. Despite this, the average annual landings during the 1950's declined to 639 metric tons (1,409,000 lbs).

Cooling of the ocean waters off California began in 1960 and 1961. Most of the trollers (also termed "jig boats") left the fishery during the 1960's as barracuda became less available off California. Gill net vessels have predominated since 1960, and since 1968 nearly all of the commercial landings of barracuda have been made by gill netters operating between San Diego and Santa Barbara. Average annual landings declined to 209 metric tons (461,000 lbs) during the 1960's and 19 metric tons (41,000 lbs) during the 1970's.

At present, a small fleet of less than 10 boats account for 80 to 90% of the commercial barracuda landings in southern California.

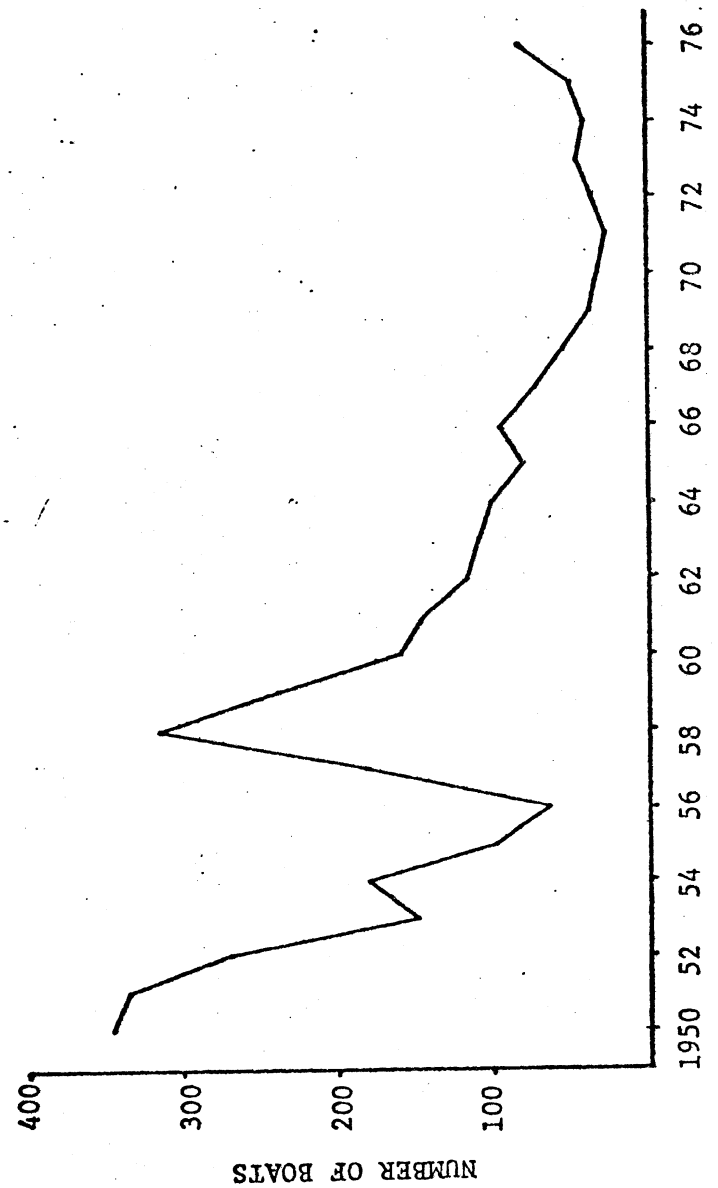


FIGURE 2. Number of commercial boats landing California barracuda at California ports from 1950 through 1976.

Season: From the early years of the fishery through the mid-1950's, barracuda were caught throughout the year. Purse seiners fishing primarily off Mexico supplied fresh fish markets during the winter months while fishermen using lamparas, gill nets, and trolling gear traditionally supplied the markets during the late spring and summer when barracuda were more available in local waters. During the 1960's and 1970's commercial landings were limited principally to months April through July.

Price: The price paid for barracuda has declined during periods of abundance and increased during periods of scarcity (Figure 3). However, even with the great demand which existed during the 1920's, oversupplies to the fresh fish markets occurred regularly, resulting in a reduced price per pound. During years 1920 through 1922, a total of 590,320 pounds of barracuda was reduced for fertilizer, because excessive landings had glutted the market (Skogsberg, 1925).

The price paid to fishermen for barracuda, adjusted by the wholesale price index, has generally been low when compared with the price paid for species caught locally such as halibut, *Paralichthys californicus*, and white seabass, *Atractoscion nobilis*. The price during the 1920's varied from 1 or 2 cents per pound to 13 cents. The price structure improved little until the 1940's when wartime demand stimulated the market for fish products.

The demand and the price declined after the war, and during the period 1950 to 1956 fishermen on many occasions had to accept low prices for their catches when a single large landing by a purse seiner, lampara vessel, or even gill netter caused a temporary oversupply. Increasing prices during the 1960's provided incentive for the more

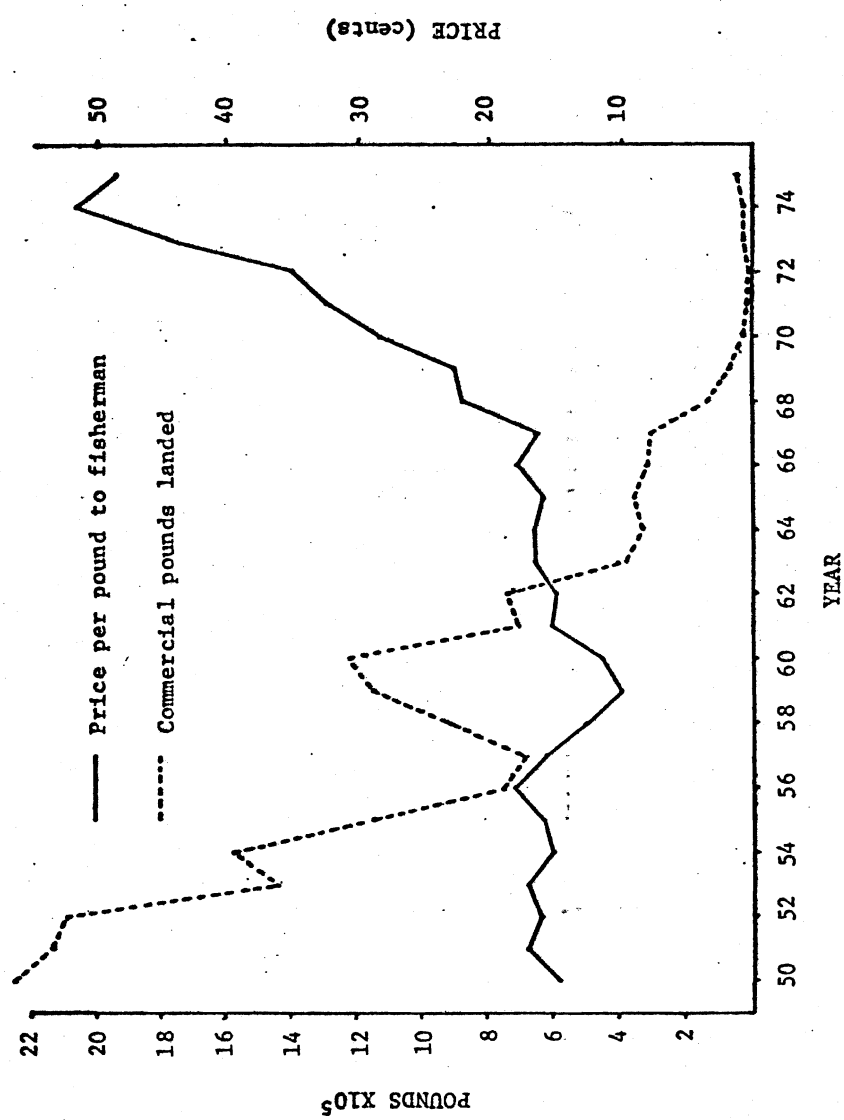


FIGURE 3. Pounds landed and price per pound paid to fishermen for California barracuda.

experienced gill net fishermen to continue fishing but many others abandoned the fishery as unprofitable.

Prices rose higher during the 1970's, to 60-70 cents per pound in 1976 and 80-90 cents per pound in 1979. The value to the fisherman of barracuda landings in 1976 (the latest year with available data) totalled between 82,000 and 113,000 dollars.

Unstable price, supply, and demand combined with increased operating costs discouraged inexperienced fishermen; however, today's increasing prices and the demand for seafood should stimulate interest in barracuda fishing.

## Gear Types

1) Roundhaul Nets

Purse seines caught a major portion of the barracuda landed during the period extending from the end of World War I through 1956.

The rapid growth of the southern California purse seine fleet from 1915 to 1920 was due largely to the success of the canning industry, which was stimulated by wartime demand and successful bluefin tuna, *Thunnus thynnus*, catches, and to availability of barracuda; white seabass; "mackerel", *Scomber japonicus* and *Trachurus symmetricus;* and yellowtail, *Seriola lalandi*, to purse seine gear (Skogsberg, 1925). Relatively small catches of bluefin tuna and yellowtail during 1920 and 1921 stimulated greater efforts to net barracuda. The destruction of young barracuda by purse seine nets is well documented (Skogsberg, 1925), yet economic pressure prevailed and continued seining off California through 1939 resulted in the destruction of large numbers of the young barracuda (Walford, 1932). Use of roundhaul gear (purse seine, ring net, and lampara) for capturing barracuda was finally banned from southern

California waters in 1940. However, such gear still could be used in Mexican waters. This regulation resulted in an increase in the proportion of the total barracuda catch made from Mexican waters. The trend continued after 1947 as 9 consecutive years of cooler than average water prevailed off southern California and local fishing declined.

Purse seiners had dropped out of the fishery by 1956. Several reasons were given by fishermen when questioned about why the seiners stopped fishing barracuda in Mexico: failure to obtain orders for fish in advance from local fish markets (reduced market and consumer demand), increased difficulty in locating schools of fishable size (decline in abundance), longer trips, uncertain prices, and increasing costs of operation.

Under present regulations, barracuda caught off Mexico by purse seine or other roundhaul gear may be landed in California after being declared and inspected by the Department of Fish and Game.

2) Trolling Gear

Trolling is probably one of the earliest methods used to capture barracuda commercially. Early fishermen trolled with various bone and metal lures to attract barracuda. Later they used rubber and plastics combined with metal to produce a dazzling array of trolling lures for both sport and commercial use.

The proportion of the landings made by troll fishermen each year is unknown. Their individual catches were generally smaller than those of purse seine, lampara, and gill net fishermen. However, trollers were numerous during years of good local barracuda availability, and their cumulative landings were substantial.

During years of reduced barracuda availability the trolling fleet declined in number. During years of warm water and increased barracuda availability additional fishermen entered the fishery. During the extremely warm years of 1957 through 1959, so many small commercial boats trolled for barracuda off Long Beach, California that they became known as the "mosquito fleet." A pronounced decline in barracuda abundance during the later half of the 1960's resulted in the virtual extinction of the barracuda trolling fleet off California.

Trolling gear, like purse seine and lampara, is less size selective than gill nets and early samples indicate that substantial numbers of "undersize" barracuda were landed by troll fishermen (Walford, 1932).

3) Gill-Net Fishery

Gill nets have been important in the barracuda fishery since it began, and today they are the only significant component. Gill-net vessels generally are 7 to 12 m (25-40 ft) long and equipped with a gurdy or net reel to retrieve the net. Most of the boats landing barracuda today were built prior to 1950. Historically, gill-nets accounted for a larger share of the landings during periods of poor local barracuda availability. During the 1960's a continued decline in stock abundance resulted in near extinction of the troll fleet, a decline in landings from Mexico, and even a reduction of the gill-net fleet to less than 10 boats by 1970. Today a small fleet of gill-net vessels catch virtually all of the commercial barracuda.

Gill-net fishermen fish in coastal waters between 20 to 40 m (11 to 22 fms) deep. Gill nets measure 10 to 11 m (5½ to 6

fms) deep and are generally drifted from the surface to 3.5 m (2 fms) below the surface at night. Fishermen drift their nets for 1-3 hr following sunset and generally fish during the dark or quarter phase of the moon. A second set may be made just before dawn if the first one is unproductive. Fishermen tend to avoid fishing during moonlit nights.

Barracuda caught locally are landed in the round, generally by boats making one-day trips or less. If a trip lasts longer, the barracuda are cleaned (only the viscera is removed) and stored on ice. When cleaned, barracuda lose about 14% of their body weight.

The gill-net season generally begins between mid-April and early May between San Diego and San Pedro. Best catches during April through June are generally made between Newport Beach and San Pedro by gill netters based at San Pedro and San Diego. San Diego boats land fish at San Pedro markets when fishing north of Newport Beach, and San Pedro and San Diego boats may follow the barracuda schools north of Santa Monica Bay or remain in more localized areas during the season. In July many of the fishermen abandon barracuda fishing for white seabass; they seldom fish barracuda beyond August. During the winter, they may fish for California halibut; rockfishes, *Sebastes* spp.; or Pacific bonito, *Sarda chiliensis*.

Gill-net fishermen from Santa Barbara and nearby ports occasionally fish barracuda during the fall and winter months, setting their nets from Pt. Dume to Pt. Conception and near the northern channel islands near kelp beds. Reports indicate that some of these gill netters have used their nets as encircling

nets, by surrounding a school of barracuda. The fish then either swim into the net or an explosive device or other source of loud noise is cast into the center of the encircled area to startle the fish and cause them to gill in the webbing. Large catches are often produced in this manner.

Barracuda are generally the target species when caught with gill nets, but often bonito; Pacific mackerel; thresher shark, *Alopias vulpinus*; bonito shark, *Isurus oxyrinchus*; and occasionally white seabass also are captured in the nets and sold. Purse seiners and lampara vessels occasionally net barracuda while pursuing anchovies, bonito, or mackerel. Occasionally these sets are intentional violations of the law, and the fish are landed at night to avoid detection.

Prior to 1956, most barracuda gill nets were made of cotton rather than the multifilament nylon used since then. Cotton was heavy compared to nylon and the stacked net occupied nearly twice the area on the boat. Also, cotton deteriorated rapidly if not dried and "tanned" periodically. This maintenance was generally accomplished during the period of the full moon, and fishing resumed during the quarter and dark of the moon.

Nylon nets are made of finer twine than cotton nets. Also more pieces of net can be set from the same boat, and fishing can occur more often throughout the season because of the time saved by reduced maintenance. Fishermen who have used both cotton and nylon agree that nylon is more efficient in netting barracuda.

In recent years monofilament gill nets set near shore to catch "perch" have captured both legal and sublegal-size barracuda.

Small barracuda also may be subjected to substantial exploitation by the white croaker, *Genyonemus lineatus*, or kingfish gill-net fishery. This fishery exists near shore between San Pedro and Huntington Beach and north of Pt. Dume. Gill nets with small mesh (less than 3.5 in. stretched) are set on the bottom in areas also frequented by barracuda during their spawning season. The quantity and size of barracuda captured by these small mesh nets should be determined.

B. Mexico Commercial

Little is known about commercial barracuda fishing by fishermen from Mexico. An outdoor fresh fish market at Ensenada, B. C. Mexico was visited by the author on three occasions and barracuda were observed for sale on each occasion. The barracuda were captured by hook and line and most were small fish 1 to 3 years of age.

Landings of barracuda at Ensenada declined from 28,124 kg (61,957 lb) in 1966 to 380 kg (837 lb) in 1972 (Instituto Nacional de Pesca, Mexico) (Figure 4). While these landings are low compared with California landings, they show the same distinct decline evident in California landings, with a great decline occurring from 1966 to 1968.

California sportfishing interests have voiced concern recently that the gill-net fishery being developed near the Pacific coast of Baja California will overexploit migratory fishes such as barracuda, white seabass, yellowtail, etc. Information to evaluate these claims is not presently available.

C. U. S. Recreational Fishing

Accounts of sportfishing off California during the 1920's and early 1930's indicate that the barracuda was a popular gamefish and

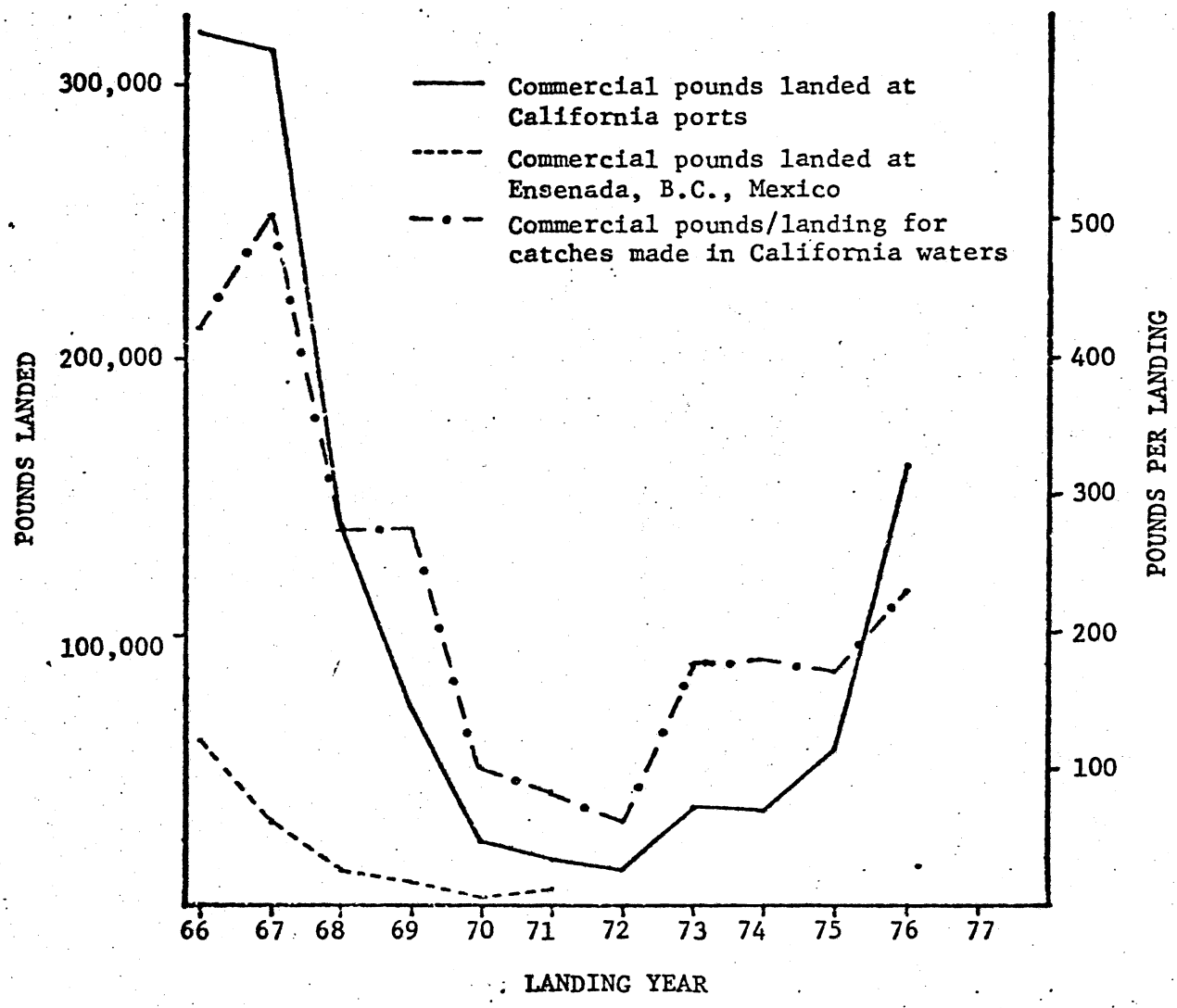


FIGURE 4. Commercial pounds landed at California ports and Ensenada, B.C., Mexico and commercial pounds per landing day for California landings.

one of the most numerous species captured on hook and line. As deep sea angling grew in popularity and as the boats and barges carrying anglers for a fee increased in number, Department scientists realized that the sport catch could have a significant impact upon marine resources. During these early years, the gamefishes for which an angling license was required were caught principally from Commercial Passenger Fishing Vessels (CPFV's, previously termed partyboats) and barges. Since the early 1930's, the Department's efforts to collect catch records of marine sportfishing has been directed almost exclusively at CPFV's and barges, although barges account for a small portion of today's sport catch. California recreational fishermen catch barracuda predominantly during late spring and summer (May through August) when fish are most available off southern California. Recreational fishermen could sell their catch up until 1941, when this practice was prohibited.

1) Commercial Passenger Fishing Vessels (CPFV's)

Sportcatch records of California barracuda were first collected on a voluntary basis during 1932 through 1934 from CPFV's, barges, and piers. These data provide some insight into the size of fish captured and their abundance, but proved impractical for determining total sport landings.

In 1936, regulations required CPFV skippers and barge operators to keep daily records of the number of fish captured by species, the passenger count, and area fished. The reported sport catch California barracuda made from CPFV's and barges during 1936 through 1940 averaged over 550,000 fish and roughly equalled or

slightly exceeded the commercial catch in pounds landed (Table 2, Figure 5) (California 1940). Warm water off our coast during late 1939 and 1940 resulted in large catches during these years.

CPFV catches during the war years were not reported, but recreational fishing declined from the prewar level due to U. S. Coast Guard restrictions on vessel movements and to gas rationing (Young, 1969). During the war, many sportfishing boat owners obtained both a partyboat permit and a commercial fishing license (California 1946, 1947). The additional license qualified them for a larger fuel allotment and permitted greater vessel movement.

The number of vessels operating under partyboat permits declined from 602 boats in 1940 to an average of 274 boats during 1942 through 1945 (a 54% decrease). The number of barracuda landed by CPFV anglers during the war years probably declined to less than 50% of prewar landings.

Daily catch records were again collected during 1946 but were obtained only for July through December. The 113 southern California boats submitting records during the second half of 1946 reported 2,394,594 lb, representing about 598,000 barracuda at 4 lb per fish (Croker, unpublished).* The rapid resurgence of sportfishing following the war, light sportfishing exploitation of barracuda during years 1942 through 1945 (increased survival of I to IV year old fish), presence of many large fish from the successful 1939 through 1941 year classes, and the presence in 1947 of barracuda in large numbers off our coast due to exceptionally warm water resulted in a record catch of 677,400

* Compiled from records of California Department of Fish and Game, Long Beach, CA

TABLE 2. Number of California Barracuda Reported Landed by Southern California Commercial Passenger Fishing Vessel Operators.

| | Barracuda |
|---|---|
| 1936 | 595,062 |
| 1937 | 742,849 |
| 1938 | 374,109 |
| 1939 | 732,878 |
| 1940 | 704,520 |
| 1946 | 598,000* |
| 1947 | 677,499 |
| 1948 | 383,757 |
| 1949 | 366,423 |
| 1950 | 242,380 |
| 1951 | 269,418 |
| 1952 | 336,562 |
| 1953 | 166,478 |
| 1954 | 281,049 |
| 1955 | 154,939 |
| 1956 | 87,218 |
| 1957 | 577,060 |
| 1958 | 782,226 |
| 1959 | 1,195,579 |
| 1960 | 755,360 |
| 1961 | 391,853 |
| 1962 | 335,507 |
| 1963 | 483,699 |
| 1964 | 303,070 |
| 1965 | 443,304 |
| 1966 | 892,697 |
| 1967 | 470,480 |
| 1968 | 372,246 |
| 1969 | 358,518 |
| 1970 | 373,801 |
| 1971 | 50,474 |
| 1972 | 38,243 |
| 1973 | 92,483 |
| 1974 | 55,284 |
| 1975 | 26,289 |
| 1976 | 107,557 |
| 1977 | 48,701 |
| 1978 | 72,840 |

*Landings incomplete

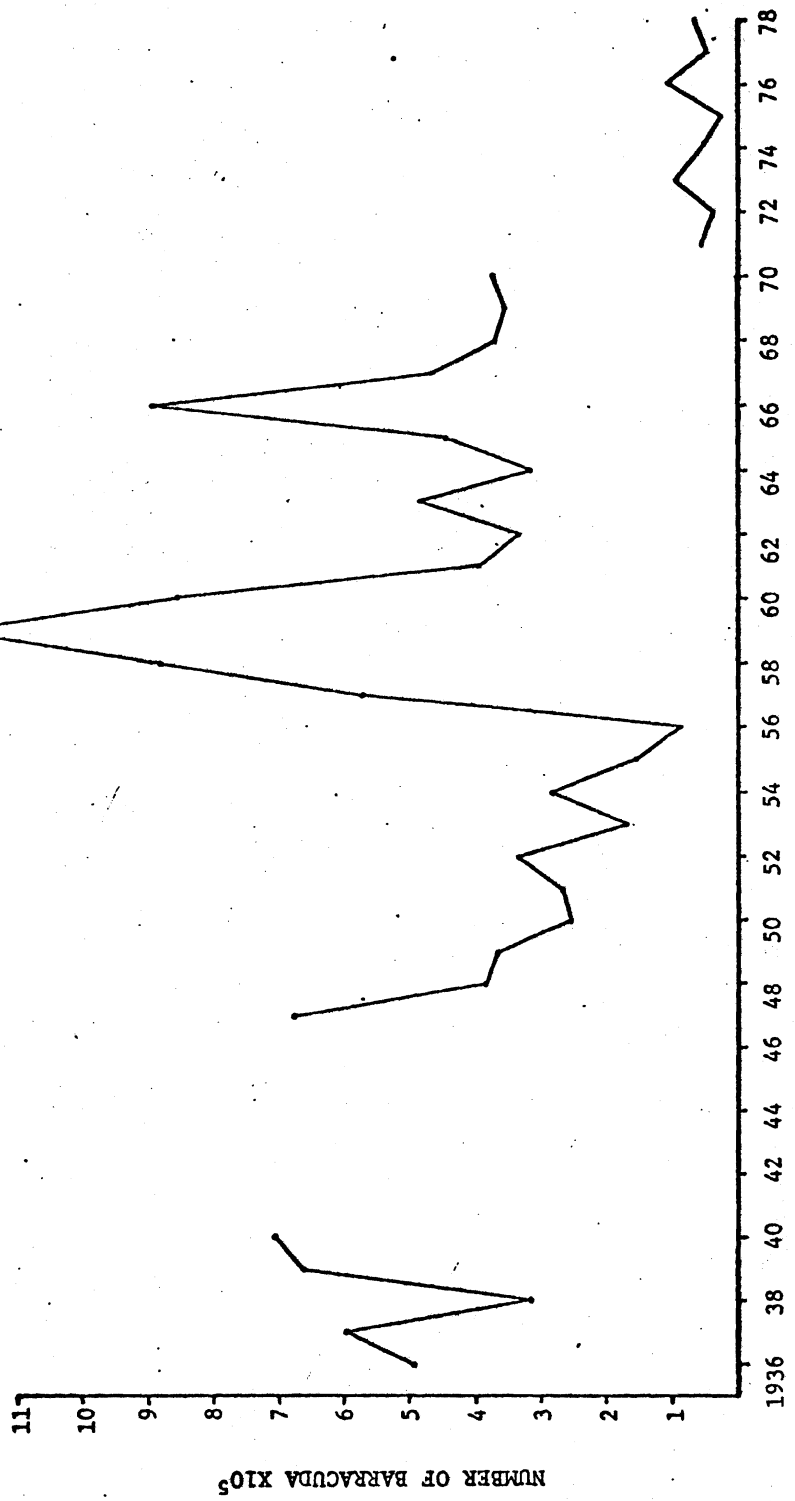


FIGURE 5. Landings of California barracuda reported by California commercial passenger fishing vessel operators.

barracuda reported by 201 southern California partyboat permit holders (California 1949, Pinkas, 1966).

The years 1948 through 1956 saw a steep decline in the sport catch. Water temperatures cooled considerably during this period, and fewer barracuda migrated northward into the fishing grounds. Also, the strong year classes of 1939, 1940, and 1941, which helped produce good post-war catches, were becoming less abundant and less available. Fewer than 90,000 barracuda were reported by CPFV's during 1956; however, during years 1957 through 1959 water temperatures warmed considerably and large numbers of barracuda again became available off southern California. Record catches were made during 1959 and then they began to decline in following years as the water temperature cooled.

Prior to, and during the years 1958 and 1959 barracuda larger than 71.1 cm (28 inches legal size) were abundant in the catches. Following the warm water years (1957 through 1959) fewer were caught. Apparently a combination of reduced availability, fishing pressure by all segments of the sport and commercial fishing fleets and poor recruitment during the 1950's and early 1960's led to a decline in the numbers of fish caught and their average size. By 1968 few barracuda larger than 71.1 cm (28 in.) were caught. In 1971 the size limit of 28 in. total length was made effective by removing the allowance of two short barracuda in the daily bag limit. Reported CPFV landings immediately declined from 373,801 barracuda in 1970 to a record low 50,474 in 1971. This illustrates the degree to which the fishery had become dependent upon young, immature barracuda. Since 1971

the proportion of barracuda larger than 71.1 cm (28 in.) has increased from 10% in 1972 to over 30%; however, CPFV landings of legal size barracuda are still averaging less than 100,000 barracuda per year.

2) Independent Private Sport Boats

Records of barracuda caught by anglers aboard private boats are limited to those obtained by the Department during a survey in 1964 (Pinkas et al. 1968) and to those collected at launch ramps, boat hoists and skiff rentals during years 1974 through the present (Wine and Hoban, 1976, Wine, 1979a, b, c, d). The results indicate that barracuda were the tenth most frequent species caught from private boats, and the total catch (16,235 barracuda) amounted to only 3.1% of the average partyboat catch reported for 1963 through 1966.

Sampling from July 1975 through June 1976 indicated that barracuda was still the tenth most frequently caught species by private boat anglers (estimated 9,519 barracuda caught) (Wine and Hoban, 1976).

3) Piers, Jetties, Open Coast, Bays, and Harbors

A survey of sportfish caught from piers and jetties was conducted in 1963 (Pinkas, Oliphant, and Haugen, 1968). California barracuda was the fifteenth most commonly caught species. A total pier and jetty catch of 17,351 barracuda was estimated for 1963 accounting for 0.9% of the total catch from these sources.

No barracuda were observed during a survey of open coast (surf) fishermen conducted in 1965-66 (Pinkas, Oliphant, and Haugen, 1968). A survey of southern California inland bays during 1965-66 (Pinkas, Oliphant, and Haugen, 1968) resulted in an

estimated annual catch of 892 barracuda. Barracuda ranked 23rd by species in numbers of fish caught (0.34% of all fish caught in inland bay waters).

D. Mexican Recreational Fishing

Our knowledge of Mexican recreational fishing for California barracuda is limited to charter vessels operating from Ensenada, B.C., Mexico. Sportfishing for nearshore gamefishes has been conducted for many years from Ensenada and substantial numbers of barracuda are landed. At least one large modern charter boat and a number of smaller and older boats have operated from Ensenada during the last 10 years. These boats fish primarily in Todos Santos Bay and around the Todos Santos Islands. Estimates of the number of barracuda landed and number of anglers were recently obtained for the years 1961 and 1971 (Susumo Kato pers. commun.). Reported landings increased from 111,113 barracuda caught by 42,335 anglers in 1961 to 193,296 barracuda caught by 44,671 anglers in 1971. The catch rates for 1971 are nearly four times the landings made at California ports by similar boats that year. No minimum size limit on barracuda exists in Mexico and landings include large numbers of fish less than 28 in. (71.1 cm) long (one to four years old). Assuming that the size composition is similar to that off of California in 1971, then roughly 134,000 barracuda less than 28 in. (71.1 cm) were probably landed at Ensenada in 1971. Current figures are not available; however, if charterboat fishing off Ensenada has continued at the 1971 rate or greater, then the greatest mortality on barracuda 4 years of age and younger is occurring in the fishery located off northern Baja California.

IV. Biology

A. Distribution: California barracuda range from Prince William Sound,

Kodiak Island, Alaska (Pinkas, 1966) south to Cape San Lucas, Baja California, Mexico (Berdegue', 1956). Within this range they are common from about Santa Barbara (during late summer and fall) south into Baja California where the bulk of the population is found. During years of warmer than average water off California, barracuda penetrate farther north along the coast and are caught in larger numbers off California.

Young fish may occur all year in protected harbors and estuaries where water temperatures are generally a few degrees above those outside. Barracuda are seldom caught in waters deeper than about 60 m (200 ft).

B. Migration: Tag-recapture studies conducted during years 1957 through 1959 and years 1973 through 1975 show that California barracuda migrate northward along the coast of Baja California, Mexico, and southern California during spring and early summer (Pinkas, 1966). Barracuda arrive off San Diego in April or May and move north as water temperatures increase. One, two, and three-year old fish are distributed in the shallow inshore areas, while older and larger fish occur in deeper waters (to 30 m or 100 ft) along the mainland and offshore at the channel islands. The occurrence of a relatively greater proportion of larger barracuda near the islands was observed as early as 1928 (Walford, 1932) (Figure 6). Compared to small ones, large barracuda appear to be distributed farther north during the season and then become relatively less available to anglers during August and September.

The magnitude of this migration has been shown to be closely associated with changes in water temperatures (Radovich, 1961, 1975). During years when the spring and summer water temperatures off California rise well above average, barracuda are found well north of their usual range

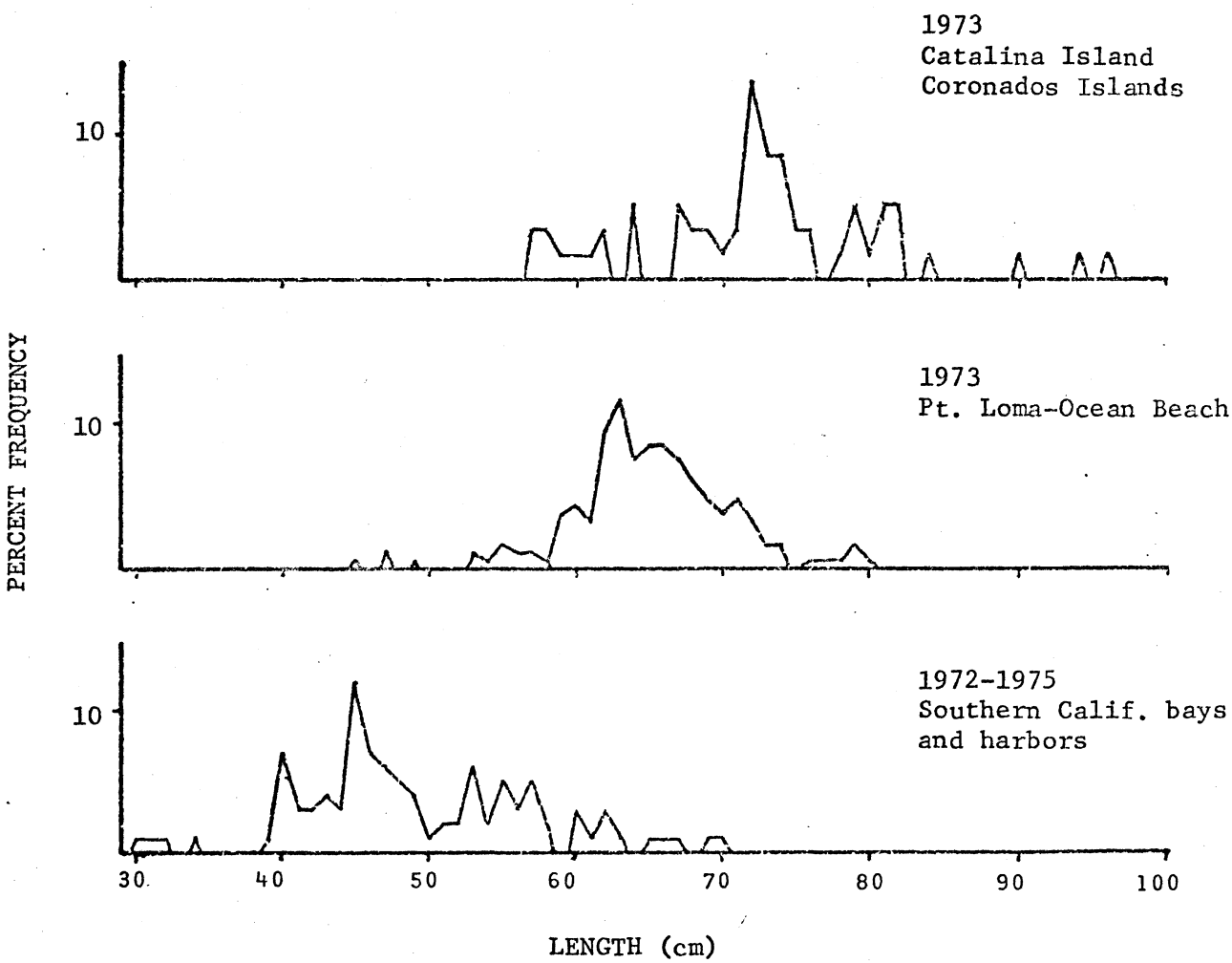


FIGURE 6. Size composition of California barracuda collected from offshore islands, the open coast of the mainland and inside bays and harbors.

and are caught in larger numbers off southern California (Hubbs, 1948, Radovich, 1961, 1975). A correlation (r = .87) was found between the mean January through June sea temperatures (Scripps Pier, La Jolla) for each year 1947 through 1975 and the annual partyboat catch of barracuda for these years. A less impressive yet significant correlation (r = .47) exists between the commercial barracuda catch from California waters for years 1950-1967 and the average annual surface temperatures.

Barracuda tagged during May off nothern Baja California and off southern California appeared to intermingle off southern California indicating they are a single stock. Those tagged in August and much farther south (from Cedros Island to Asuncion Bay, Baja California) were not recovered, leaving unanswered questions about the movements of this portion of the population and its relationship to the portion entering our waters (Pinkas, 1966).

Southern migration during the late fall and early winter is less apparent because fewer tagged fish were recaptured. These show movements both north and south of the release area. Apparently a portion of the fish migrating into southern California during the spring and summer (April through July) remain in our waters through the fall and winter. Also, a movement into deeper water in the fall and winter has been suggested (Skogsberg, 1925) but not well documented.

A continued northward migration into the fall months has been suggested by some California gill-net fishermen. Schools of apparently inactive barracuda have been observed near kelp beds from Ventura to near Pt. Conception and the Channel Islands during September through

December. Statements of barracuda being present near Santa Barbara and the Channel Islands from late fall and into December and January are supported by gill net catch records. By comparison, few barracuda are caught by sportfishing during the winter months indicating changes in availability and/or changes in feeding habits and general activity.

C. Reproduction: California barracuda spawn from April through August with major activity during June and July (Walford, 1932). The northern migration during these months is probably related to spawning.

Eggs are released into the water and fertilized, where they drift until hatching. Eggs collected in plankton nets off La Jolla began hatching the following day. Prolarvae averaging 2.5 millimeter at hatching required 3 to 4 days (under laboratory conditions) to consume their yolk sac, and some larvae were feeding on brine shrimp nauplii 4 days after hatching (Orton, 1955).

Microscopic examination of barracuda ova indicate the presence of three size groups (mature, maturing, and immature) during the spawning season (Walford, 1932). All eggs larger than 1.14 millimeters were considered mature, those larger than 0.2 mm and smaller than 1.14 millimeters were maturing, and the others were considered immature.

Apparently barracuda spawn more than once each season because all size groups of eggs were found within the ovaries throughout the season and no spent females were observed during the height of the spawning season (Walford, 1932). The number of mature eggs produced per spawning season correlates closely with the fishes' weight. Egg counts varied from 42,000 mature eggs for a female measuring 50 cm (20 in.) total length and 414 grams (1 lb) to 484,000 mature eggs for a female 94 cm (37 in.) total length and weighing 3,226 grams

(7 lbs) (Walford, 1932). These estimates may be high because corrections for extraneous ovarian tissue may not have been made.

The barracuda sex ratio within the population as a whole is unknown, but it appears close to 50% males based upon samples collected from the commercial fishery. In 1927, 52% of 16,530 barracuda examined were males while in 1928, 55% of 18,005 were males (Walford, 1932). In 1977, 47% of 525 barracuda examined were males. This indicates a fairly uniform sex ratio of males to females within the exploited population, with males perhaps slightly predominant in the catch during the spawning season. Reproductive success or failure appears to be related to environmental conditions, with large year-classes often produced during years of abnormally warm waters off southern California and smaller year classes produced during cooler years. A similar relationship has been implied for Pacific mackerel stocks (Parrish and MacCall, 1978).

D. Habitat: Habitat preferences differ somewhat between barracuda of different sizes. California barracuda one and two years old are often captured inside bays and harbors while older barracuda are not. It is uncertain if warmer water, protection, greater food availability or a combination of these or other conditions make the bays and harbors attractive to young fish (size comp. Figure 5). Large numbers of young barracuda are also found near the shallow water habitat dominated by giant kelp (*Macrocystis pyrifera*) (Feder, Turner and Limbaugh, 1974). Both the bay-harbor and kelp bed habitats may be important as nursery grounds where young barracuda obtain protection and food. Kelp bed biomass and water quality of bays and harbors in southern California have declined since the turn of the

century. It is not known how harmful these declines have been to barracuda and other fishes.

E. Food Habits: California barracuda are schooling predators which depend upon smaller schooling species for food. They pursue and feed on such species as anchovies, *Engraulis mordax;* sardine, *Sardinops sagax caeruleus;* jack mackerel, *Trachurus symmetricus;* Pacific mackerel, *Scomber japonicus;* and grunion, *Leuresthes tenuis,* etc. Barracuda in turn are fed upon by seals, sea lions, porpoises, and giant sea bass, *Stereolepis gigas* (Frey, 1971). Young-of-the-year barracuda (to 125 mm, 5 in.) have been found in Pacific bonito stomachs (Phelan, DF&G, pers. commun.) and cannibalism has been observed in larval barracuda under laboratory conditions (Hunter, Theilackar, NMFS-SWFC pers. commun.).

Feeding behavior of California barracuda has been observed with barracuda showing a preference for live food over dead and large barracuda showing a preference for sardines over anchovies (Anon).*

A reduction in barracuda feeding activity appears to coincide with reduced water temperatures. Poor sport catches have been observed on numerous occasions when nearshore waters have cooled suddenly.

F. Age and Growth: Age determinations of California barracuda were first undertaken by Walford (1932). He made special collections of small barracuda, traced their growth through the 1st year, and then noted the formation of the first annulus upon the scales. Ages were assigned with confidence through age six; all fish older than this were assigned as 7+ years of age. Pinkas (1966) determined the ages of barracuda through 8 years and assigned those older than eight

---

* From records of California Department of Fish and Game, Long Beach, CA

as 9+ years. The average length (l) of California barracuda, (males and females), at annual increments (t) is expressed by the von Bertalanffy growth equation $l_t = L^{\infty} (1-e^{-k_{(t-t_o)}})$ where $L^{\infty}$ = 1022.54, k = .24924, and $t_o$ = -.7689 (Pinkas, 1966).

Growth of California barracuda expressed in terms of weight at length ($W = al^b$) is allometric with a = .003962 and b = 2.983 (Walford, 1932).

California barracuda grow rapidly in their first 2 years of life, reaching about 36 cm (14 in.) the first year and 50 cm (20 in.), the second. At that time their length is about one half of the computed maximum length ($L^{\infty}$ = 102.2 cm, (40.2 in.). The greatest reported length verified for a California barracuda is 119.0 cm, (46.9 in.) (Pinkas, 1966).

California barracuda reach legal size 71.1 cm, (28.0 in.) in 4 to 5 years and almost all age 6 and older are legal. Nine-year-old and older fish are uncommon, while the oldest California barracuda yet examined for age appeared to be 11 to 12 years old. After age 4, females appear to grow slightly faster than males (Walford, 1932).

Growth in weight is relatively slow during the first 2 years, increases during the 3rd, 4th, and 5th years then begins to slow during later years.

Maximum gain in weight (0.95 lb/year) occurs during the 4th year of life, but is nearly equalled by the gain (0.92 lb/year) during the 5th year.

About one half of $W^{\infty}$ (the maximum weight towards which the fish is tending, equal to 3,765 grams or 8.29 lb) is reached during the middle of the 6th year of life. The greatest documented weight for

a California barracuda is 18 lb 3 oz (8.26 kg) indicating that barracuda reach ages older than 12 years.

G. Size and Age Composition: California barracuda length and age data were first collected from the San Pedro fresh fish markets during 1927 and 1928 (Walford, 1932). A broad size range of fish (53-108 cm, 2 to 10+ years old) (Figure 7) was caught by the diverse fishing gears in use at that time and Walford concluded that nearly all barracuda 4 years old and older were being fully exploited by the commercial fishery.

Judging from the reported weight of sport caught barracuda during the 1930's and 1940's, the mean age of exploitation varied between 4 and 6 years or roughly the same as that of the present commercial fishery.

Individual and mean sample weights (converted to length frequencies) of barracuda examined during 1948 through 1951 aboard party-boats (*unpublished) indicate that extreme variability in year class strength occurred between 1939 and 1945 (Figure 8). Large numbers of barracuda that were spawned during the warm water years of 1939 through 1941 were caught following the war and were still being caught as late as 1951. By 1951 these barracuda were between 10 and 12 years old (6-10+ pounds) and constituted many of the legendary "log" barracuda that fishermen like to refer to when reminiscing about the "good old days." The 1939 through 1941 year-classes probably benefitted from reduced sport fishing of the war years. These three year-classes also helped support the commercial fishery during the 1940's. Year classes that

* Compiled from records of California Department of Fish and Game, Long Beach, CA

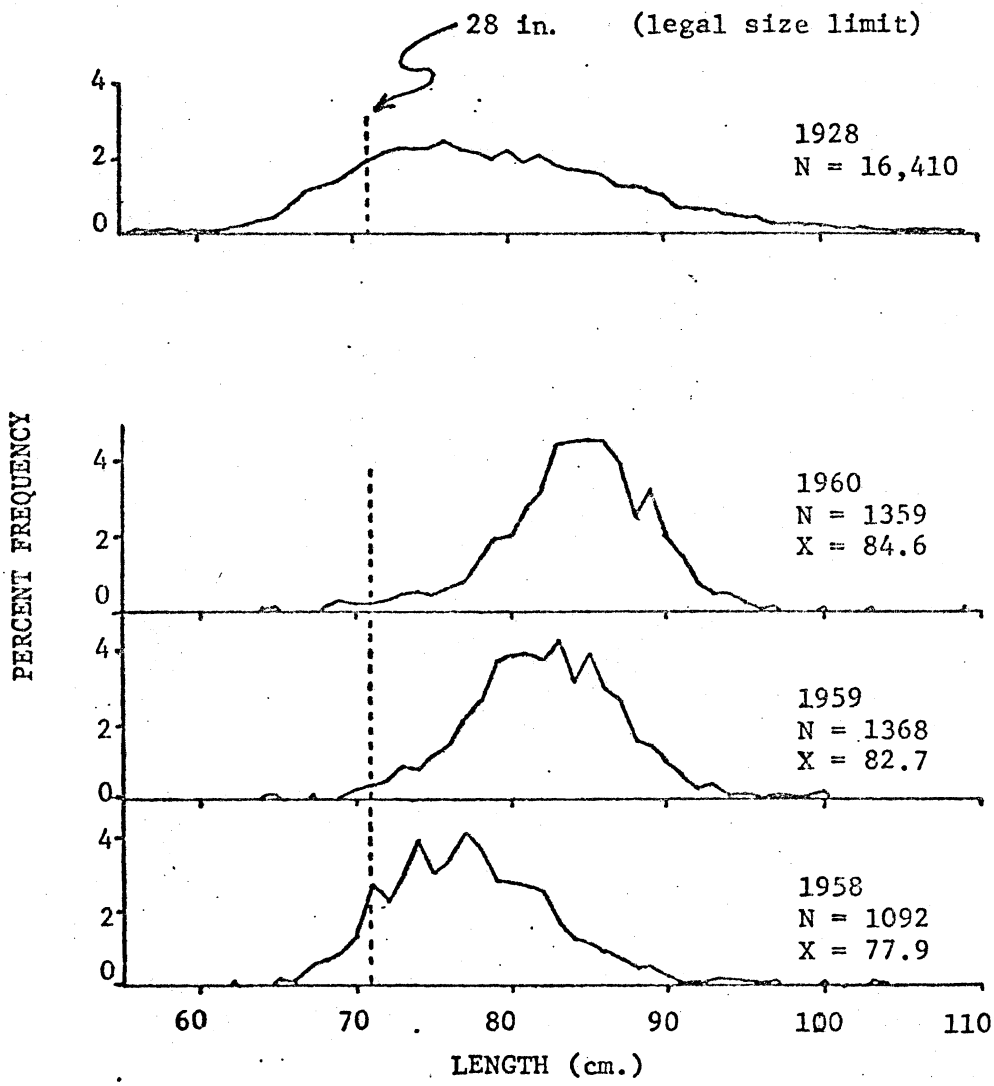


FIGURE 7. Size composition of California barracuda sampled at the San Pedro fresh fish markets.

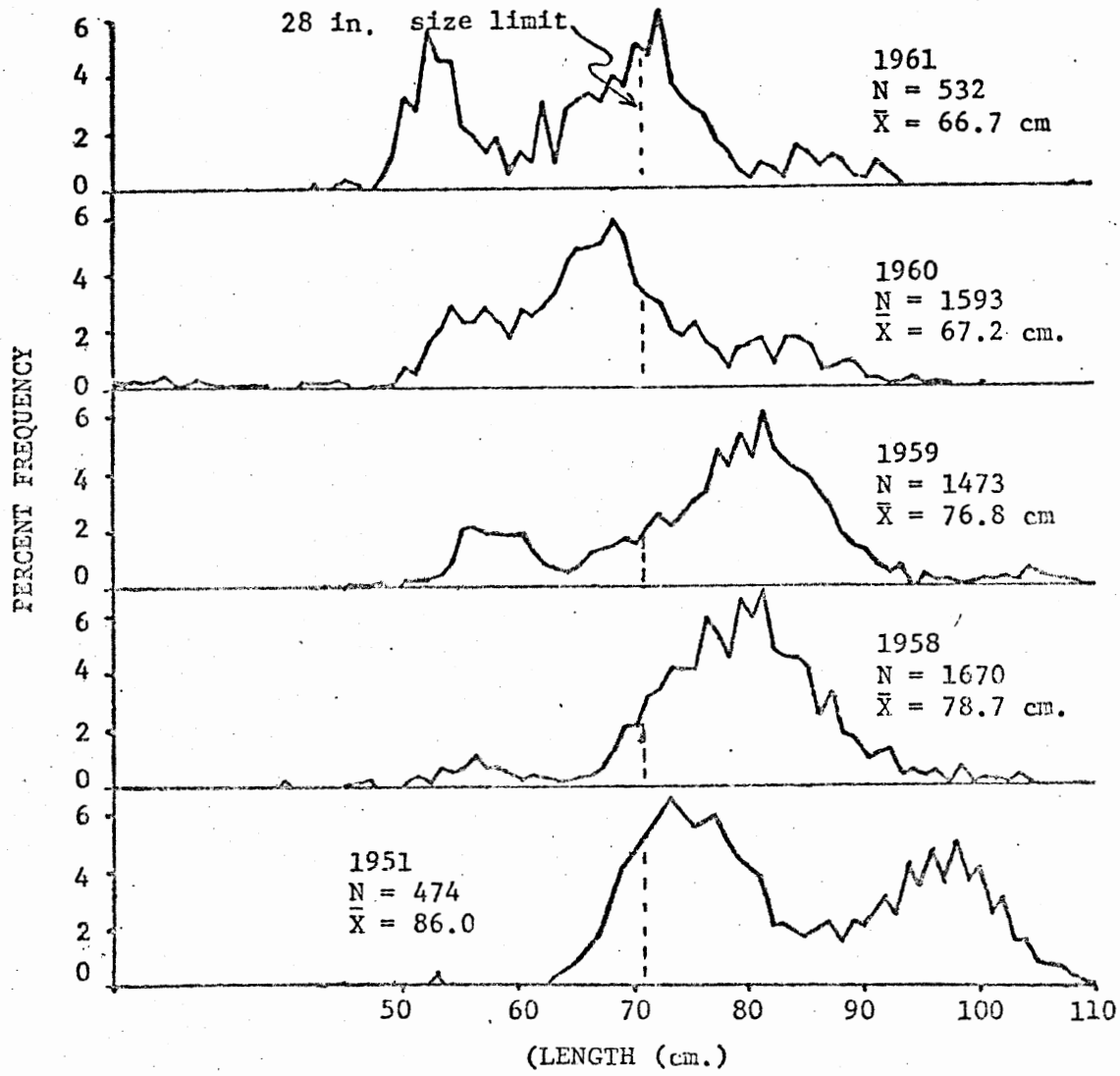


FIGURE 8. Size composition of California barracuda sampled aboard southern California commercial passenger fishing vessels during 1951, and 1958 through 1961.

were spawned during 1942 through 1944 were relatively small compared to those of 1939 through 1941 and those of of 1945 through 1947. This indicates that substantial variability in annual production occurred during years of moderate to large stock size.

Size and age composition data collected during 1958 through 1961 reveal that the success of year classes that were spawned during the 1950's was also quite variable (Figures 7 and 8) (Pinkas, 1966). The relatively strong year-classes of 1952 and 1953 were followed by relatively weak year-classes during 1954 and 1955 which were then followed by moderate to very strong year-classes produced during the period 1956 through 1959. The average size and age of barracuda landed by sportsmen declined from 1959 to 1960 as large fish became relatively less available. Average size and age (666 mm, 3.5 years) of barracuda landed by partyboat anglers in 1960 probably increased gradually as the dominant 1957 through 1959 year-classes became more heavily exploited; however, data to help verify this were not collected until 1972. Popular accounts of catches made during the 1960's indicate that large barracuda (probably 1957 through 1959 year classes) were caught through 1967, after which only small (less than 28 in.) fish could be found. From 1968 until 1972 the sport catch of barracuda was composed predominantly of 2, 3, and 4-year-old fish, although since 1971 these small barracuda may not be legally kept.

Since 1972, barracuda 3 through 5 years old (50-72 cm) have been the most frequently sampled barracuda aboard CPFV's and private boats (Figures 9 and 10). Larger barracuda 5 through 7 years old (70-85 cm) have predominated in the commercial fishery during recent years (Figure 11).

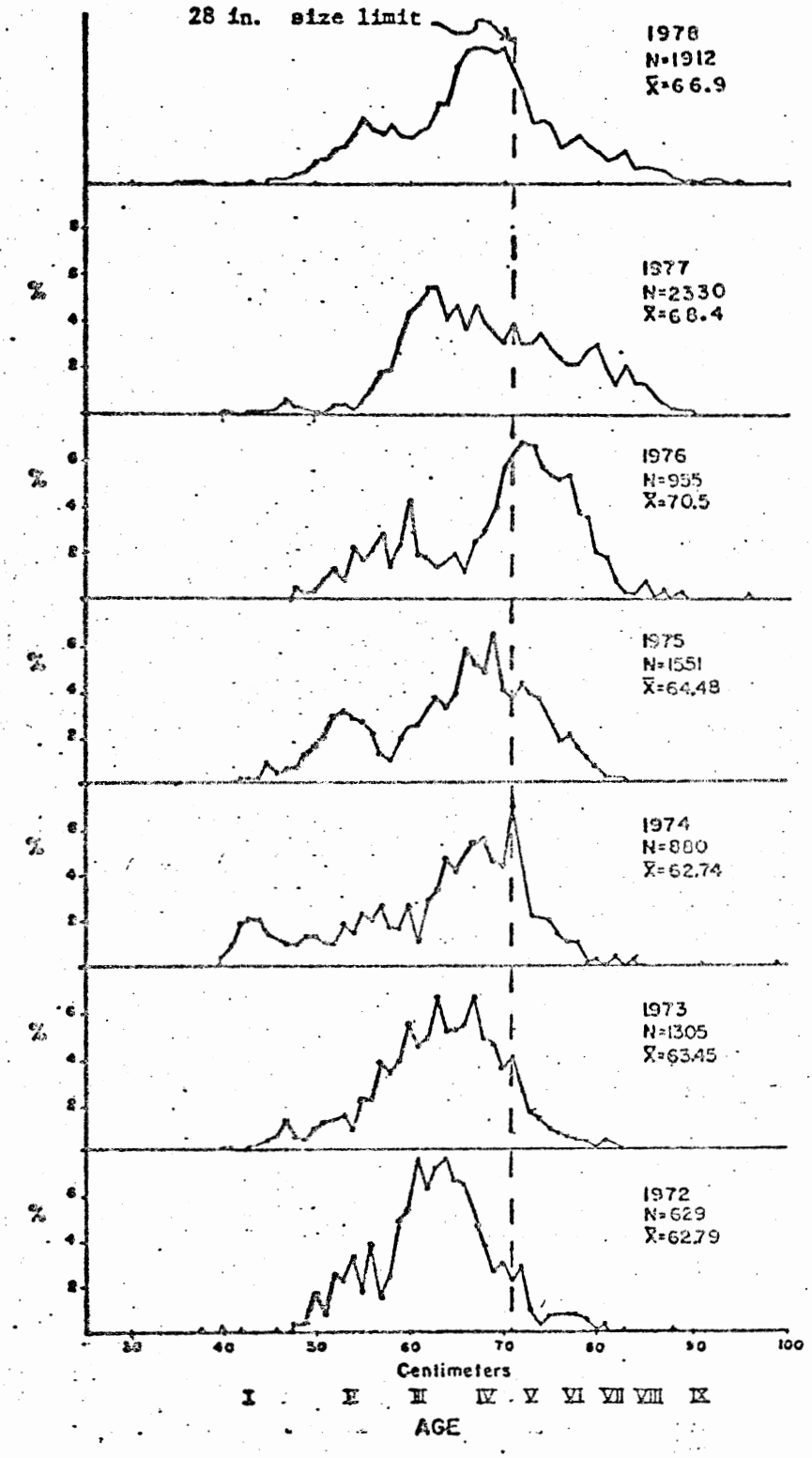


FIGURE 9. Size and age composition of California barracuda measured aboard southern California commercial passenger fishing vessels during years 1972 through 1978.

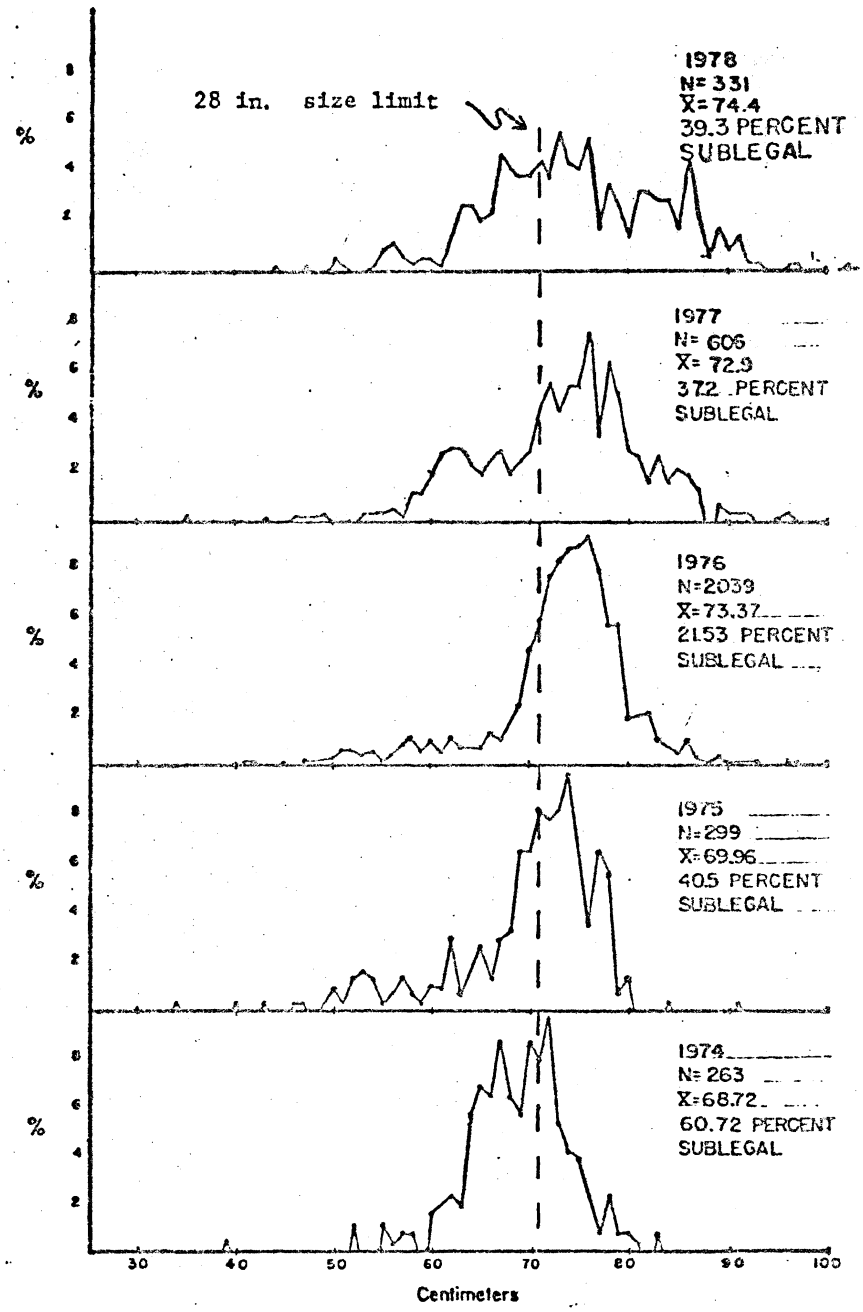


FIGURE 10. Size composition of California barracuda landed by southern California independent private boat fishermen.

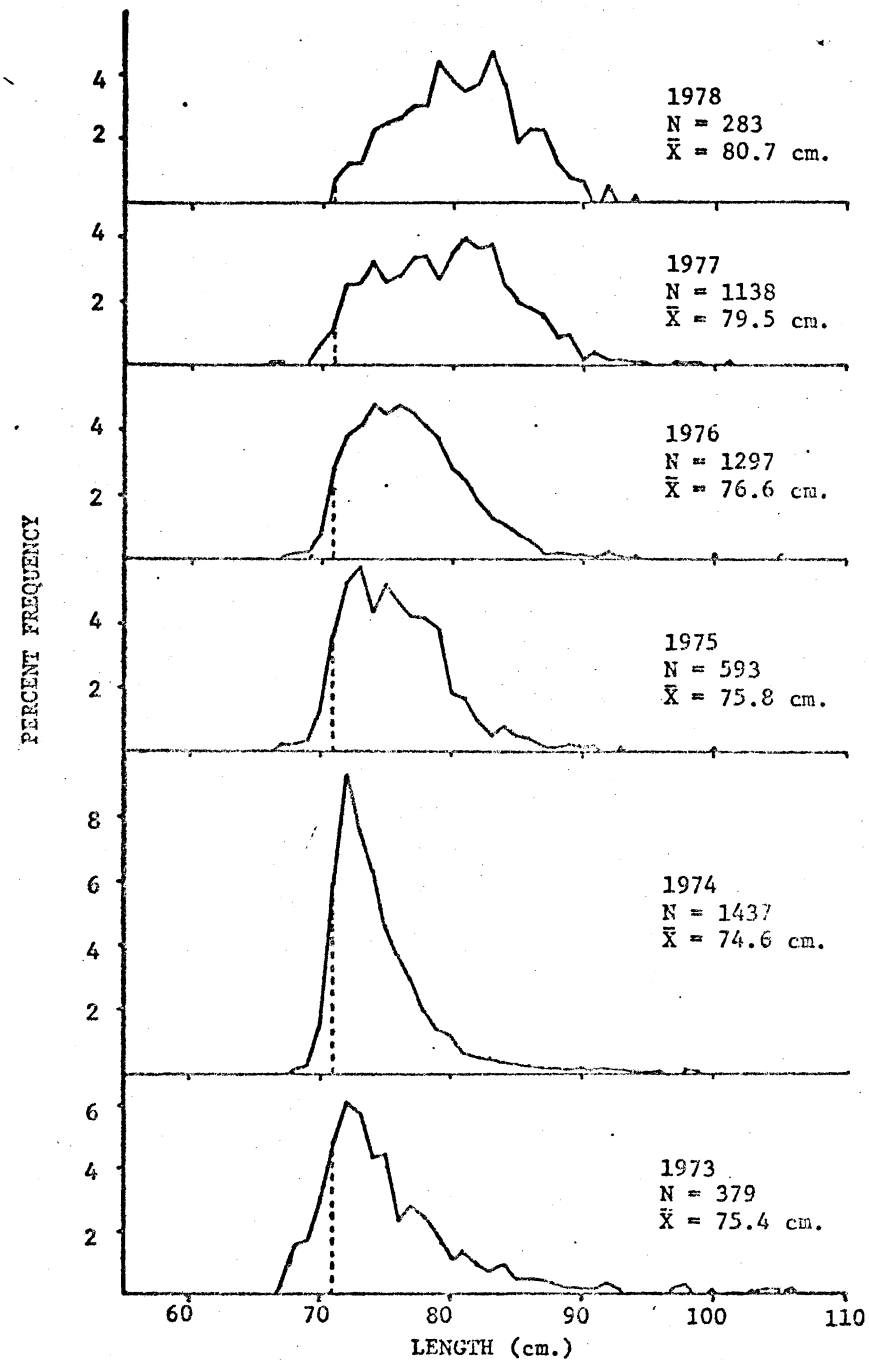


FIGURE 11. Size composition of commercial landings of California barracuda measured at the San Pedro fresh fish markets.

Relatively strong year-classes now contributing to the catch were spawned in 1970, 1973, and 1974. The 1976 year-class also appears to be strong. It will reach legal size in 1981. By comparison the 1971, 1972, and 1975 year-classes appear weak. The weak 1975 year-class will reach legal size in 1980 resulting in fewer legal size barracuda available. The 1977 and 1978 year-classes are still too young to determine their relative strengths.

H. Mortality: Mortality rates of California barracuda 5 years old and older have been computed for years 1958 through 1960 (Pinkas, 1966) and 1972 through 1978 (Table 3). Mortality rates for 1958 through 1960 were computed by using the age composition of sport and commercial fisheries and the catch and effort data from the sport fishery. These independent estimates agree and were felt to be close to the real values affecting the population off California. However, recent examination of size and age composition samples for 1958 through 1960 indicate that the relatively strong 1952 and 1953 year classes, preceeded and followed by weaker ones, probably resulted in low estimates of fishing mortality. Annual fishing mortalities computed recently for 5-year-old and older barracuda declined from 76% in 1972 to 46% in 1978.

It is uncertain if the decline will continue under current rates of exploitation and reproduction, or if a new "equilibrium" between mortality and reproduction will be reached. The continued presence of large barracuda, which were virtually absent in 1972 through 1974, indicates that the protection of young since 1971 has reduced mortality sufficiently that more year classes are now spawning.

The importance of protecting barracuda through at least age 4 can

TABLE 3. Annual Estimates of California Barracuda Survival, Annual Mortality, and Instantaneous Total Mortality Computed from Numbers of Barracuda Five Years Old and Older.

| Fishery | Year | No. of fish age V+ | Annual survival | Annual mortality | Total mortality a | Instantaneous Rates: Total mortality b | Instantaneous Rates: Fishing mortality c | Instantaneous Rates: Natural mortality d |
|---|---|---|---|---|---|---|---|---|
| CPFV's | 1958 | 1299 | 0.467 | 0.533 | 0.764 | .751 | .568 | .183 |
| | 1959 | 268 | 0.484 | 0.516 | 0.726 | .723 | .539 | .183 |
| | 1960 | 106 | 0.482 | 0.518 | 0.730 | .745 | .562 | .183 |
| | 1972 | 104 | 0.207 | 0.793 | 1.57 | | | |
| | 1973 | 249 | 0.239 | 0.761 | 1.43 | | | |
| | 1974 | 211 | 0.247 | 0.753 | 1.40 | | | |
| | 1975 | 450 | 0.263 | 0.737 | 1.34 | | | |
| | 1976 | 477 | 0.315 | 0.685 | 1.15 | | | |
| | 1977 | 253 | 0.306 | 0.694 | 1.18 | | | |
| | 1978 | 571 | 0.391 | 0.609 | 0.94 | | | |
| Private boats | 1974 | 105 | 0.241 | .759 | 1.42 | | | |
| | 1975 | 166 | 0.289 | .711 | 1.24 | | | |
| | 1976 | 1403 | 0.333 | .667 | 1.10 | | | |
| | 1977 | 80 | 0.419 | .581 | 0.87 | | | |
| Commercial boats | 1958 | 885 | 0.378 | 0.622 | .975 | | | |
| | 1959 | 331 | 0.545 | 0.455 | .607 | | | |
| | 1960 | 271 | 0.538 | 0.462 | .620 | | | |
| | 1973 | 279 | 0.361 | 0.639 | 1.02 | | | |
| | 1974 | 1082 | 0.320 | 0.680 | 1.14 | | | |
| | 1975 | 478 | 0.345 | 0.655 | 1.06 | | | |
| | 1976 | 852 | 0.365 | 0.635 | 1.01 | | | |
| | 1977 | 1029 | 0.448 | 0.552 | 0.80 | | | |
| | 1978 | | | | | | | |
| Sport & Commercial combined | 1959 | 599 | 0.499 | | .695 | | (.511)e | (.18405)e |

a From tables of Natural or Naperian logarithms (Pinkas 1966)
b Calculated from catch, effort and age data (Pinkas 1966)
e Calculated from tag recapture data (Pinkas 1966)

be illustrated by examining the relative reproductive potential (eggs produced) and relative production in weight over the life of the fish, at different levels of mortality (Figures 12 and 13). When only natural mortality is removing barracuda from the population, the most productive ages appear to be 4 through 7 years.

Fishing mortality was operating at a very young age prior to the strict 28 in. size limit in 1971. This type of situation tends to result in a rapid decline in biomass before the fish reach their greatest reproductive potential. As older fish disappear, the population depends more and more upon the reproduction of only young fish, thus increasing the danger of a total collapse of the stock should consecutive years of poor recruitment occur. Today, production is still dependent primarily upon successful reproduction by 2-to 5-year-old barracuda; however, better protection of these age groups represents more conservative management than existed prior to 1971.

V. Fishery Analysis

A. Abundance and Availability

Abundance of California barracuda off our coast is difficult to measure because of their migratory behavior and the annual variability in the magnitude of this migration. The magnitude of the seasonal migration largely determines the number of barracuda that will arrive here and the number of months that they will be available. Availability correlates well with changes in sea surface temperatures off our coast, and the increases or decreases in availability cause corresponding changes in indices of abundance computed from catch and effort data. It is necessary to examine these abundance indices for a series of years to detect real changes in abundance and/or examine them in relation to the availability indices (in this case water

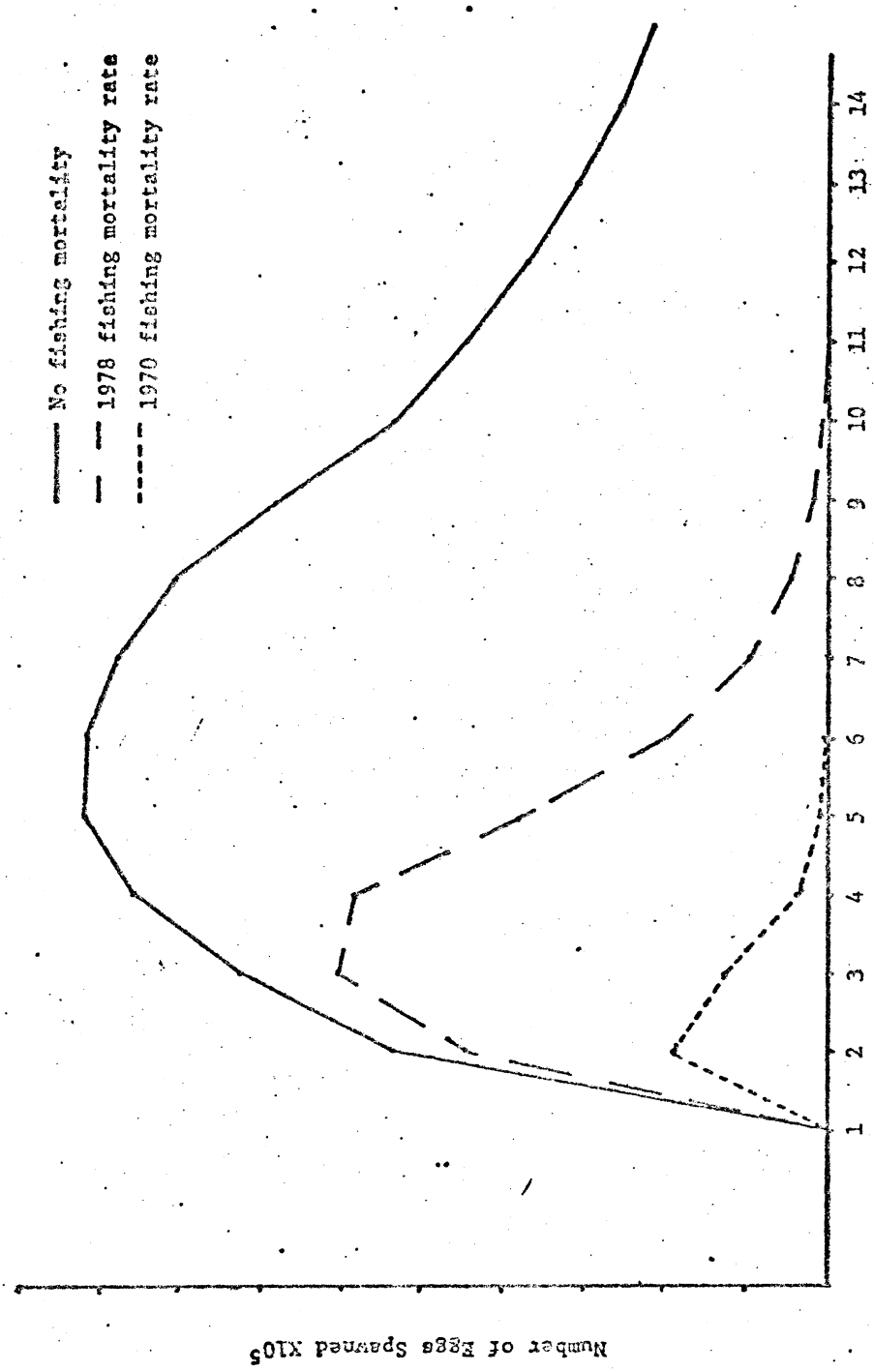


FIGURE 12. Number of eggs produced by a year class at each age at three different mortality rates.

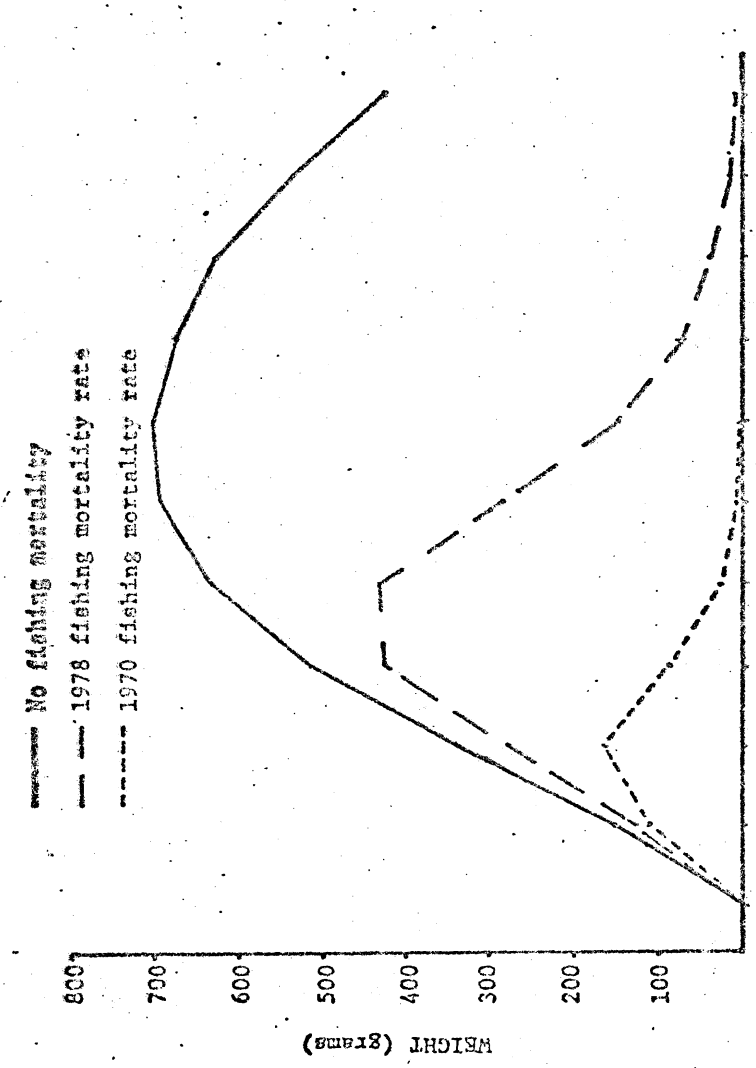


FIGURE 13. Weight of California barracuda surviving at three different mortalities.

temperature) to see if the expected relationship between environment and CPUE is changing.

During the last 60 years changes in fleet size, gear, and fishing effort directed at many species have made it difficult to develop indices with which to evaluate changes in abundance and availability. Purse seiners and lampara boats, which landed large amounts of barracuda during the 1920's and 1930's were restricted to Mexican waters by 1940, and had virtually retired from the fishery by the middle 1950's.

On the other hand gill net fishermen have continued to net barracuda since the beginning of the fishery. Summarized records of daily barracuda landings for individual boats are available for years 1950 through 1976. Using a sample of about 10 "standard" gill net boats per year, a series of catch per unit effort (CPUE) values of "pounds-per-landing-day from California waters" was generated for years 1950 through 1976 (Figure 14). "Standard" gill net vessels are identified as those which landed barracuda during at least May and June from Fish and Game blocks 700 and/or 800 and that fished for more than 1 year. Only landings for May through July (the height of the fishing season) were used.

Cold water off California during most of the period from 1948 through 1956 discouraged northward migrations of barracuda, and as a result the CPUE figures for 1950 through 1956 are artificially low estimates of stock abundance. During 1957 through 1959 the environmental pendulum reached the opposite extreme when ocean temperatures warmed for 3 consecutive years and barracuda arrived in large numbers. As a result the CPUE figures computed for years 1957 through 1960 are

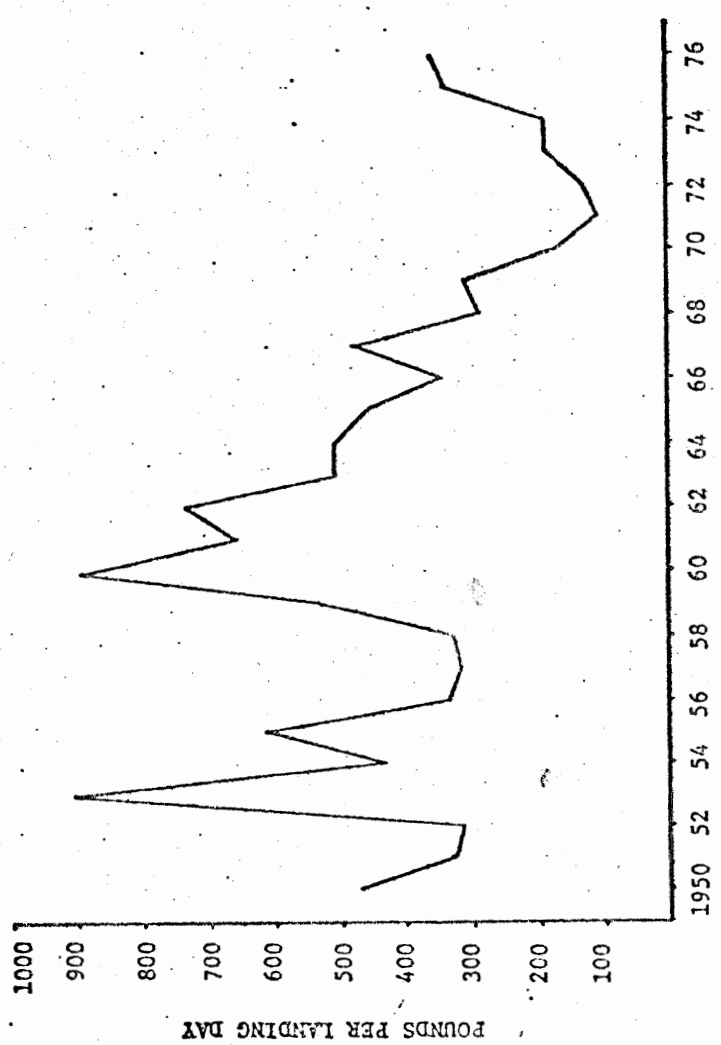


FIGURE 14. Pounds per landing day of California barracuda caught by "standard" gill net boats in southern California waters.

artificially high. They are also high because of two other important reasons: 1) a shift from cotton gill nets to more effective nylon occurred during 1956 through 1959, and 2) following 1959 some fishermen used aircraft during daylight to spot schools of barracuda (Pinkas, CDF&G pers. commun.), which were then encircled with the gill nets much as roundhaul fishermen do, thus producing heavier catches than usual.

Using a yield-per-recruit model and data for years 1958 through 1960 it was concluded that the optimum harvest in weight could be obtained at 4½ years of age for barracuda and that the exploitation amounted to a substantial but not critical drain upon the barracuda resource at that time (Pinkas, 1966). Lowered availability and CPUE during the early 1950's, high availability and CPUE during the late 1950's, and dependence upon small barracuda by the sportfishery following 1959 suggest that a decline in stock abundance occurred during the 1950's; this was not obvious at that time from the available data. The CPUE steadily declined following 1960, and from 1968 to 1972 a sharp decline occurred. The CPUE has increased somewhat during more recent years; however, the stock available off California appears to be well below the levels of the 1940's.

More recently an assessment of the barracuda stock by MacCall et al. (1973) included the use of a surplus production model from which it was concluded that the barracuda resource was probably fully exploited by the 1930's and heavily overexploited by the 1960's, and that recruitment failures may have contributed to the decline. The failure to institute a strict minimum-size limit prior to 1960 when many small barracuda were being retained by anglers probably compounded the effects of suspected poor recruitment during the early 1960's

resulting in the drastic decline of the stock.

A pronounced decline in barracuda landings also occurred at Ensenada from 1966 through 1971 (the last year for which we have data), indicating that there was a decline off northern Baja California as well (Figure 4).

The component of the barracuda population off central and southern Baja California may have recently undergone less of a decline than the component off California and northern Baja California due to reduced exploitation off Mexico by U. S. vessels in recent decades; however figures are not available for landings, if any, south of Ensenada, B. C., Mexico.

Barracuda catch and effort figures from partyboat operators from 1932 through 1940 provide a first look at the condition of the early barracuda sportfishery (Figure 15). Variability in local success caused by the environment is apparent during these years, as it is today; however, the abundance indices (number of barracuda per angler) also indicate that the population was substantially more abundant than it is today.

Following World War II a steady decline in the number of barracuda caught per partyboat angler during June, July, and August coincided with the 9-year cooling trend (1948-1956) in ocean temperatures off California. Warm waters off our coast during 1957 through 1959 were accompanied by a resurgence of barracuda sport fishing success.

Catch-per-effort values for 1958 and 1959 were comparable to the levels of the 1930's and 1940's, but only because environmental conditions tended to optimize barracuda availability off California during these later years. This indicates that by the late 1950's the

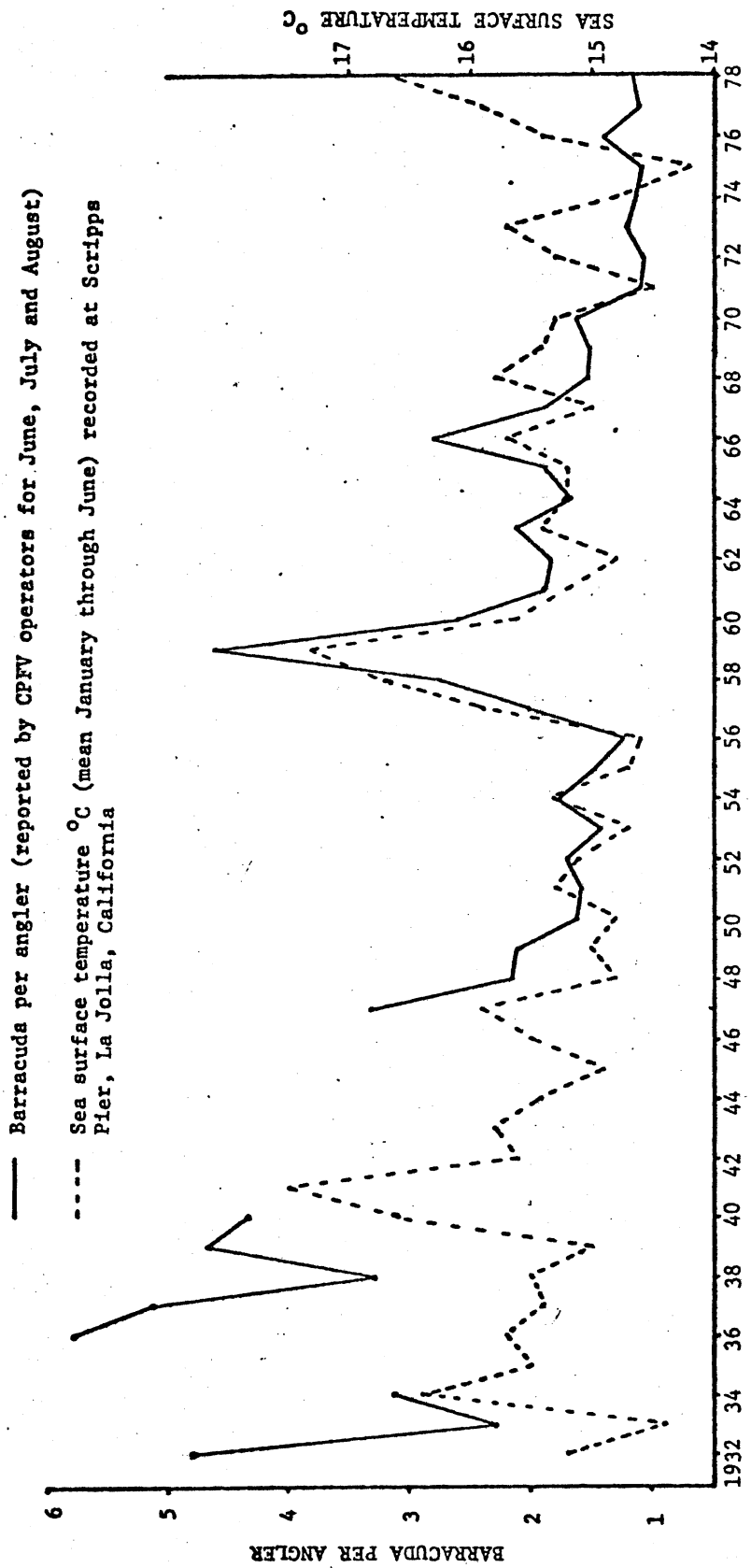


FIGURE 15. Reported barracuda per angler and sea surface temperatures off southern California for years 1932 through 1978.

barracuda resource had significantly declined in abundance from the 1930 and 1940 levels. During 1958 and 1959 the center of the barracuda's range probably had shifted northward to southern California where the few relatively strong year classes (1952-1953) that were spawned during the early 1950's were heavily exploited. Successful year classes that were spawned during 1957 through 1959 appear to have sustained the sport fishery through 1967. The last of the large "log" barracuda resulting from spawning during 1957 through 1959 were caught during 1966 and 1967. Only small (less than 28 in.) barracuda could be found by fishermen in the years that followed. Barracuda recruitment during the early 1960's appears to have been very poor resulting in a virtual collapse of the commercial fishery in 1968, and subsequent dependence upon very young fish by the sport fisheries. Barracuda catch per angler values reported by CPFV's and computed for individual Fish and Game block/areas that historically produced good barracuda catches illustrate the decline in CPUE that occurred during 1968 through 1971 (Figure 16). Since 1971 fewer barracuda have been reported due to the size limit in effect; however, an increase in the average barracuda size has been observed, and there has been a slight trend towards greater abundance.

Indices of abundance derived from data collected aboard partyboats (Figure 17) has also led us to conclude that a measurable decline in barracuda abundance has occurred since the 1940's and that a slight improvement is now occurring.

Comparison of the number of barracuda per angler caught prior to 1940 and since 1971 indicates a decline in stock abundance of about 75 to 90%. Barracuda reported during the 1930's and 1940's were

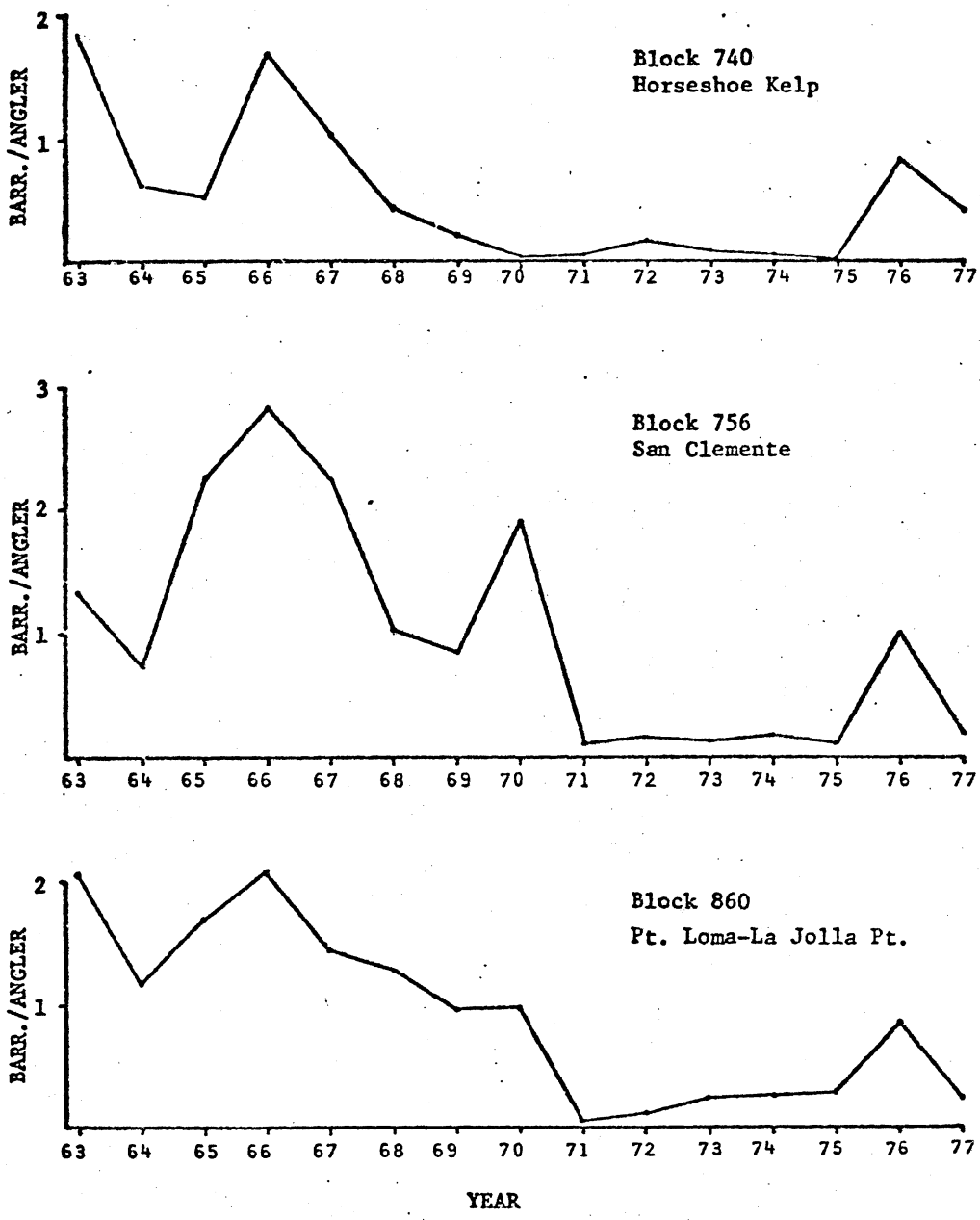


FIGURE 16. Number of California barracuda reported caught aboard southern California commercial passenger fishing vessels within three block areas along the mainland coast from 1963 through 1977.

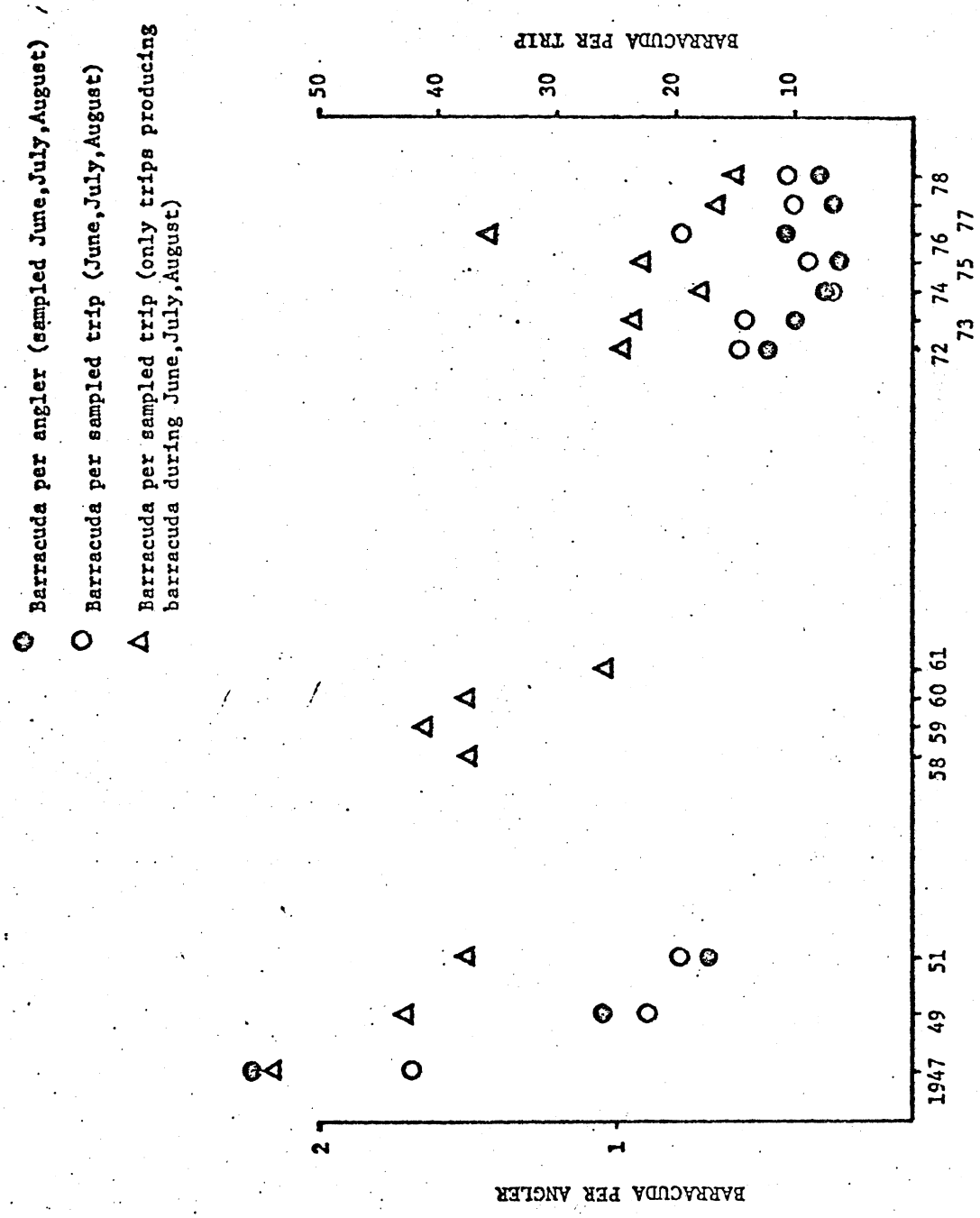


FIGURE 17. Indices of California barracuda abundance from samples collected aboard commercial passenger fishing vessels.

primarily larger than today's legal minimum length, while fish-per-angler values of 1960 through 1970 were maintained only at the expense of undersize barracuda which were allowed in the daily bag. Following 1970 the fish-per-angler reported by partyboat skippers declined sharply due to abolishment of the short barracuda allowance for sportsmen and the reporting of only barracuda larger than 28 inches.

During recent years (1975 to present) fish-per-angler values computed for the CPFV fishery do not show the degree of increase indicated by the 1975 and 1976 commercial CPUE indices. However, a greater diversion of partyboat effort to capture rockfishes, *Sebastes* spp. and associated species in recent years, may be affecting the data and thus masking an increase in barracuda abundance (Figure 18).

Future increases in barracuda abundance are going to depend upon the ability of the stock to recover under increasing pressure from recreational fishermen and commercial fishermen alike. Mexico is making a concerted effort to develop her fisheries which will undoubtedly include increased exploitation of barracuda. California's increasing population will result in a greater demand for sportfishing and a subsequent increase in pressure on barracuda.

If year-class production is more variable at low stock size, which is likely, then several, or a series of consecutive years of successful spawning combined with strict compliance with size, bag, and gear regulations will be required to build a substantially larger population. An increase in the number of year classes during recent years should result in increased spawning potential. Given favorable environmental conditions, the stock size should improve; however, another series of years with marginal spawning conditions could result in poor recruitment

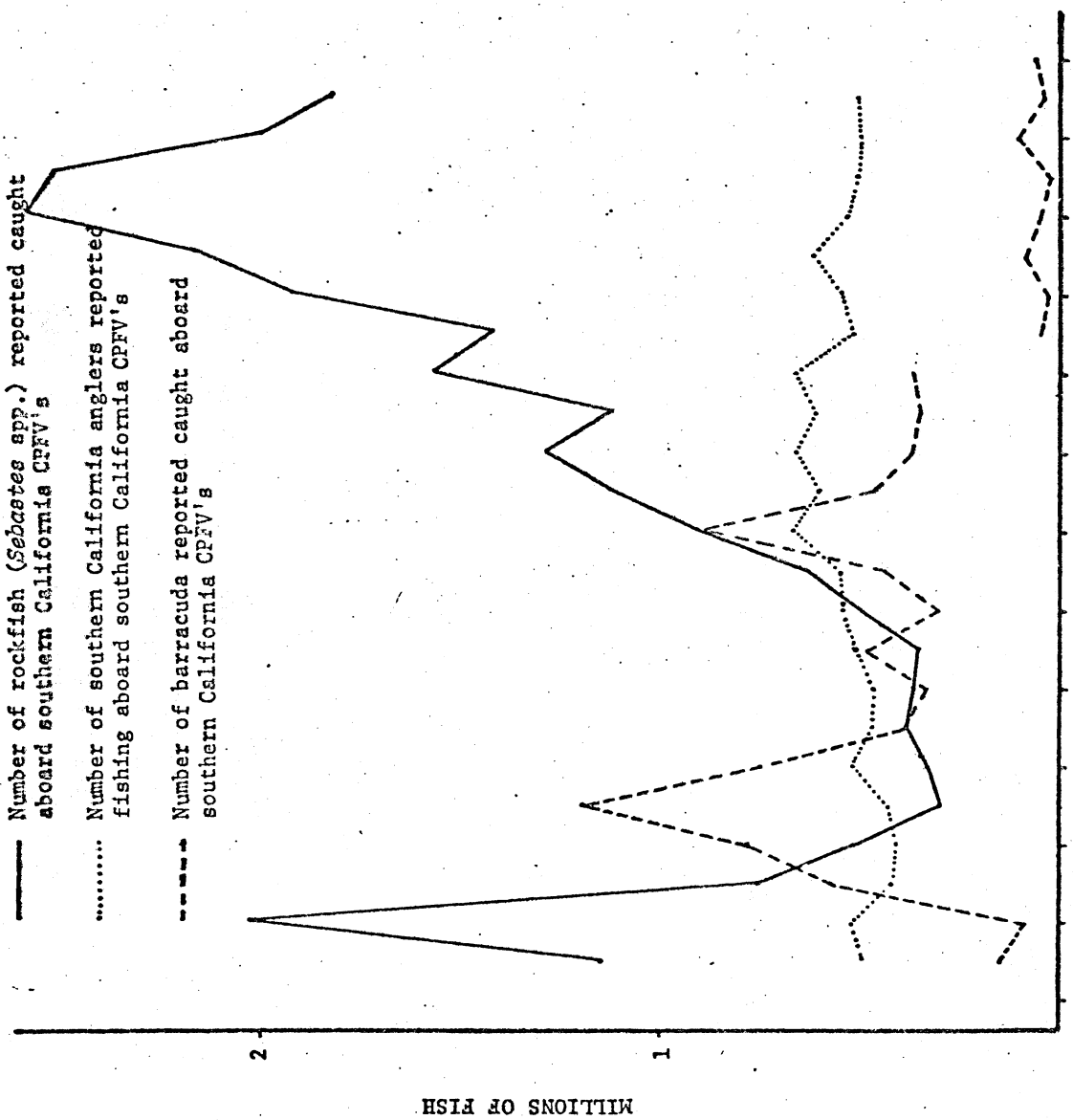


FIGURE 18. Rockfish (*Sebastes* spp.) CPFV landings, southern California CPFV anglers and barracuda CPFV landings.

and a further decline.

B. Yield

Surplus production (equilibrium yield) curves for barracuda in California waters were estimated using combined commercial and CPFV CPUE and effort indices adjusted for changes in ocean water temperatures and gear (MacCall, pers. commun.). This represents a first effort at compensating for these effects.

Catch-per-angler values for CPFV were adjusted for the effects of ocean temperature on availability and behavior by adjusting the annual barracuda CPUE values to a new value at a standard ocean temperature (average annual January to June sea surface temperature at Scripps Pier, La Jolla) of 15.2 C using the temperature-partyboat CPUE relationship for years 1947 through 1967 ($r = .75$) and the following:

$$\frac{U_{st}}{\hat{U}_{st}(15.2)} = \frac{U_{obs}}{\hat{U}(T)}$$

where: $U_{st}$ = standardized CPUE adjusted to 15.2 C.

$\hat{U}_{st}(15.2)$ = CPUE at 15.2 C predicted from temp.-CPUE regression

$\hat{U}(T)$ = CPUE at observed temperature (T) predicted from temp.-CPUE regression

$U_{obs}$ = observed CPUE at temperature (T).

Adjusted catch-per-angler values were multiplied by the mean fish weight to obtain standardized partyboat CPUE in weight. Each annual CPUE value was divided by the mean CPUE for all years to produce a CPUE index with a mean value of 1.0, which could then be combined and averaged with commercial CPUE indices.

A correlation between commercial CPUE (pounds-per-landing day for gill net vessels) and ocean temperature was not strong enough to be

used to adjust commercial CPUE to a standard temperature. The commercial CPUE off California increases during warm-water years, due to an increase in the number of barracuda; however, the decline during cold-water years is partially offset because of additional multi-day trips to distant and more productive fishing grounds. These longer trips resulted in more pounds landed each day during cold-water years. When the data were plotted, the decline in CPUE from 1950 through 1976 resulted in a non-linear relationship between CPUE and water temperature. The failure to adjust commercial CPUE for the effects of water temperature upon barracuda availability was not felt to be as critical as for CPFV CPUE. CPFV CPUE is probably affected more than gill-net CPUE by temperature changes because barracuda feeding behavior which affects CPFV catch rates also appears to be tied to water temperature. By contrast commercial gill nets catch barracuda whether or not they are feeding thus reducing somewhat the effects of changing water temperature.

Adjustments were made to CPUE data for net changes (cotton to nylon) during the late 1950's and for the use of airplanes during a few years following 1959. These took the form of an efficiency factor adjustment. Each resulting annual CPUE value was divided by the mean CPUE for all years, to produce a CPUE index on the same scale as the CPFV indices (mean = 1.0).

CPFV and commercial indices for each year, 1950 through 1976, were averaged. The total annual southern California landings in pounds was divided by the annual combined CPUE index to produce an effort index for each year. As an equilibrium approximation, effort was averaged over half the fishable life-span of the barracuda, (about 6 years),

giving 3-year averages.

Plotting the CPUE index against average effort for each year produced a loose but recognizable relationship (Figure 19). Two lines representing the apparent relationship between effort and CPUE under two different assumptions were drawn. Both were fitted by eye. The outlying points for years 1959 and 1960 were atypical and were ignored under the assumption that increased landings, due to airplane use and environmentally increased availability, were not adequately compensated for.

Curve A of Figure 19 was drawn assuming that all the plotted points through 1976 represent the true relationship between abundance and fishing effort. The resulting curve A (Figure 20) indicates that the barracuda stock could produce a maximum equilibrium yield of about 1.68 million pounds.

Curve B of Figure 19 was drawn assuming the decline in CPUE indices following 1967 was mainly the result of recruitment failure and not representative of the relation between exploitation rate and abundance under normal reproductive conditions. The resulting curve B (Figure 20) indicates a 15% greater maximum yield (1.93 million pounds). However, 40% additional effort would be required to obtain the additional yield. As a first approximation it can be assumed that the relationship between exploitation and abundance lies between those expressed by curves A and B.

The points representing 1972 and 1974 through 1976 lie below the production curves indicating that at the present stock abundance, the amount of effort expended should allow an increase in barracuda numbers to occur, given favorable reproductive success. The rate of recovery is not predicted by using the model.

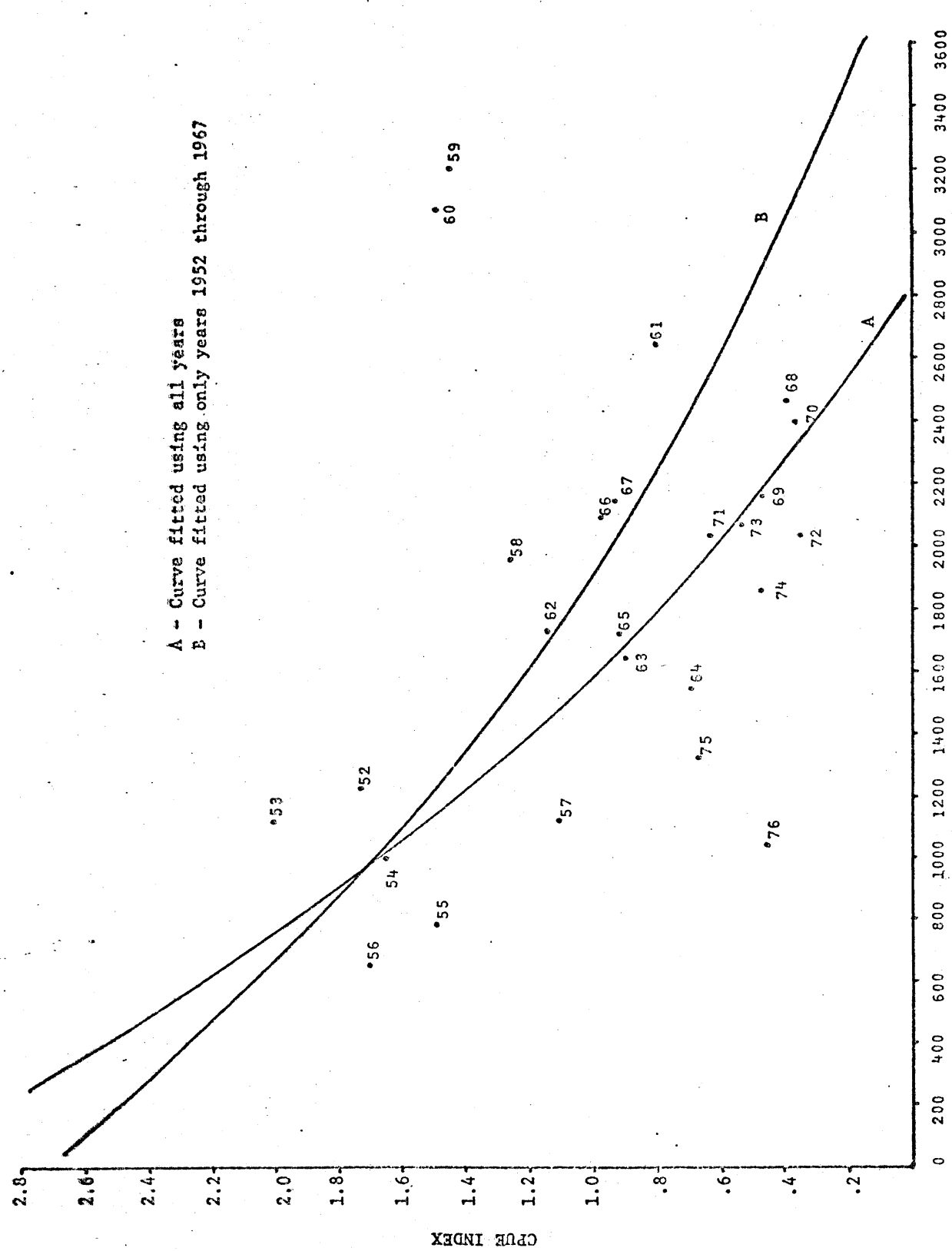


FIGURE 19. Relationship between abundance and effort for California segment of the California barracuda fishery-curve fitted by eye.

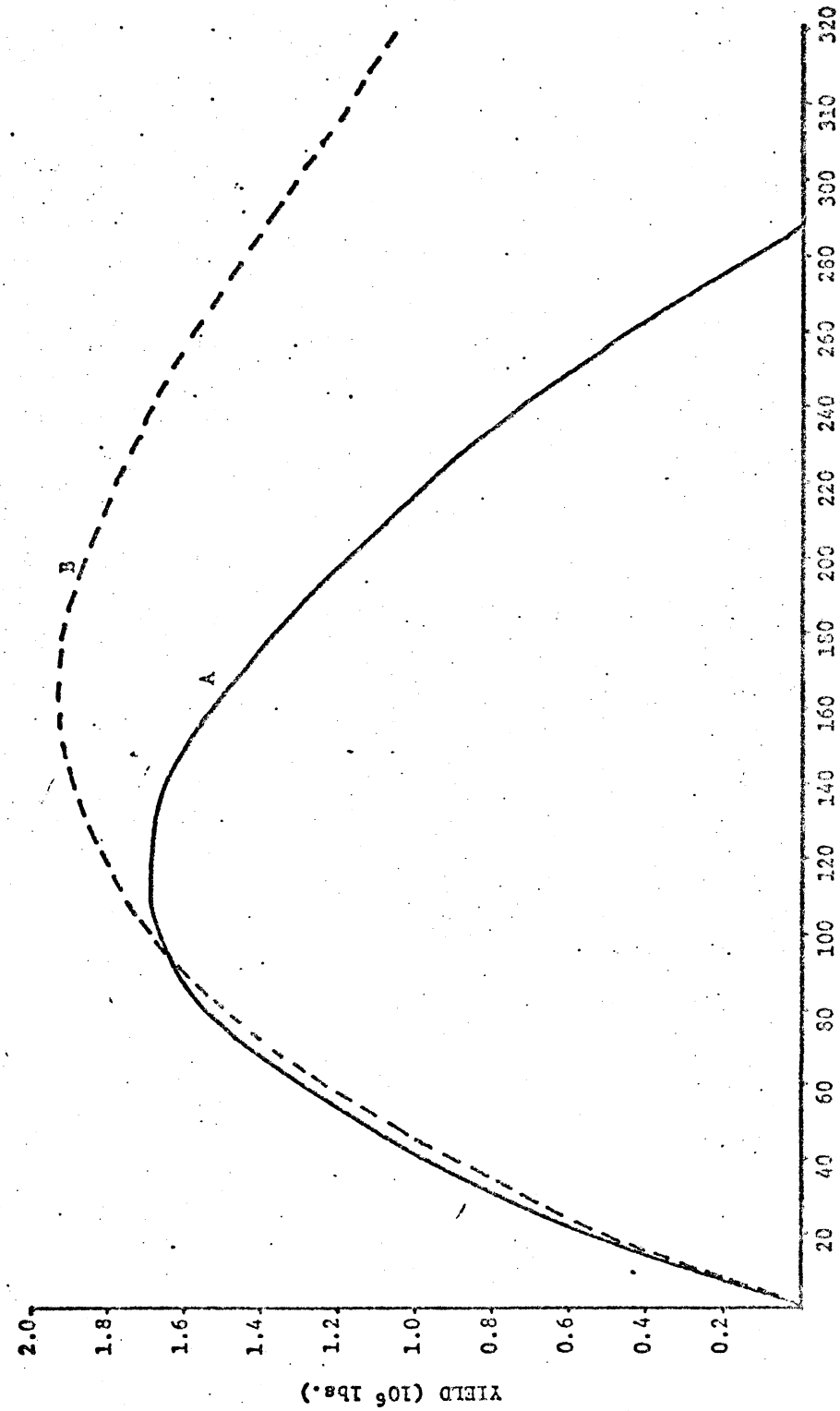


FIGURE 20. Equilibrium yield curve for California barracuda landed from California waters.

Catch and effort during the 1930's and 1940's are being examined in an attempt to obtain reference levels of stock abundance during years when landings were substantially larger than during the 1950's. These additional data may indicate different levels of maximum yield. The computed values of maximum equilibrium yield from California waters of less than 2 million pounds (under average conditions) appear to be substantially less than the average annual landings from California waters of the 1920's, 1930's, and 1940's of over 3 million pounds.

Use of CPUE (even with efficiency adjustments) is likely to underestimate a decrease in abundance. If so, the index used in the model underestimates the actual rate of fish removals from the stock, and the recent fishery has been more heavily overfished than appears from the model (MacCall CDF&G, pers. commun.). This is also consistent with the higher productivity of barracuda in the 1920's through 1940's. California landings of the magnitude made during the 1920's through 1940's may have been possible only as long as the portion of the stock off northern Baja California remained moderate to large. Continued fishing pressure throughout the barracuda's range probably overfished the entire stock by 1950, the earliest years of our data series. Larger maximum equilibrium yields may be possible today if little or no exploitation occurs at the center of the barracuda range off Baja California, Mexico, and the numbers increase substantially to those of the 1930's.

This condition is unlikely to exist in the future as Mexico brings increasing pressure to bear upon this resource. Also tremendous variability in recruitment which is implied by size and age composition information should encourage us to be conservative in our

estimates of maximum yield.

VI. Assessment of Management Practices

A. History of Regulations: Early efforts to manage the California barracuda resource focused upon the commercial fishery. In 1915, an 18-in. size limit was enacted, and since then there have been restrictions on gear and seasons (Table 4). The 18-in. size regulation was changed to 3 lbs in 1917. Despite these regulations, measurements taken at fresh fish markets during 1928 revealed that large numbers of undersize barracuda were being landed (Walford, 1932).

In Skogsberg's (1925) survey of the purse seine industry of the 1920's, accounts are given of large numbers of small barracuda being destroyed by purse seine and other roundhaul nets. Measurements of over 16,000 barracuda in 1928 indicated that between 18 and 21% were smaller than the 3-lb limit. The actual number of undersize barracuda caught and removed from the stock was greater than this, as many were discarded or otherwise disposed of before the vessels arrived in port.

Walford (1932) concluded that in 1928 nearly all barracuda four years old and older were being fully exploited and recommended that the weight limit of 3 lbs be changed to a length of 30 in. He recommended a limit of length rather than weight because of the difficulty fishermen and market operators had in accurately estimating the weight of the individual fish which were close to the legal 3-lb weight. On the other hand, measuring the length is relatively simple and accurate. He also reasoned that raising the size limit to 30 in. (equivalent to about a 3.5 lb barracuda) would reduce the excessive proportion of undersized fish being landed. However, the weight limit was not changed until 1949, when it became 28 in.

TABLE 4. Regulations.

| YEAR | REGULATION |
|---|---|
| 1915 | No barracuda less than 18 inches may be bought or sold.<br>Barracuda designated a game fish requiring a sport license to take. |
| 1917 | No barracuda less than 3 pounds may be bought or sold. |
| 1927 | Unlawful for purse seine or other roundhaul to take or possess barracuda between May 15 through July 31. |
| 1932 | Unlawful for purse seine or other roundhaul to take or possess barracuda between May 1 through July 31. |
| 1934 | No barracuda may be sold between May 1 and June 30.<br>No more than 5 barracuda weighing less than 3 pounds each may be possessed each day, but are not to be sold or purchased. |
| 1935 | Barracuda not less than 3 pounds may be taken with hook and line.<br>No nets may be used to take barracuda between May 1 and August 31.<br>Between May 1 and August 31 a limit of 500 pounds of barracuda per man or 2,500 pounds per boat. |
| 1939 | Daily marine sport bag limit of 15 game fish in aggragate (no more than 15 barracuda if only barracuda caught). |
| 1940 | No purse seine or roundhaul may be used to take barracuda north of the international boundary with Mexico.<br>Barracuda gill net mesh must be no less than 3½ inches stretched mesh. |
| 1941 | May not sell any sportfish taken under the authority of a sport-fishing license.<br>Repeal restriction on 500 pound of barracuda per person and 2,500 pounds of barracuda per boat. |
| 1947 | Weight limit of 3 pounds changed to length limit of 28 inches for sport and commercial.<br>Not more than 5 barracuda less than 28 inches per day in sport bag. |
| 1949 | Daily sport bag limit no more than 10 of one species and 15 in aggregate of species. |
| 1957 | No more than 2 barracuda shorter than 28 inches allowed in the daily bag limit.<br>Daily bag limit of 10 game fish in aggragate. |
| 1971 | No barracuda less than 28 inches allowed in daily bag limit. |

total length (equivalent to just 3 lbs). The delay resulted in the loss of large numbers of young barracuda over the intervening years.

Unfortunately the underlying problem of the ability of the nets to remove undersize barracuda from the stock, was never resolved. Purse seine and lampara nets continued to be used to harvest barracuda until 1940, when their use in this fishery was banned off California. A minimum mesh size of 3½ in. for gill nets was instituted the same year.

Barracuda sport catches were not regulated until 1939 when a daily limit of 15 per angler was established. The sale of sport caught fish was prohibited in 1941. In 1947 following WWII a daily sport limit of five undersize barracuda was established and the present limit of 10 barracuda per day was established in 1949. The number of barracuda less than 28 in. that could be retained in the daily limit of 10 was reduced to 2 in 1957 and to 0 in 1971.

The liberal allowance until 1971 of undersize barracuda in the daily bag minimized enforcement problems but did nothing to conserve the resource, which had been heavily exploited since the 1930's.

B. Management Problems: The major problem today is enforcement of the regulations.

Commercial Passenger Fishing Vessels (CPFV's): CPFV anglers have done a fairly good job adhering to the size limit and the zero allowance of undersize barracuda enacted in 1971. Experienced skippers and crews are able to inform passengers of size and bag limits, identify fish species, and they are equipped to determine if a fish is legal.

During 1977, 5.1% or about 4,400 of the undersized barracuda that came aboard these boats were kept by anglers. This figure was

2.2% or 4,600 fish during 1978. The majority of undersize barracuda are 3-and 4-year-old fish which are rapidly developing in size and reproductive capacity. The estimated percent of "shorts" caught and kept is biased because of our presence aboard the boats and it should be considered a low estimate of the true value.

A recent survey was conducted aboard southern California CPFV's to determine the ability of anglers and boat operators to identify common sport fish. Over 80% of the anglers and 100% of the skippers and crew were able to identify barracuda. With this high degree of identification ability and concurrent knowledge of sportfishing regulations, there is no valid reason for the unnecessary destruction of young barracuda aboard these vessels.

U. S. based CPFV fishermen operating off Mexico often returned with large numbers of undersize barracuda, perhaps mistakenly assuming that fishing in foreign waters exempts them from California regulations. Such undersize barracuda are included in landings reported to the Department and introduce errors into any calculations that assume that only legal barracuda are now being reported.

Careless handling of undersize barracuda has been a problem since the 1971 regulation change. Passengers often drop them on the deck or rip the hooks from the mouth or throat rather than carefully removing the hook or cutting the line before releasing them. Deckhands often gaff undersize barracuda that subsequently die even if returned to the water.

The selling of barracuda by partyboat operators and passengers is an occasional problem. This disregard for the law results in a display of poor conservation and sporting ethics for all.

Independent Private Boat Fishing: Independent anglers catch fewer barracuda than CPFV anglers; however, they land a larger percent of undersize ones. The keeping of "shorts" appears to be the rule rather than the exception, with anglers being either ignorant of California's regulations or choosing to ignore them.

Since 1974, the percent of undersized barracuda landed by anglers aboard private boats has been 61% in 1974, 41% in 1975, 22% in 1976, 37% in 1977,and 39% in 1978. The percentages during 1975 and 1976 represent about 1,500 and 5,700 barracuda respectively. This is roughly equivalent to the numbers of undersize barracuda retained by CPFV anglers and is a serious problem, particularly as the number of independent private boat anglers increase each year.

Gill-Net Fishery: Barracuda caught in gill nets were sampled at the local fresh fish markets from 1973 through 1978. Substantial numbers of undersize barracuda were landed (20% in 1973 and 9% in 1974), creating concern for the numbers that were actually being killed by these nets. The excessive numbers appearing in the market is the direct result of fishermens attitude and the selective action of the gill nets. Three and one half inches stretched mesh has been legal since 1940; however, no evaluation of the ability of this mesh to capture undersize barracuda had been made.

Recent experiments with different mesh sizes indicate that 24% undersize barracuda or about 12,800 fish during 1976 and 5,360 barracuda during 1977 were killed.

A decline in the number of undersize barracuda landed at markets during recent years is felt to result from fishermen disposing of them before unloading at the docks.

The use of gill nets set in circle around barracuda schools has been reported on numerous occasions. These nets are reportedly deeper than those used by most fishermen. Such fishing may destroy an entire school of barracuda and result in abnormally large catches being made; this can oversupply the market and drop prices.

Gill-Net Mesh Evaluation: A survey was conducted to determine the percent of undersize barracuda caught by 3½-in. mesh gill nets and to determine what the mesh size should be if a larger one is indicated.

Twelve pieces of gill net, four each of 3.5 inches (8.9 cm), 3.75 in. (9.6 cm) and 4.0 in. (10.2 cm) stretched mesh, totalling 384 m (210 fms) in length and 9.15 m (5 fms) in depth were constructed.

Each section of net was 32.1 m (17.5 fms) in length and separate sections were connected in the order of 3.5 in., 3.75 in., 4.0 in., 3.5 in., 3.75 in., 4.0 in. . . . . etc.

Fishing took place between Whites Point on Palos Verdes Peninsula and Huntington Beach, California in depths ranging from 15 to 33 m (8 to 18 fms). A total of 25 trips was conducted during July and August 1978 and May 1979. The nets were set approximately 1/2 hr before sunset and left in the water for at least 1.5 hr following sunset. Generally, one set was made each night; however, on seven nights, two sets were made and on one night, three were made.

Nets were set perpendicular to the beach whenever possible. However, sets made parallel to the beach were equally productive.

Fish captured in each mesh size were removed and stored in separate containers and returned to the laboratory where their length, weight, and sex were recorded.

A total of 293 barracuda weighing nearly 545 kg (1200 lbs) was captured. The 3.5-, 3.75- and 4.0-in. mesh captured 25.8, 12.7, and 7.0% undersize barracuda respectively. Barracuda from 630 to 931 mm gilled in the 3.5-in. mesh, 673 to 951 mm for the 3.75-in. mesh, and 678 to 875 mm for the 4.0-in. mesh. Of the three mesh sizes, the 3.75-in. mesh captured the greatest number and poundage of legal barracuda, followed by the 3.5-in. mesh. The 4.0-in. mesh caught significantly fewer barracuda in the smaller size increments of 75 to 80 cm (29.5 to 31.5 in.).

At present, five undersized barracuda may be retained each day by commercial fishermen for their own use (not to be sold). At 4 lbs per fish, this represents 20 lbs of barracuda per day per man. Our work indicates that using 3.75-in. mesh, a catch of 375 lbs of barracuda (the average pounds per landing for 1976) would result in 30 lbs of undersize barracuda being caught. This equals the daily allowance for 1.5 men. Crews normally number 1 or 2 men aboard the gill-net boats. The current legal mesh of 3.5 in. resulted in more than twice this quantity of undersize barracuda being gilled.

Ten percent of the barracuda were alive when removed from the nets, and some of these would have died if released. Releasing an undersize barracuda caught in gill nets is not a successful means of returning them to the water alive.

The 3.75-in. mesh appears to be the most favorable size based upon the current barracuda size limit of 28 in. There is no indication that the catch of legal barracuda would be reduced significantly by an increase in mesh size, but the number of undersize barracuda killed would be reduced significantly.

## VII. Recommendations

Although the California barracuda resource shows signs of slow recovery from the low in the late 1960's and early 1970's, there is no assurance that it will continue to do so if it is subjected to an uncontrolled increase in exploitation.

Management action should continue to concentrate on insuring the maximum survival of barracuda through at least three spawning seasons. The present minimum size limit of 28 in. (71 cm) is necessary to increase the size of the population, and to maintain it at optimum levels under continued exploitation.

Several methods were identified during this work, that would increase the survival of barracuda through their first spawning:

1. Increase the minimum mesh size to 3.75 inches. This would bring the gill net catch more into line with present size restrictions on other fishermen and allow an increase in the number of 3 and 4 year old barracuda to escape and spawn. In 1976, a minimum of 5,300 undersize barracuda would have escaped to spawn if 3.75 in. mesh had been used.

   A change in mesh size will require the construction of new nets, and conversion time should be allowed. Barracuda gill nets tend to last longer than some others due to their limited contact with abrasive surfaces and to limited exposure to light. Allowing 3 years to convert to 3.75-in. mesh should reduce the financial inconvenience by spreading the cost over a period of time. The fleet is the smallest since before World War I, and a change in nets will have less overall impact now than in the future should the barracuda fishery expand. With an increased mesh size,

fishermen would expend less effort in removing undersize barracuda from their nets, and the markets should receive fewer sublegal ones.

2. Limit the depth of the gill nets to 170 meshes or 11.4 meters (6.25 fms). This would reduce their effectiveness if unlawfully used as encircling nets, without affecting legal operations.
3. Prohibit any barracuda aboard vessels carrying gill nets of less than 3.75-in. mesh. This should reduce the temptation to fish for undersize barracuda with small mesh nets, and it will expedite law enforcement by eliminating the need to apprehend fishermen in the act of capturing "short" barracuda with illegal mesh.
4. Apply present size and gear restrictions to all California barracuda landed or imported regardless of origin. This is directed primarily at the roundhaul nets that may still capture California barracuda in Mexican waters. Restriction against roundhaul nets would have no impact upon the fishery but it would eliminate future exploitation by this gear. Size restrictions upon imported barracuda would aid law enforcement and encourage conservative practices by Mexican fishermen.
5. Remove the allowance of undersize barracuda for all commercial fishermen with the exception of five per boat per day for gill net fishermen. An allowance for other than gill net fishermen is unnecessary because undersize barracuda caught by rod and reel or trolling (the only other fishing methods other than roundhaul nets) are easily released alive.
6. Increase efforts to educate recreational fishermen about the

regulations. A reduction in the large numbers of undersize barracuda destroyed by anglers would contribute much towards the recovery of the resource. Simplified aids to fish identification and the reasons for regulations must be made available to all anglers. Newspapers and magazines should be utilized to distribute this information.

7. California barracuda should have high priority in discussions with Mexico. The California barracuda resource has historically proven itself vulnerable to overexploitation, and, although Mexico has applied relatively light commercial fishing pressure upon the resource, the sportfishery claims large numbers of young maturing barracuda each year. If the barracuda resource is to recover to a sustainable level of maximum abundance then Mexico can be expected to play a key role in managing, or failing to manage it. Data pertinent to management should be made available to Mexico to aid in the rational management of the entire stock. Heavy fishing effort off Mexico would undoubtedly reduce the availability of barracuda off California, however historical catch data indicate that at moderate to large stock sizes moderately successful catches should be possible throughout the range of the California barracuda.

REFERENCES

Berdegue' A. Julio. 1956. Peces de importancia comercial en la costa nor-occidental de Mexico, Secretaria de Marina, Direccion General de Pesca e Industrias Conexas, Comision para el Fomento de la Piscicultura Rural: 345.

California Division of Fish and Game. 1946. The commercial fish catch of California for the years 1943 and 1944. Calif. Div. Fish and Game. Fish Bull., (63):1-81.

_____. 1947. The commercial fish catch of California for the years 1945 and 1946. Calif. Div. Fish and Game. Fish Bull., (67):1-80.

_____. 1949. The commercial fish catch of California for the year 1947 with an historical review 1916-1947. Calif. Div. Fish and Game. Fish Bull., (74):1-267.

Feder, Howard M., Charles H. Turner and Conrad Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. Calif. Dept. Fish and Game. Fish Bull., (160):1-144.

Frey, Herbert W. (ed). 1971. California's living marine resources and their utilization. Calif. Dept. Fish and Game, Sacramento. 148.

Hubbs, Carl L. 1948. Changes in the fish fauna of western North America correlated with changes in ocean temperature. Jour. Mar. Res., 7(3):459-482.

Janssen, John F. Jr. 1937. *In* The commercial fish catch of California for the year 1935. Calif. Div. Fish and Game. Fish Bull., (49):1-170.

MacCall, Alec D., Gary D. Stauffer, and Jean-Paul Troadec. 1976. Southern California recreational and commercial marine fisheries. Mar. Fish. Rev., 38(1):1-32.

Magnuson, John J. and John H. Prescott. 1966. Courtship, locomotion feeding and miscellaneous behavior of Pacific bonito *(Sarda chiliensis)*. Animal Behavior, 14:54-67.

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

Parrish, Richard H., and Alec D. MacCall. 1978. Climatic variation and exploitation in the Pacific mackerel fishery. Calif. Dept. Fish and Game, Fish Bull., (167):1-110.

Pinkas, Leo. 1966. A management study of the California barracuda, *Sphyraena argentea* Girard. Calif. Dept. Fish and Game. Fish Bull., (134):1-58.

Pinkas, Leo, Malcolm S. Oliphant and Charles W. Haugen. 1968. Southern California Marine Sportfishing Survey: Private boats, 1964, Shoreline, 1965-66. Calif. Dept. Fish and Game. Fish Bull., (143):1-42.

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):1-62.

_____. 1975. Ocean temperatures and southern California angling success. A paper presented at a symposium on fisheries science at the Higher School of Marine Science of the Autonomous University of Baja California Ensenada, B. C. Feb. 16 -22, 1975.

Schultze, Donald L. 1973. The status of the California barracuda resource and its management. Calif. Dept. Fish and Game. Mar. Resour. Tech. Rpt. (6):1-20.

Skogsberg, Tage. 1925. Preliminary investigation of the purse seine industry of southern California. Calif. Fish and Game Comm. Fish Bull. (9):1-95.

Walford, Lional A. 1932. The California barracuda *(Sphyraena argentea)*. Calif. Div. Fish and Game. Fish Bull., (37):1-122.

Wine, Vickie L. 1979a. Southern California independent sport fishing survey quarterly report for July-September, 1976. Calif. Dept. Fish and Game. Mar. Resour. Admin. Rpt., 79-7:1-22.

_____. 1979b. Southern California independent sport fishing survey quarterly report for October-December, 1976. Calif. Dept. Fish and Game. Mar. Resour. Admin. Rpt., 79-8:1-19.

_____. 1979c. Southern California independent sport fishing survey quarterly report for January-March, 1976. Calif. Dept. Fish and Game. Mar. Resour. Admin. Rpt., 79-9:1-20.

_____. 1979d. Southern California independent sport fishing survey quarterly report for April-June 1976. Calif. Dept. Fish and Game. Mar. Resour. Admin. Rpt., 79-10:1-20.

Wine, Vickie and Therese Hoban. 1976. Southern California independent sportfishing survey, annual report July 1, 1975-June 30, 1976. Calif. Dept. Fish and Game. Mar. Resour. Admin. Rpt., 76-14:1-299.