EXPLOITATION AND RECRUITMENT OF PACIFIC MACKEREL, *SCOMBER JAPONICUS*, IN THE NORTHEASTERN PACIFIC

RICHARD H. PARRISH *
California Department of Fish and Game
Long Beach, California

The Pacific mackerel stock discussed in this paper originally extended from the Gulf of Alaska to Punta Eugenia, Baja California and the fishery has been centered in southern California and northern Baja. The fishery, biological knowledge, and current status of the resource were recently reviewed by Blunt and Parrish (1969) and Kramer (1969) has prepared a synopsis of this species in the northeastern Pacific.

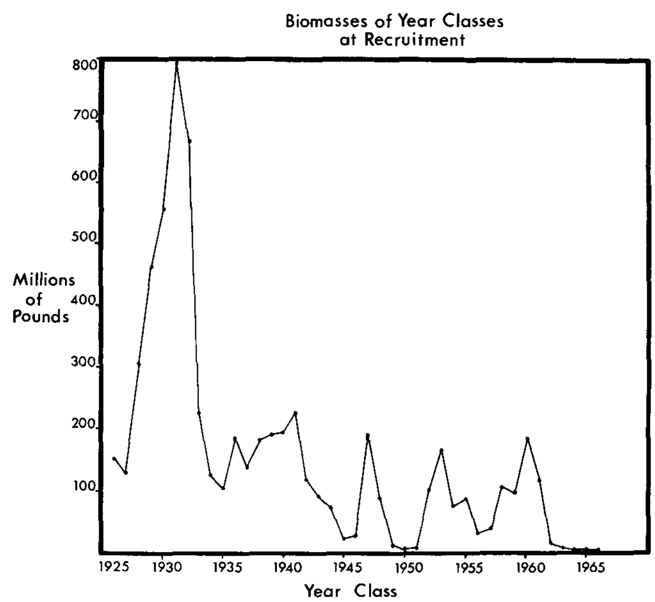
Population estimates used in the paper are based on a Murphy method (1966) program using age composition data derived from otolith readings (32,841) of Pacific mackerel, *Scomber japonicus*, sampled in the southern California commercial catch. Age composition data representing landings from 1939 to 1967 were taken from a series of papers describing the southern California catch. (Fitch 1951, 1953a, 1953b, 1955, 1956, 1958, Hyatt 1960, Parrish and Knaggs 1971, 1972). The 1926 to 1938 data were estimated by using length frequency data taken from market samples during the early fishery, age-length data from the otolith readings, and separating the mixture of normal distributions into separate normal distributions; this was accomplished using a computer program (NORMSEP).

The Murphy method is essentially an expanded virtual population estimate. It uses an assumed natural mortality rate and produces a calculated fishing mortality rate for each age group of each year-class.

The Murphy method program was run for three instantaneous natural mortality rates; 0.4, 0.7, and 1.0. The 1.0 value gives an unreasonably large population estimate in the early fishery where this mortality rate produced population biomass estimates which approach the magnitude of the sardine population in the early 1930's. In the recent fishery instantaneous fishing mortality rates are so large (up to 2.29) that there is little difference in the total annual mortality between an instantaneous natural mortality rate of 0.7 or 1.0. The 0.4 instantaneous natural mortality rate gives exploitation rates greatly in excess of those found by tagging studies. This 0.4 rate gives exploitation rates from 0.25 to 0.50 for the late 1930's and early 1940's, while Fry and Roedel (1949) found exploitation rates from 0.08 to 0.19 for the same period. The 0.7 instantaneous natural mortality rate was thus chosen as the best estimate of natural mortality.

SPAWNER–RECRUIT RELATIONSHIP

The recruit biomass (Figure 1) used throughout the study is the Murphy method estimate for each year class at the beginning of its second year (age group I). For most of the fishery, the fish first entered the fishery as 1 year olds. Since population estimates represent the biomass present at the beginning of a season, the method cannot validly estimate



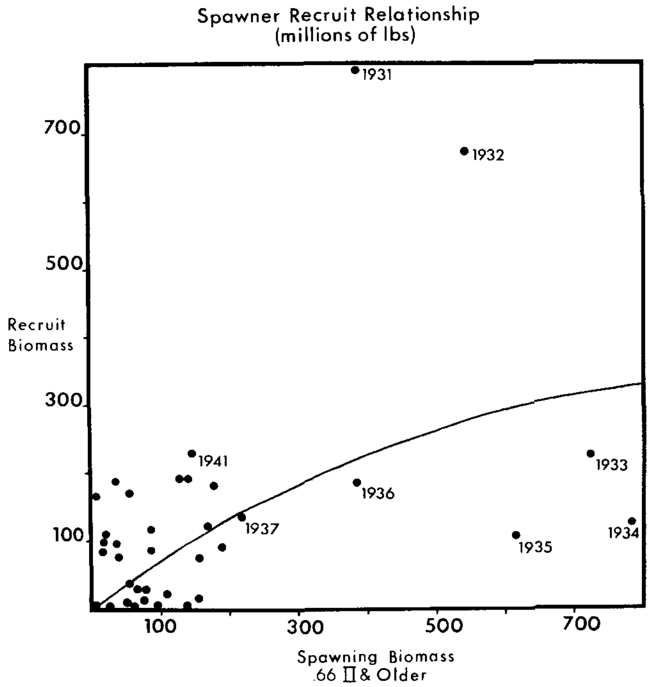
the population of 0 age fish. Since 1965 there has been significant exploitation of 0 age fish and in 1967 0 age group fish comprised more than 65 percent of the poundage landed. For the purposes of this paper, however, exploitation of 0 age fish has been omitted.

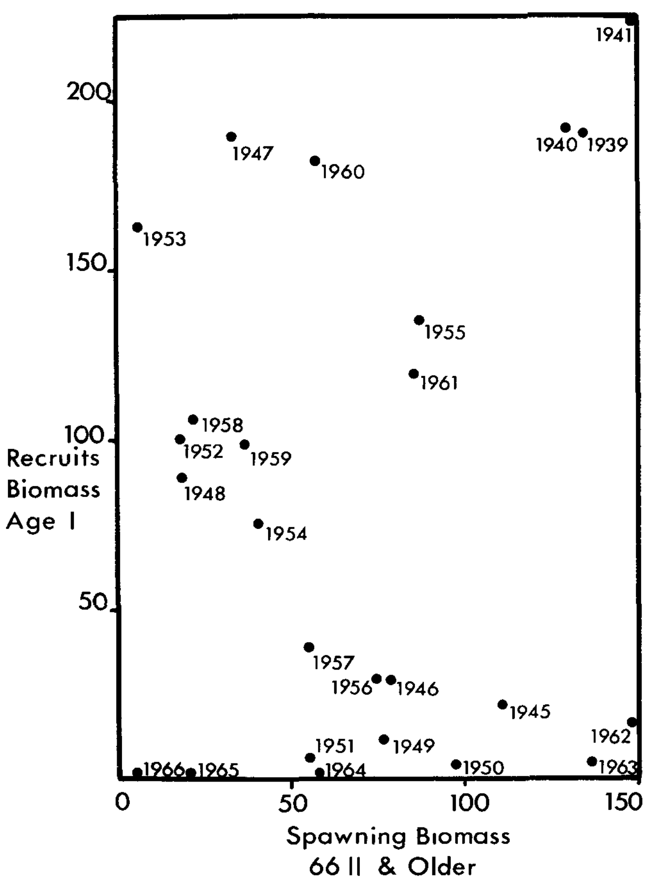
Estimates for spawning biomass were considered to be 66% of age group II fish plus all older fish. Recent evidence, (Knaggs and Parrish, 1972) showing that approximately 23% of age group I females spawn, was excluded since Fry (1936) did not find age group I fish spawning during the period of the early fishery. This spawning of age group I fish in recent years may be in response to the very low biomass and better condition of individual fish.

Calculation of a Ricker spawner-recruit curve for Pacific mackerel results in a shallow curve ($R = 0.7780Se^{-0.0000008117S}$) with increasing recruitment as spawning biomass increases: both spawners (S) and recruits (R) are in units of thousands of pounds. The curve (Figure 2) remains positive for the entire range of observed data, 1931 to 1966. The extremely small constant in the exponent reflects a small hindrance to relative recruitment with increasing spawning biomass. However, the model predicts that recruitment is directly density dependent over the observed range of spawning biomass. Thus, the greater the spawning biomass, the greater the mean resultant year-class.

The shallow Pacific mackerel spawner-recruit curve suggests that there is little resiliency in the Pacific mackerel population. For example, at a spawning biomass level of 500 million pounds, the spawner-recruit curve predicts that each pound of spawners will pro-

*Present address: Oregon State University, Corvallis, Oregon



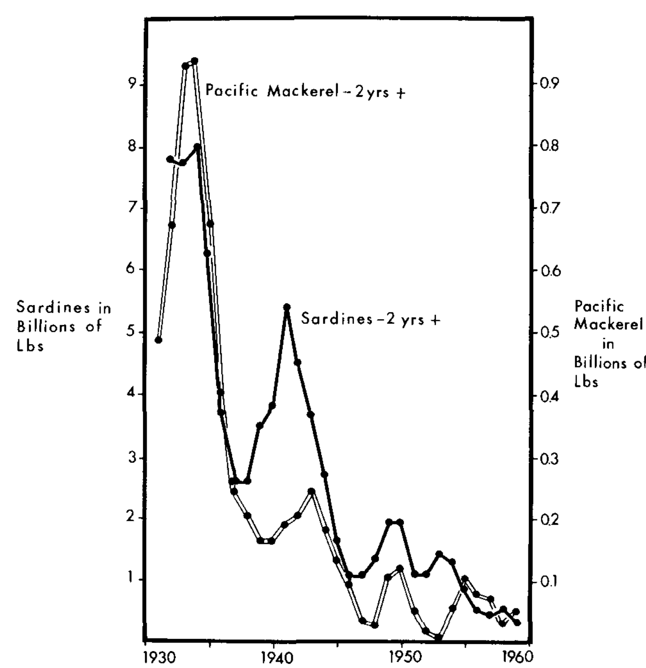


duce 0.5185 pounds of recruits. This rate only rises to 0.7173 pounds at a spawning biomass of 100 million pounds and 0.7717 pounds at 10 million pounds. If the exploitation rate exceeds the level at which growth and survival allow a year class to produce a spawning biomass, spread over its life span, equal to its parent biomass the Pacific mackerel population will continue to shrink; according to the model.

The large amount of scatter about the spawner-recruit model limits the predictive value of the model over a short time period. However, it does reflect mean recruitment within a given spawning biomass level.

A look at recruitment (Figure 2 and 3) from a time series suggests several factors. First, the extremely large biomass that accompanied the fishery peak in the mid-thirties was produced by the 1931 and 1932 year classes which were much larger than any succeeding year classes. Second, spawning success is aperiodic and varies in series of from 2 to 10 or more years. The period of 1933 to 1944 was characterized by a wide range of spawning biomass and relatively stable recruitment of between 70 and 230 million pounds. This period was followed by a period (1945 to 1948) of much smaller spawning biomass and the same general range of recruitment; however, there were two relatively weak year classes (1945 and 1946). There were then three poor year classes (1949 to 1951) at the same general spawning biomass levels. Good recruitment then returned for 10 years (1952 to 1961). Following the end of this good recruitment period (1962), the spawning biomass reached almost 150 million pounds, the highest level since 1944.

Since 1962, there has been a near total spawning failure and the spawning biomass fell below 5 million pounds in 1966 (Figure 3) and below 1 million pounds in 1967.

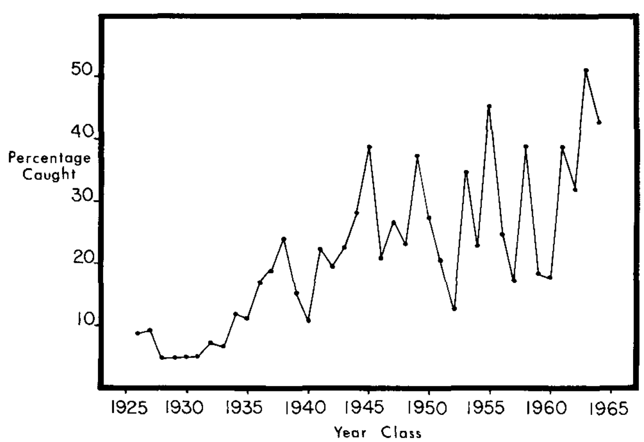


It appears Pacific mackerel recruitment is heavily influenced by factors other than spawning biomass. This hypothesis is strengthened by the association between Pacific mackerel population estimates and Murphy's (1966) sardine population estimates. Murphy's estimates included 2 year old and older sardines. Using Pacific mackerel of the same ages for comparative estimates (Figure 4), it appears that the years of decline in both the sardine and Pacific mackerel are very similiar; suggesting that both populations may have been influenced by the same or related factors.

FISHING MORTALITY AND EXPLOITATION RATES

There has been a long trend of increasing fishing mortality rates during the fishery's history. Although older age groups show increases in fishing mortality, the younger age groups (0's and I's) exhibit the greatest increases. Age group 0 fish were virtually unexploited before 1965. The first season that fishing mortality for age group I exceeded 0.5 was 1964. The overall trend is demonstrated by the percentage of recruits which were caught from each year class (Figure 5). These data are based on the assumption that instantaneous natural mortality equals 0.7 and include the combined catch of each year class from age group 0 to V.

Percentage of Pacific Mackerel Recruits (Age I) Taken by the Fisheries From Age O–V (numbers) at M =.7



The scatter about a trend line, and possibly the trend line itself, is primarily caused by the fact that poor year classes are exploited at a higher rate than strong year classes. High exploitations in 1945, 1949, 1963, and 1964 were all on very weak year classes. The 1955 year class was of moderate biomass. Low exploitation in 1940, 1952, 1959, and 1960 was due to strong year classes; 1957 was a low, moderate year class. For the period of 1931 to 1966, there is a correlation coefficient of —0.6 between the catch per recruit from 0 to V and the size of the year class. This correlation coefficient of —0.6 also is found between the catch per recruit and total population size of Pacific mackerel present at time of recruitment. In addition, exploitation is affected by following year classes, and by the population size of other fish, particularly sardines and jack mackerel. Market demand, of course, has an overriding control of the fishing effort exerted on the species and economic factors have affected the exploitation rates.

To illustrate the relationship between population biomass and exploitation rate, data since 1950 were separated into three categories:

(1) high biomass, which includes 8 years and levels between 154 and 322 million pounds;

(2) low biomass, which includes 8 years and biomass between 23 and 109 million pounds; and

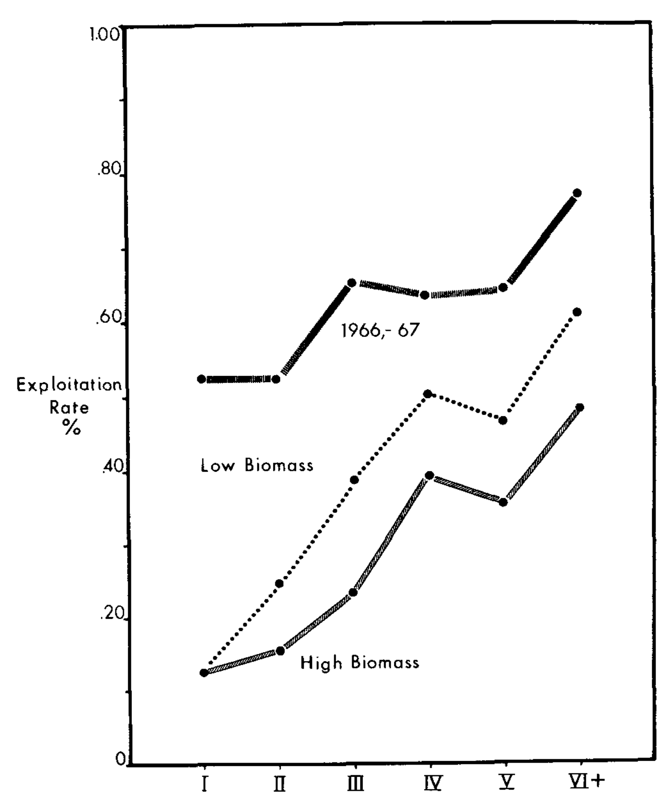
(3) the very low biomass of the 1966–67 to 1967–68 seasons, which includes biomass levels of 1.1 to 6.7 million pounds.

This last level is close to expected exploitation rates since the 1967–68 season because the biomass has been very low since the 1966–67 season.

These exploitation levels do not include age 0 fish which did not have exploitation rates exceeding 0.05 until 1965. Exploitation rose to 0.43 in 1966 and remained high until the moratorium went into effect in 1970.

Exploitation rates in the low biomass years run in excess of 0.10 higher than the high biomass years (Figure 6). Very high rates have been operating on age IV and older fish at all biomass levels since 1950. The very low biomass seasons of 1966–67 and 1967–68 have exploitation rates well above those that any fishery could sustain. In these seasons, all age groups have

Population Biomass VS Exploitation Rate in Pacific Mackerel



rates above 0.5, and the bulk of the spawning age fish have rates in excess of 0.6.

Although the fishermen traditionally prefer larger fish, during these years of very low population levels, their exploitation of immature fish, 0's, I's and II's, increased greatly. The demise of the scoop fishery which was more selective for older fish than the purse seine fishery also is a factor.

These high exploitation rates came at a time, 1966–68, when fishing mortality should have been reduced because there had been a series of poor recruitment years.

CONSEQUENCES OF ALTERNATE MANAGEMENT DECISIONS

In view of the fact that regulation of the commercial Pacific mackerel fishery is the responsibility of the State Legislature, avenues of management seem to include four possibilities: no catch limitations; a size limit; a moratorium, and a catch quota. Rapid changes in biomass that result from wide variation in Pacific mackerel recruitment appear to me to exclude a management policy based on a maximum sustained yield concept. A quota method of management must therefore include flexibility to change the quota annually. This could encourage fishing during years of good recruitment and limit or close the fishery when recruitment is poor.

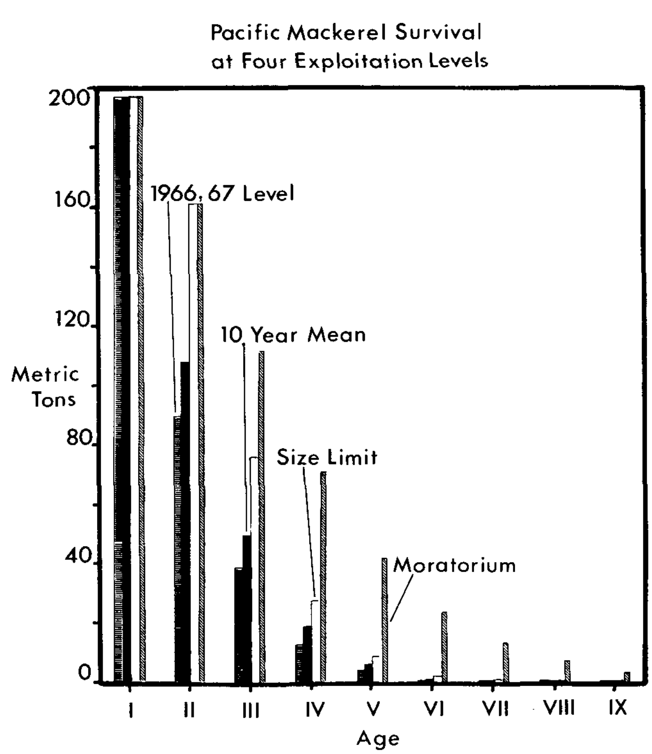
A no catch limitation policy would result in exploitation rates similar to those of the recent past and I have separated these into two exploitation levels; that of a 10 year mean, 1958–67, and second, the level of 1966–67, 1967–68. This second level would be similar to that which would be expected if commercial fishing were to begin at the present low population level. Both of these levels are underestimates of total exploitation of a year class since they do not include fishing mortality on 0 age fish.

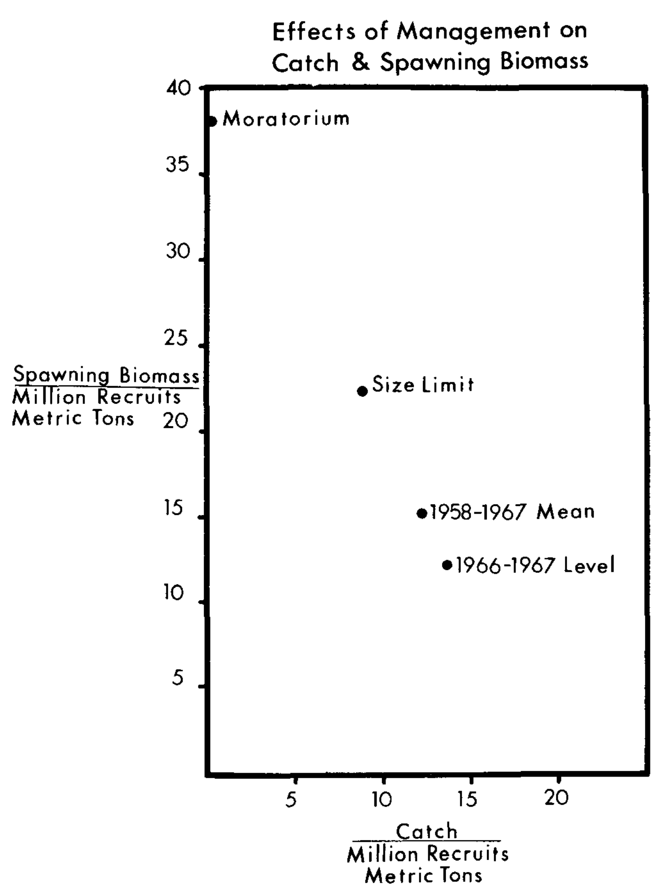
A size limit would only protect the 0 and I age-group fish, since by the time Pacific mackerel reach age group II they travel in schools of mixed ages. A size limit of 11 inches with a 15% allowance for smaller fish would be an expected regulation if a size limit policy were decided upon.

The third category, a moratorium, is presently in effect.

The three exploitation levels listed above and the moratorium each have different survivor curves. The surviving biomass from 1 million recruits is shown for each curve (Figure 7). In both exploitation levels that might result from a no catch limitation management policy, the surviving biomass drops very quickly and few fish reach spawning age. Under a size limit management plan there would be significantly greater numbers at age groups II and III, but little difference by age group IV. Under a moratorium, the surviving biomass is greatly increased at the older age groups.

The relationship between catch and surviving spawning biomass contribution from 1 million recruits under these management plans shows significant variation (Figure 8). The greatest contribution to spawning is under a moratorium. With the size limit plan, there is a large drop in spawning biomass and a predicted





catch of 8.8 metric tons per million recruits. With both of the exploitation levels from a no catch limitation management plan, the spawning biomass is further reduced and the predicted catch per 1 million recruits rises to 12.2 and 13.6 metric tons.

PRESENT SITUATION

Present estimates of the population size of Pacific mackerel off southern California, exclusive of the 1971 year class which should have been detected by November 1971 but was not, is a hopeful 1,000 tons, of which less than 300 tons are spawning stock. These estimates are based on the assumption that 25% of age group I fish will spawn.

The best recruitment per spawner occurred in the low spawning biomass of 1953 when each pound of spawners produced 23.6 lbs. of recruits. The second and third best years were 1947 and 1952 when 5.5 and 5.4 lbs. of recruits were produced by each pound of spawners.

If the present spawning biomass is as large as we hope (i.e., .6 million lbs.) and if it could have spawning success equal to the best year since 1931 (i.e., 23.6 lbs. of recruits per lb. of spawners), we could only expect 14.1 million lbs. (7,050 tons) of recruits. Thus, the best observed spawning success with the spawning biomass at the present level would produce a year-class that could only be described as a failure. It is obvious the present spawning biomass is too low to produce a strong year class. Therefore, it appears the only logical management decision at this time is to continue the moratorium. This policy will allow the population a chance to increase to a level where an optimum recruitment year could produce a strong year class.

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