

PACIFIC MACKEREL: A RESURGENT RESOURCE AND FISHERY OF THE CALIFORNIA CURRENT

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ABSTRACT

The Pacific mackerel, *Scomber japonicus*, supported one of California's major fisheries during the 1930s and 1940s but by the mid-1960s was a depleted stock. After a decade of virtual economic extinction, a series of successful spawns in the mid-1970s restored the fishery to levels of the early 1940s.

Subsequent to the collapse, regulation efforts culminated in the first Pacific mackerel management measure—a commercial fishing moratorium. Fishery and management developments during the years of resurgence were complicated by the incidental catch of Pacific mackerel in the jack mackerel fishery and by the difficulty of accurately assessing the biomass of Pacific mackerel. The rationale behind measures adopted for managing a recovered rather than a recovering resource is discussed.

RESUMEN

La caballa, *Scomber japonicus*, ha mantenido desde 1930 una de las pesquerías más importantes de California durante dos décadas; pero a mediados de la década de 1960-1970, sus poblaciones disminuyeron notablemente, y después de diez años de extinción virtual, sobrevinieron épocas de buena reproducción con supervivencia larval elevada, dando por resultado que, a mediados de la década entre 1970 y 1980 las poblaciones de caballa llegaron a alcanzar los niveles de principios de la década de 1940-1950.

Al decaer la pesquería, los esfuerzos regulatorios culminaron con la primera reglamentación prohibiendo la pesca comercial de esta especie. La reglamentación y pesca durante el período de resurgencia resultaba complicada, debido a que la caballa se capturaba también durante la pesca del jurel (*Trachurus symmetricus*), lo cual dificultaba la estimación exacta de las poblaciones de *Scomber japonicus*. Se discuten las bases para establecer las regulaciones de la pesquería, adoptadas para una reserva que se ha recobrado, y no para poblaciones en período de recuperación.

INTRODUCTION

For a period of almost four decades beginning in the mid-1920s, Pacific mackerel (*Scomber japonicus*)

supported one of California's most important commercial fisheries. As canneries developed better processing capabilities and more marketable packs, the small but important fishery of the late 1920s quickly became second only to the Pacific sardine (*Sardinops sagax caeruleus*) fishery in annual landings. Mackerel landings increased to a peak of 73,000 short tons in 1935. Then came a long fluctuating decline to a catch of less than 4,000 tons in 1953. The fishery rebounded in 1954, but landings remained below expectation, averaging less than 17,000 tons per year for the next decade. After 1963 the fishery experienced a quick and dramatic decline; by 1966, for all practical purposes, it ceased to exist (Figure 1). More detailed descriptions of the fishery prior to the 1960s collapse include Fry (1931), Croker (1933, 1938), Roedel (1952), Fitch (1952), Roedel and Joseph (1954), Blunt and Parrish (1969), and Parrish and MacCall (1978).

The precollapse history is devoid of regulations to control the fishery, but not necessarily because of a lack of warnings or management recommendations. The earliest warnings were sounded just subsequent to the peak landing year (Fry 1937; Croker 1938). Later Fitch (1951) concluded that the fishery was not good; closed seasons, overall yearly bag limits, and minimum size restrictions would no doubt help relieve the situation. In 1951 the California Fish and Game Commission (FGC) recommended legislation to empower it to set seasonal limits on both Pacific mackerel and sardines. Similar warnings and management attempts are less apparent during the next decade, but just prior to the eventual collapse, the California Department of Fish and Game (DFG) concluded that the outlook was not bright and the population was at a low level (Anonymous 1961).

After the collapse, management efforts eventually resumed. The first regulations were established in 1970, and the resource and fishery began their respective and rapid recoveries during the late 1970s. By 1979 the total biomass was estimated (Klingbeil 1982) as approximately equivalent to the average biomass, 143,000 tons, for the years 1937-43 (Parrish and MacCall 1978).

The purpose of this paper is twofold: (1) to describe management efforts during the years of depletion, and (2) to document fishery and management developments during the years of resurgence.

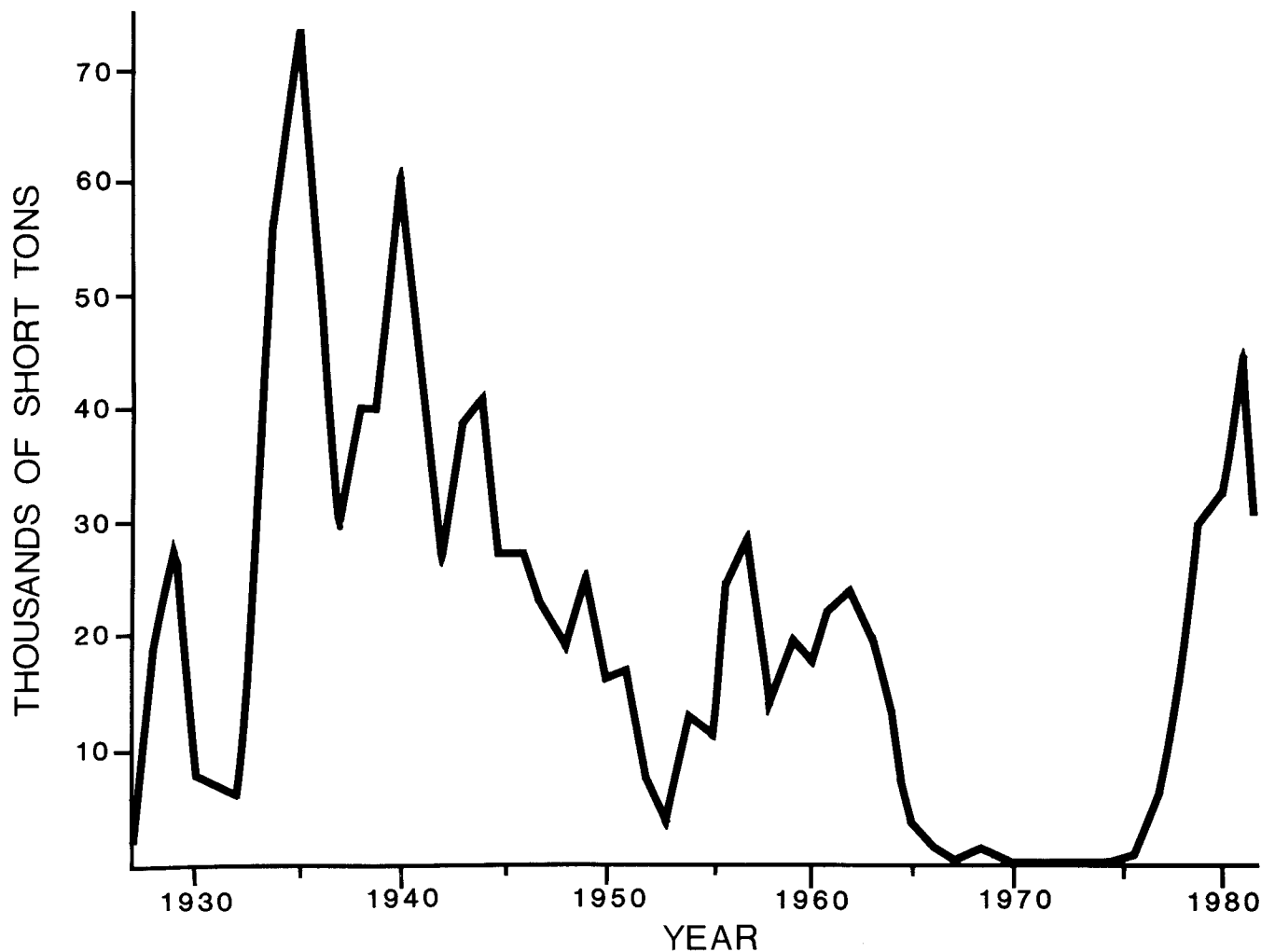


Figure 1. Pacific mackerel landings in California, 1928-82.

MANAGEMENT EFFORTS DURING THE YEARS OF DEPLETION, 1965-75

Although the fishery collapsed in 1965, it was not until 1969 that management legislation was introduced. The exact reasons for this lag are not well documented. Parrish and MacCall (1978) point out that the scientific community was in a politically awkward position at the time, and there is little doubt that a variety of social, economic, and political forces interacted to delay meaningful management.

With the depletion of both Pacific mackerel and Pacific sardines off California completed by the mid-1960s, the fishing industry dependent on these resources became extremely depressed. Government, including both state and federal agencies, and the fishing industry seemed to concentrate their efforts during this period toward developing "replacement" fisheries. The northern anchovy, *Engraulis mordax*, was the major species of interest, and the FGC authorized an anchovy reduction fishery in late 1965. Con-

troversies continued, and administrators, scientists, and commissioners continued to interact frequently, usually amid considerable controversy, as the anchovy fishery and its management slowly evolved. Talbot (1973) and Messersmith (1969) discuss in detail the controversies and problems of managing California's pelagic fisheries during this period.

Meanwhile, warnings of the critical condition of the Pacific mackerel fishery continued (Parrish 1968; Blunt and Parrish 1969). In March 1968 DFG scientists formally presented the problem to fishing industry representatives and raised the question of placing a moratorium on Pacific mackerel. Industry reaction was generally skeptical that overfishing was the cause of the decline or that a moratorium was necessary (Anonymous 1968). At the same meeting the California Cooperative Oceanic Fisheries Investigations (CalCOFI) Steering Committee, consisting of scientists from the DFG, the United States Bureau of Commercial Fisheries (now known as National Marine Fisher-

ies Service), and Scripps Institution of Oceanography offered the following opinion: "The stakes in scientific management are greater than the potential yield of the Pacific mackerel fishery . . . despite scientific evidence attesting to its decline, presented over many years, no action has been taken which might rehabilitate this resource. . . . This prima facie evidence substantiates allegations that the State cannot manage its resources on a scientific basis" (Baxter et al. 1968).

On May 2, 1968, Assembly Joint Resolution No. 26 was passed. It requested the DFG, in conjunction with the Bureau of Commercial Fisheries, to arrange meetings with Mexican scientists to ascertain the exact status of the Pacific mackerel resource. In retrospect, this action seems to have been little more than legislative foot dragging. State and federal scientists had been conducting research cruises off Baja California for many years; they were aware of decreased landings in Mexico, and probably expected to gain little additional insight into the exact status of the population. A three-page report to the assembly in January 1969 supports these conclusions (Anonymous 1969).

In February 1969 the DFG tried again. Assembly Bill (AB) No. 570 was introduced to prohibit the commercial take of Pacific mackerel, except for a 15% by weight incidental catch tolerance in a load of other fish. The tolerance provision was needed to allow for a "reasonable" incidental catch of Pacific mackerel for fishermen targeting on other species, primarily jack mackerel (*Trachurus symmetricus*). Since the two species often school together, the intent of the proposed regulations was to limit both the exploitation of Pacific mackerel and to minimize any negative impacts this action might have on the jack mackerel fishery. This legislation was not enacted during 1969. Industry opposition caused management to postpone the bill. Meanwhile, commercial interests agreed to support legislation to increase fish landing taxes and license fees, and to work with the DFG for a moratorium during the 1970 legislative session.

It was not until August 1970 that a Pacific mackerel management measure became law. AB 1732 provided that Pacific mackerel could not be taken commercially for two years except for an 18% by weight tolerance for incidental catches. In 1972 lawmakers extended the moratorium indefinitely and provided for a quota fishery should the stock recover. The moratorium would remain in effect until the spawning biomass exceeded 10,000 tons. If recovery occurred, an annual harvest of 20% of the spawning biomass in excess of 10,000 tons plus 30% of the spawning biomass in excess of 20,000 tons would be allowed.

Assessing the effect of the delayed implementation of a moratorium, after the fishery had already col-

lapsed, is difficult. Recruitment was virtually nonexistent after 1962, and by the fall of 1968 six poor year classes in a row had been documented (Blunt and Parrish 1969). Landings remained low, with the annual catch averaging less than 2,000 tons from 1965 to 1969. A majority of this harvest was caught incidentally with jack mackerel, and a substantial amount of these catches were small, immature fish-of-the-year (Parrish and MacCall 1978).

During the early years of the moratorium, 1970 to 1975, Pacific mackerel were rarely taken incidentally with jack mackerel; recruitment remained poor, and annual landings seldom exceeded 100 tons. Assessments of stock size remained well below the level needed to initiate a fishery (Frey and Knaggs 1973; Knaggs 1974; Knaggs and Sunada 1975).

FISHERY AND MANAGEMENT DEVELOPMENTS DURING THE YEARS OF RESURGENCE, 1975-80

During 1975, Pacific mackerel party boat (commercial passenger-carrying fishing vessel) catch increased, as did the occurrence of Pacific mackerel in jack mackerel landings. Although both these increases were relatively weak, the 1974 year class, which produced these catches, was judged a success relative to what had been observed during the previous decade (Klingbeil 1976).

The occurrence of incidental catches rose dramatically in 1976. Age composition data indicated that the increased catches were primarily the result of the 1974 year class and in spite of a 1975 spawning season that appeared to be yet another failure (Klingbeil 1979). However, reason for optimism developed with early signs of a successful 1976 spawning season.

During the summer of 1976 live-bait fishermen who were operating daily in nearshore waters throughout southern California reported frequent catches of young-of-the-year Pacific mackerel while targeting on anchovies. This had been a rare event during the previous 15 years. During the subsequent fall these yearling fish were being caught incidentally by purse seiners engaged in the offshore anchovy reduction fishery. In addition, the DFG young-fish survey in the autumn of 1976 detected these fish in 37% of midwater trawls, the highest trawl success ratio for Pacific mackerel since the inception of midwater trawl surveys in 1966 (Mais 1974).

These young fish, averaging approximately 200 mm FL (8 inches) began occurring in jack mackerel landings during the following winter under the incidental catch tolerance provision. However, by early spring 1977, unlike the 1974 year class, the 1976 year class was available and vulnerable to the extent that

fishermen maintained the fish were interfering with fishing for jack mackerel.

The complaints of fishermen centered around their ability to identify and set on schools of "mackerel" that contained 18% or less Pacific mackerel. Most fishermen asserted that this was often an impossible situation and that the composition of a school could only be estimated after the net had been pursed, and brailing had begun. A few fishermen felt that this was mainly a problem when setting on "sonar" or "fathometer" schools, rather than on surface schools. Whatever the scope of the problem, boat operators had two choices once they had determined that a catch exceeded the allowable tolerance: (1) roll the catch, with considerable but unknown mortality to both Pacific and jack mackerel, or (2) continue to brail and run the risk of having the load seized by law enforcement officers at off-loading facilities. By mid-spring 1977, after several citations and a decline in jack mackerel landings, this problem became acute enough for fishermen to seek remedial legislative action.

During May, AB 1783 was introduced as urgency legislation for the purpose of relaxing the incidental catch provision of a moratorium law. In its final form, the new law increased the allowable incidental tolerance to 40% by weight and allowed for landings of "pure" loads of Pacific mackerel if they did not exceed three tons. The law also stipulated that only the pure loads and the tonnage exceeding 18% in mixed loads could be counted against any quota established for the 1977-78 season. Because of the urgent nature of this legislation, a time-lock provision was included so that the new provisions would only remain in effect until January 1, 1978.

The intent of these actions seems to have been to ease the negative impacts on the "unregulated" jack mackerel fishery of a resurgent biomass of Pacific mackerel. The problem for management was to insure the recovery of a depleted stock, while minimizing the regulatory interference on the harvest of what most scientists felt was an underutilized resource (MacCall et al. 1980). The DFG feared that any law that encouraged targeting on Pacific mackerel might lead toward increased catches that would preempt recovery, and that too liberal a tolerance provision would result in fishermen topping-off catches of jack mackerel primarily with still immature 1976-year-class Pacific mackerel.

In retrospect, the urgency legislation, which took effect in June 1977, had the desired effect. Although several small lampara net vessels often took advantage of the pure load provision to target on Pacific mackerel, and larger purse seiners periodically topped-off landings of Pacific mackerel remained relatively low.

Since the beginning of 1977, Pacific mackerel had averaged less than 7% of total mackerel landings; this increased to only 13% of total landings from June through December 1977. Meanwhile, jack mackerel landings soared to a 25-year high of 50,000 tons.

Aside from apparently accomplishing the desired effect, AB 1783 was a unique piece of fisheries management legislation. It allowed (1) a quota to be fished before it was established, and (2) for only a portion of the catch to be counted against the quota.

While hindsight easily allows me now to label Pacific mackerel landings during the latter half of 1977 as "relatively low," that was not the case at the time. During the spring of 1977 the spawning biomass was tentatively assessed as exceeding 14,200 tons, and a quota of 1,500 tons was recommended for the season scheduled to open October 1, 1977 (Klingbeil 1977). However, the catch of Pacific mackerel during the summer and fall had already exceeded 3,000 tons by mid-November under the urgency provisions. A reassessment of the spawning biomass became imperative, especially in view of the fact that management would revert to the moratorium law on January 1, 1978.

The reassessment took into account comparisons of current and historical data including age composition, young-fish surveys, CPUE, spawner-recruit relations, and airborne monitoring abundance indices. These comparisons resulted in a reassessment of the 1977 spawning biomass to approximately 30,000 tons. The quota for the 1977-78 season was set at 5,000 tons, of which approximately 4,000 tons could be taken in an open *permit* fishery after January 1, 1978 (Klingbeil 1978, addendum 1).

The permit fishery allowed the DFG to prescribe conditions for the taking of Pacific mackerel as long as the fishery was operating on a quota. Once a quota was filled, regulations would revert to those dictated by the current law (18% incidental tolerance, and no pure loads until the following season). Because of the small 1977-78 season quota, and in order to postpone reverting to the 18% tolerance, permit restrictions were used to stretch out landings over as long a period as possible. The initial permit restrictions called for 15-ton daily boat limits when Pacific mackerel accounted for 60% or more of a catch. However, at the insistence of boat owners, permits also allowed for "paper transfers"—a concept that let boats land more than 15 tons and transfer the excess, in 15-ton increments, to boats that did not have fish for the day. None of this was necessary, of course, if a landing contained more than 40% jack mackerel. There seemed to be good reasons for fishermen to target on jack mackerel.

Although few, if any, landings were seized for

violation of these restrictions, this was more a result of their unenforceability than because fishermen abided by them. With Pacific mackerel readily available, landings against the quota increased dramatically during January and February 1978. In late February, permit restrictions were tightened in order to reduce catch rates. Pacific mackerel could only be landed in loads containing 40% or less by weight. The daily limit and paper transfer provisions were deleted. However, on March 10, 1978, the 1977-78 season was closed when the 5,000-ton quota was filled.

After the closure, fishermen were as unable to live with the 18% tolerance provisions as they had been the previous spring. Urgency legislation (AB 3704) was again introduced. The intent was to allow for an increase in the 1977-78 season quota and to give the DFG more flexibility in adjusting permit restrictions and quotas. During most of the spring, while the new law was being formulated, fishermen's unions at San Pedro went on strike. The issues were the mackerel price, shares for aerial fish spotters, and payment of crewmen's social security taxes by boat owners. The strike continued until early July 1978, when AB 3704 was signed into law.

This management measure established a different quota formula, which called for a seasonal (October 1-September 30) harvest equal to 20% of the *total biomass* in excess of 20,000 tons. It also provided that the DFG could (1) adjust the season's allowable catch quota, if an earlier determined biomass estimate is revised, (2) set incidental catch tolerances during a season between 18% and 50% by number of fish, and (3) set daily limits for pure loads of Pacific mackerel. These provisions were supposed to remain in effect until January 1, 1981.

Because the law took effect immediately, the 1977-78 season quota was increased from 5,000 tons to 9,300 tons, based on a total biomass assessment of 66,500 tons for the summer of 1977. The season was reopened on July 10, 1978, to allow the additional 4,300 tons to be caught. Permit restrictions limited pure loads to 3 tons and allowed a 50% tolerance for larger catches to prevent the additional tonnage from being caught too quickly. Fishing was considered excellent for larger vessels during the next two months, for the 50% tolerance was seldom exceeded. Mixed schools, with jack mackerel predominating, seemed to be the rule in the areas where these boats fished. However, larger vessels were able to fish on pure schools of Pacific mackerel because they frequently topped off catches of jack mackerel with Pacific mackerel, and vice versa. The smaller seiners and lampara vessels generally could not find good concentrations of jack mackerel or mixed schools within their

range, and during most of this period were limited to landing 3-ton pure loads of Pacific mackerel. By mid-September the quota addition had been caught. The season was again closed, and for approximately 2 weeks interseason restrictions reverted to 18% tolerance with no pure loads.

The first full season of regulating the take of a resurgent stock of Pacific mackerel was finally over. The season had progressed through two urgency statutes, numerous revisions of permit restrictions, two reassessments of biomass, a fishermen's strike, and considerable interaction between fishermen and DFG's law-enforcement officers. In the end approximately 12,000 tons were harvested during the 12-month accounting season (October through September). It was not known, at the time, whether this amount was excessive in terms of damaging the changes for full recovery. However, there was little doubt that the exploitation rate would have been much higher without any regulatory mechanisms. Meanwhile, the biomass had been bolstered somewhat by the recruitment of the 1977 year class, and a quota of 14,000 tons was set for the 1978-79 season, based upon a total biomass assessment of approximately 90,000 tons (Klingbeil 1978).

The DFG and fishermen were skeptical that 14,000 tons was enough to last through 12 months, without necessitating reversion to the 18% tolerance provision. Continuing permit restrictions were designed to retard catch rates and extend the season. At the outset pure loads were restricted to no more than 3 tons. This was raised to 8 tons within a few weeks to appease small-boat fishermen. The tolerance for larger catches was set at the maximum 50% by number.

The season progressed with little controversy through the fall, with moderate landings of primarily 1976 and 1977 year-class Pacific mackerel. However, when the 1978 year class began its recruitment, considerable enforcement problems resulted. These fish became readily available on local fishing grounds late in the year, and the schools exhibited very little mixing with jack mackerel. During one week in late December at least eight seiners landed Pacific mackerel in violation of permit restrictions. This trend continued into the new year, and on January 22, 1979, new permits were issued increasing pure load limits to 25 tons. Landings, of course, increased, but catch rates were held down considerably by marketing considerations. The large majority of mackerel catches in southern California are canned for human consumption, and canneries prefer a certain size-range of fish for maximum efficiency on automated fish cutters and cleaners. The 1978 year class had not yet grown to the minimum acceptable size (10-11 inches FL) by the

spring of 1978, and canneries cut back orders when they realized that these fish were dominating the catch. However, a considerable number of these small fish were delivered for pet food production and fresh fish consumption.

Although mackerel landings continued, a large part of the effort of the southern California wetfish fleet during the spring was diverted to fishing anchovies for reduction. But when the anchovy reduction season was closed in early June, fishermen again turned their attentions to mackerel, and the industry requested a reassessment of the biomass and an increase in the quota.

Justification for an increase in the 1978-79 season quota became a problem. On the biological side of the equation it was felt that an increase could not be justified. The law required that a season's catch be based on the total biomass just prior to the season opening. Thus, the biomass assessment for the 1978-79 season could not technically take into account the 1978 year class, and biologists could not see any reason to increase previous assessments of the 1977 and older year classes. On the social and economic side of the equation (1) the anchovy season was closed until September 15; (2) market squid (*Loligo opalescens*), Pacific bonito (*Sarda chiliensis*), and bluefin tuna (*Thunnus thynnus*) were largely unavailable; (3) jack mackerel were becoming less available; (4) a closed season for Pacific mackerel by July meant 3 months of fishing under the 18% tolerance with no pure loads; and (5) no increase in the quota probably would have resulted in the introduction of industry-sponsored urgency legislation. Under these circumstances the 1978-79 season quota was increased from 14,000 to 18,000 tons. In later years it became apparent that this increase was far from excessive.

With the attention of managers and fishermen focused on an open fishery, concern about filling the quota too quickly surfaced again. Pacific mackerel permits were modified in late June to reduce the pure-load limit from 25 to 8 tons. Permits were modified again in early July to allow 40-ton pure-load weekly limits or 8 tons per day. Any load having more than 50% Pacific mackerel was supposed to be counted against the pure-load limits. These provisions proved logistically impossible to enforce. The catch of Pacific mackerel increased dramatically in July, and before the end of the month the 1978-79 season was closed. The interseason restriction of 18% incidental tolerance took effect immediately. Landings of jack mackerel continued at a brisk rate for a couple of weeks, and then the fishery virtually shut down until the new season began on October 1, 1979.

The second "season" of managing a recovering

Pacific mackerel resource as a part of a dual-species mackerel fishery had been only slightly less hectic than the first. The 12-month landings of Pacific mackerel from October 1978 through September 1979 (21,000 tons) represented a 16-year high in seasonal landings. One-third of this tonnage was contributed by the apparently very successful 1978 year class.

The 1979-80 season opened on October 1, 1979, with a quota of 25,000 tons. This was based on a total biomass assessment of approximately 145,000 tons for the summer of 1979 (Klingbeil 1979). The biomass of the 1978 year class was estimated at approximately 70,000 tons. At this level, the 1978 year class represented the largest year class in 37 years, when compared with historical biomass estimates produced by cohort analysis (Parrish and MacCall 1978). Also, it meant that the 1978 spawning season was one of the most successful on record (Figure 2), assuming that the assessment of spawning biomass for the summer of 1978 was also reasonable (Klingbeil 1978). At the time, there was some concern that the assessment was too liberal. Two years later it became apparent that the 1978 year class was larger than any since the early 1930s and possibly the largest on record.

Because of the size of the 1979-80 season quota, and the ability to adjust it on fairly short notice, management resisted suggestions for permit restrictions, in particular a special allocation for owners of small boats. The season began without regulatory interfer-

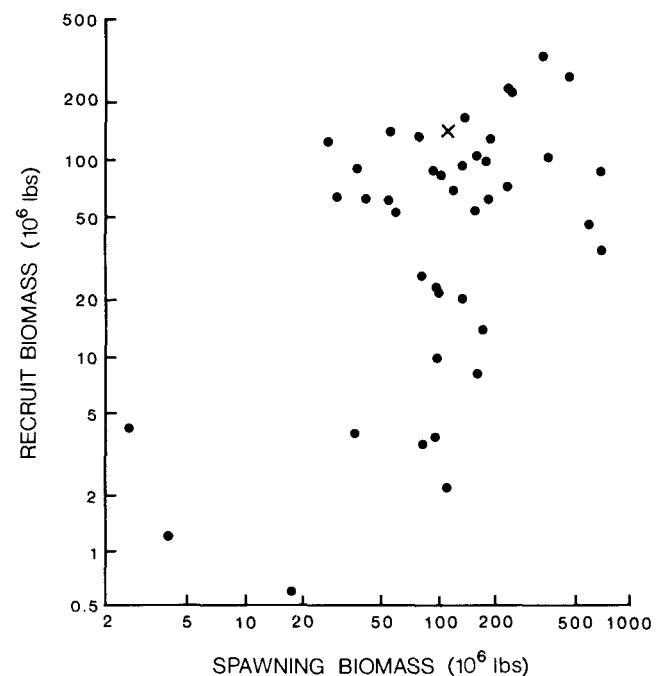


Figure 2. Spawner-recruit relationship (dots reproduced from Parrish and MacCall 1978; "x" represents estimated relationship between 1978 year class at one year of age and 1978 spawning biomass).

ence, other than the quota itself, for the first time since the resurgence commenced. But not even a 25,000-ton quota was enough to quell fishermen's anxieties about returning to an 18% interseason tolerance. Not even the hope of an early 1980-81 season opening (July 1 rather than October 1) because of new management proposals was enough to dissuade management from regulating lower catch rates. In early February 1980, with approximately 9,000 tons left on the quota, permits were amended to slow the catch rate. This time, the permits limited daily landings that contained more than 18% Pacific mackerel to 25 tons, and prohibited the possession of such loads on Friday, Saturday, and Sunday of each week.

In the fall of 1979, the DFG had begun planning new management legislation. The intent was to produce guidelines for managing a recovered rather than a depleted or recovering Pacific mackerel resource—one which could not be managed without considering the harvest of the underexploited jack mackerel.

The planning phase of the new management proposals had several objectives:

1. to maintain quota management of Pacific mackerel
2. to retain the ability to establish a moratorium if the resource again declined
3. to minimize impacts on the harvest of jack mackerel
4. to provide the flexibility needed to set and adjust "more reasonable" incidental catch provisions during the interseason
5. to allow for seasonal quotas, but limit the time in which the DFG could adjust them
6. to protect against growth overfishing, particularly at low biomass levels
7. to align the fishery, as much as possible, with the unregulated seasonal and size considerations of the 1930s
8. to establish the season opening in a way that took into account the regulated season closures of the anchovy reduction fishery.

The mechanisms for obtaining these objectives were formulated and presented to industry representatives late in 1979. The proposals were introduced as urgency legislation in early 1980, and, with one minor change, they were enacted into law in early May 1980.

The first two objectives were met by retaining the provision for a seasonal allowable catch quota of 20% of the total biomass over 20,000 tons. A moratorium with an 18% incidental catch tolerance would ensue should the biomass decrease below 20,000 tons. The third and fourth objectives were fulfilled by giving the DFG authority to assess the need for, to establish, and

to adjust interseason incidental catch provisions. After a seasonal quota was reached, the DFG could set tolerance levels between 18% and 50% by number. The possibility that interseason catches could be substantial, if tolerances were established at 50%, was partially offset by retaining a fairly conservative harvest formula.

The fifth objective recognized the need to adjust quota levels during a season. This flexibility was formalized in the new law. Specifically, managers recognized that biomass assessments made in the spring of each year were always tentative and often intuitive, that little might be known about the most recently recruited year class, and that the performance of the fishery during the subsequent first part of a season could be invaluable in reassessing previous estimates. The political nature of a decision to raise or lower a quota was recognized by stipulating that quota adjustments had to be made prior to February 1 of each season. This provision forced one decision rather than allowing for a series of incremental adjustments as a season wound down.

Protection against growth overfishing restricts fishing on a year class until the gain in weight of individuals is overcome by the loss in numbers (Cushing 1977). A size limit, often thought of as protection against the harvest of too many immature fish, can also protect against growth overfishing by delaying recruitment until a year class experiences its maximum biomass. Because of a lack of detailed data on juvenile mortality, it is more feasible to design the size limit around the season of most rapid growth in body weight. For Pacific mackerel this growth occurs during its first 16 months of life and is generally complete after its first 6 months in the fishery (Figure 3). The new management proposals included a size-limit provision to discourage targeting on an emergent year class until this growth spurt was near complete.

Original proposals called for an 11-inch FL size limit from October to July of each year, with a 50% tolerance for undersized fish. The adopted provision set the size limit at 10 inches FL from January to July with a 50% tolerance for sublegals. It included a caveat that the size limit could be lowered to 9 inches if a year class had not grown above 10 inches by the second January of its life. The provision was designed to work in the following way: establish the size limit during the winter of each year when 0-age-group fish are becoming more vulnerable to nets; lift the size limit in the summer after the period of rapid growth; allow these fish to grow through the size limit during the subsequent summer and fall; reestablish the size limit the following winter to protect the next incoming group of small fish (Figure 4). The 50% tolerance

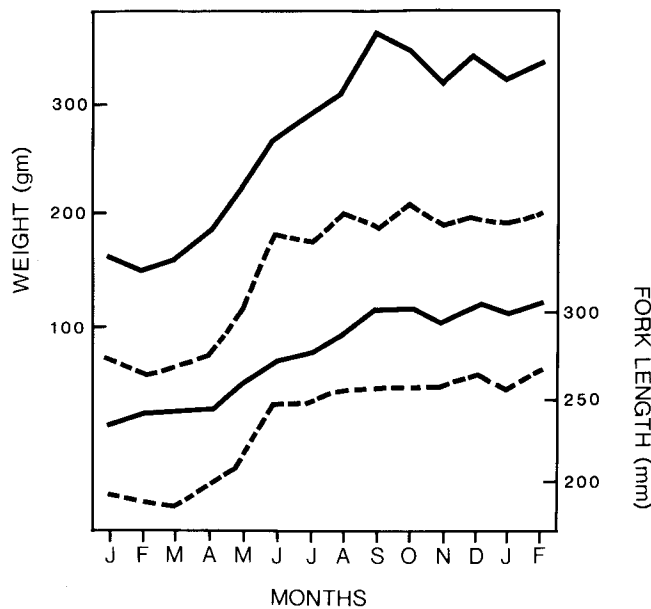


Figure 3. Monthly mean lengths and weights of 1976 (solid lines) and 1978 (dashed lines) year classes during approximately first 12 months in fishery.

provision was not considered too liberal, because 7-9-inch FL Pacific mackerel seldom can be found schooling with a larger size class of fish. The seasonality of the size limit also recognized the practical difficulties fishermen might have if a year class was readily available during the time that it was growing through the size limit.

The size limit was also a way of more closely aligning the fishery with industry-enforced considerations of the 1930s. Fry (1936) noted in a graph (Figure 5) that canneries often enforced a 13-inch TL (approximately 12 inches FL) size limit by refusing deliveries of smaller fish. This probably helped production in the early years of the fishery. Croker (1933) noted that canneries preferred to take fish from midsummer to midwinter. Pacific mackerel were considered firmer and of higher quality during this time. In fact, during the 1930s slightly more than 80% of annual catches were taken from July through December. The moving of the season opening from October to July was in recognition of this fact; however, it was also an attempt to coordinate the seasons for anchovy reduction and Pacific mackerel.

The anchovy and mackerel fisheries have been the mainstays of the southern California wetfish fleet for many years. Management of the anchovy reduction fishery had included season closures since its inception in 1965. During the late 1970s Pacific Fisheries Management Council's guidelines provided for an anchovy reduction season off southern California from September 15 to June 30 with a midseason closure during February and March. By retaining the October

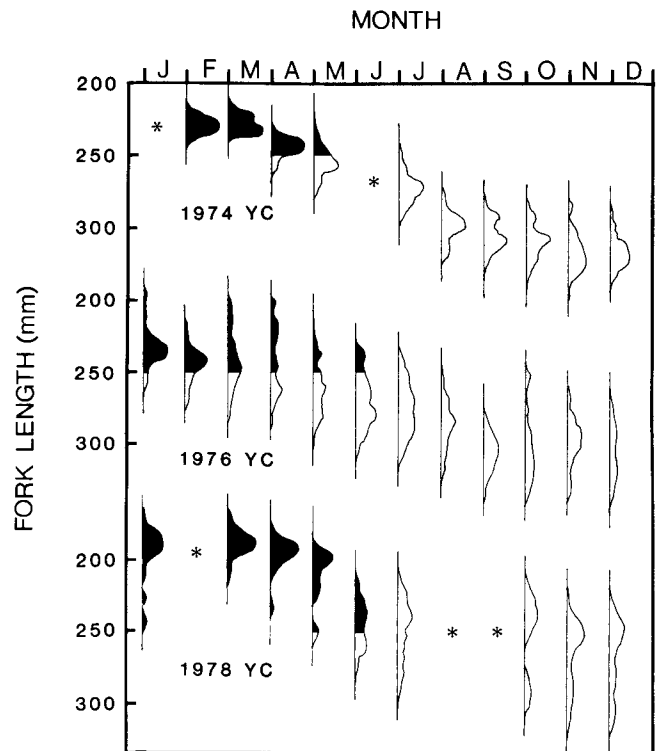


Figure 4. Monthly length frequency diagrams of 1974, 1976, and 1978 year classes during approximately first 12 months in fishery. Darkened areas show fish protected by seasonal (January to July) 10-inch FL size limit (* no sampling data).

opening for Pacific mackerel the DFG would have enhanced the probability that fishermen might often be faced with two closed fisheries during the summer. Opening the Pacific mackerel season in July allows fishermen to begin fishing a new quota for mackerel immediately upon the closure of the anchovy reduction fishery. The months that were most likely to be closed for Pacific mackerel after a quota was filled (April, May, June) remained open for the anchovy reduction fishery.

These regulations took effect during the late spring of 1980 and resulted in only a 9-month accounting season for 1979-80. Actually, the season was closed on May 15, 1980, when the 25,000-ton quota was harvested. For the next month and a half fishermen operated under the 18% incidental catch provision for the last time to the date of this publication. Fishing effort was minimal until the new season opened July 1, 1980.

THE EPILOGUE TO RESURGENCE, 1980-83

During the subsequent three seasons, the Pacific mackerel fishery was managed without urgency legislation and without any modification of permit restrictions during the open or closed portions of the 12-month accounting season. Quotas for the 1980-81 and

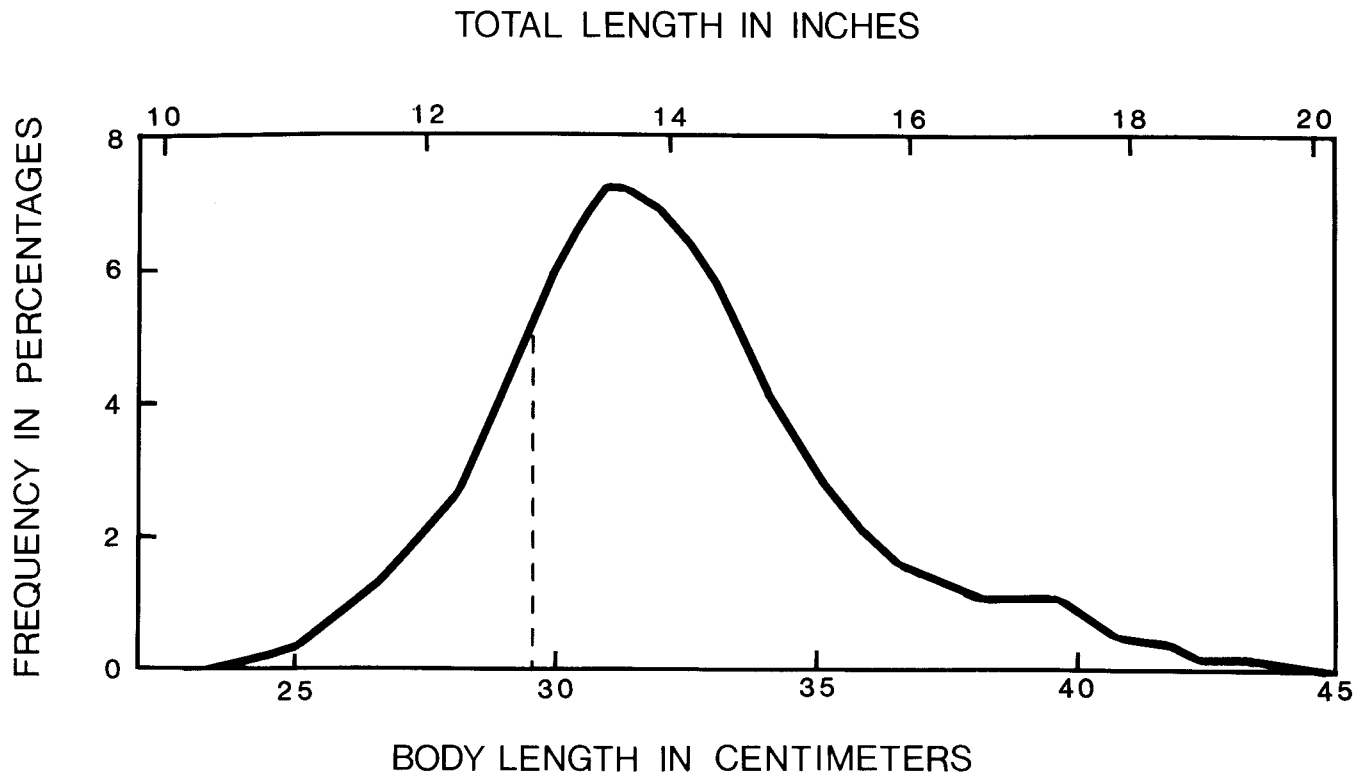


Figure 5. Size of San Pedro cannery mackerel: July, 1929-June, 1931. Vertical line at 13 inches total length, the minimum size limit sometimes set by canneries (reproduced from Fry 1936).

1981-82 seasons were initially set at 15,000 and 33,000 tons, and eventually raised to 20,000 and 38,000 tons, respectively (Table 1). Both quotas were filled during the 12-month accounting season, and interseason tolerances were set at the maximum 50% by number. The 1982-83 season quota was set at 29,000 tons, and by April 1983 approximately 8,000 tons remained to be caught.

During these three seasons the 1978 year class dominated the landings. The 1979, 1980, and 1981 year classes have been assessed as poor, weak, and moderate, respectively. Even though recruitment from

the 1979 and 1980 year classes was weak, annual landings increased from 29,000 tons in 1979 to 32,000 tons in 1980 to 42,000 tons in 1981—the highest annual catch since 1940. In 1982 the catch fell, for the first time since the recovery, to 31,000 tons, but Pacific mackerel remained the dominant of the two species in “mackerel” landings for the fourth straight year (Table 2). During the first six months (July-December) of the 1982-83 season, 4-year-olds (1978 year class) and older fish accounted for 70% of the tonnage landed.

A noteworthy development during these last three seasons was the northward extension of the Pacific

TABLE 1
Seasonal Quotas, Adjustments, and Total Landings of Pacific Mackerel in California, 1977-78 to 1982-83

Season	Quota		Total ¹ catch
	Initial	Adjusted	
1977-78	5,000	9,300	11,600
1978-79	14,000	18,000	20,900
1979-80 ²	25,000	—	25,410
1980-81	15,000	20,000	30,760
1981-82	33,000	38,000	42,090
1982-83	29,000	—	<30,000 ³

¹All landings of Pacific mackerel during 12 months following season opening, i.e., quota landings plus interseason incidental catches.

²Nine-month accounting season.

³Projected catch.

TABLE 2
Species Composition of California “Mackerel” Landings, 1974-1982, Short Tons

Year	Jack mackerel	Pacific mackerel	Pacific sardine	Total landings
1974	12,729	67	7	12,803
1975	18,390	144	3	18,537
1976	22,278	328	27	22,633
1977	50,163	5,975	6	56,144
1978	34,456	12,540	5	47,001
1979	17,652	29,392	17	47,061
1980	22,225	32,349	38	54,612
1981	15,513	42,477	31	58,021
1982	28,908	31,057	144	60,109

mackerel's range. During the summer of 1981, a small commercial fishery developed in Monterey Bay for the first time since before the depletion years. Annual landings for the next two years of 1,000-2,000 tons at Monterey were held down considerably by processing capabilities and market demand. By the summer of 1982, Pacific mackerel were contributing substantially to the bag limits of sport fishermen off Fort Bragg, and were being caught by salmon trollers and commercial trawlers off Oregon for a brief period of time. Interestingly, this expansion in range seems to have occurred in response to increased age of the population as well as increased biomass, but may also be closely tied to a warming trend, which appears to have begun during 1982 in the northeast Pacific.

SUMMARY AND CONCLUSIONS

Following development of a large fishery in the 1930s the declining Pacific mackerel resource endured for a little more than 3 decades before the collapse of the 1960s. Management, despite warnings and suggestions for regulatory proposals, was nonexistent during these years, except for a brief period during the 1930s when the canning industry set its own size limit. The lack of legislative action resulted in a prolonged period of virtual economic extinction of the commercial fishery.

The initial few years of depletion, marked by concerns to develop other fisheries, can be characterized as a period of continued management inaction. This was followed by a couple of years of legislative foot dragging and management-industry trade-offs, which culminated in 1970 with the first Pacific mackerel management legislation—a moratorium. It's questionable, however, if quicker action, once the fishery had collapsed in 1965, would have shortened the depletion years. In any case the Pacific mackerel spawning biomass had been fished to a very low level and remained extremely low during the 1960s and early 1970s.

The first few years of management were mostly uneventful. The DFG refined its "moratorium law," providing for quota management in the event of resurgence, and closely monitored jack mackerel landings for signs of increased incidental catches. The recovery began in 1975 with the emergence of the 1974 year class, and continued with successful spawns in 1976, 1977, and 1978. The very large 1978 year class insured recovery to biomass levels of pre-World War II years. It is doubtful that the 1978 year class would have been as large had a moratorium not been in place.

The years of resurgence were hectic, and provided DFG with the challenge of managing a recovering

resource as part of a dual-species mackerel fishery. The period was characterized by urgency legislation, frequent alteration of permit restrictions, considerable interaction between fishermen and law enforcement officers, and challenges to the validity of biomass estimates.

When legislation in 1972 first provided for future quota management based upon the annual size of the biomass, little thought had been given to how to estimate the current size of a population of pelagic fish, particularly during a moratorium. As long as the biomass obviously remained very low, the feasibility of producing valid annual estimates was seldom a matter of great concern. However, as the resurgence began and continued, much of the controversy between management and industry centered around the "accuracy" of these estimates, and still does today!

Wherever possible, I have chosen to use "biomass assessments" rather than "biomass estimates." The distinction that I have drawn is that confidence limits on an assessment cannot be quantified in any statistically valid way. This has been true for all biomass estimates of Pacific mackerel made for the purpose of establishing seasonal quotas. These assessments have relied on (1) the comparison of recent trends of the fishery with 40 years of historical landing data, (2) the age composition of these landings, and (3) the subsequent cohort analysis of this time series. The assessments of current biomasses remain "soft" (i.e., to a large degree intuitive) and in need of continual reevaluation. They have, more often than not, resulted in quotas unacceptable to fishermen. Usually these quotas have been adjusted upward during the course of a season, and other, socio-economic, considerations usually have played a large role in these decisions.

In retrospect, the system appears to have worked relatively well. Quota adjustments have not been excessive, and the costs of producing assessments have remained minimal. It seems unlikely that quotas have been too low, adversely affecting the fishery's potential, in view of recent catch levels and historical trends. The probability that catches have been too high is partially lessened by the fact that quotas have been met, seasons have been closed, and annual harvests have been less than one could have expected otherwise.

However, at the time of this writing it is becoming apparent that the Pacific mackerel fishery is in need of another large year class. It is still too early to make judgments concerning the strength of the 1982 year class. If it is weak, and mortality continues to exceed recruitment, then recovery may be short-lived. The fishery could be managed through a series of years of declining quotas, longer interseasons, and stricter in-

cidental catch provisions. As yet, it is unclear how appropriately the present management framework will work under the circumstances created by a declining biomass.

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