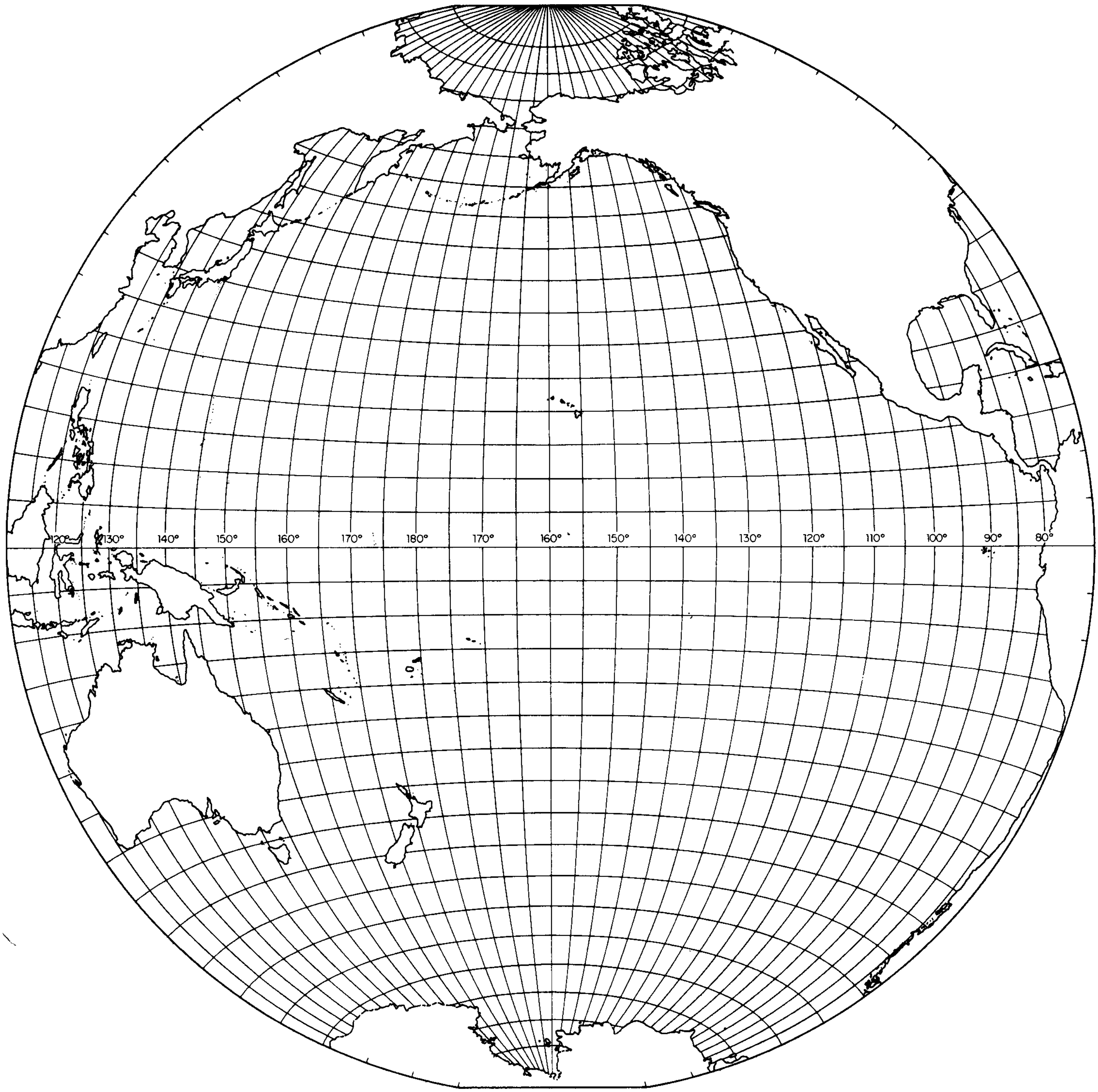
STATE OF CALIFORNIA
MARINE RESEARCH COMMITTEE



CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS

REPORTS

VOLUME XV
SEPTEMBER, 1971

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STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME
MARINE RESEARCH COMMITTEE

CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS

Reports

VOLUME XV
1 July 1969 to 30 June 1970

Cooperating Agencies:
CALIFORNIA ACADEMY OF SCIENCES
CALIFORNIA DEPARTMENT OF FISH AND GAME
STANFORD UNIVERSITY, HOPKINS MARINE STATION
UNIVERSITY OF CALIFORNIA, SCRIPPS INSTITUTION OF OCEANOGRAPHY
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL MARINE FISHERIES SERVICE

1 September 1971

STATE OF CALIFORNIA—RESOURCES AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF FISH AND GAME

MARINE RESEARCH COMMITTEE

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1 September 1971

The Honorable Ronald Reagan
Governor of the State of California
Sacramento, California

Dear Governor Reagan:

We have the honor to submit the fifteenth report on the work of the California Cooperative Oceanic Fisheries Investigations.

The report consists of three sections. The first contains a review of the administrative and research activities during the period 1 July 1969 to 30 June 1970, a description of the fisheries, and a list of publications arising from the programs.

The second section consists of papers presented at a symposium, "Development of the San Pedro Wetfish Fishery - A Systems Approach," held in December 1969 discussing economic and operational aspects of the industry as well as scientific data on the resources.

The third section is a scientific contribution to knowledge of the magnitude of a potentially valuable resource in California waters.

Respectfully submitted,

Charles R. Carry

THE MARINE RESEARCH COMMITTEE
Charles R. Carry, Chairman

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PART I

REVIEW OF ACTIVITIES

1 July 1969–30 June 1970

REPORT OF THE CALCOFI COMMITTEE

In volume *11* (1965) of these Reports, the Committee reviewed events set in motion by the California Cooperative Oceanic Fisheries Investigations culminating in the establishment in 1965 of a fishery for anchovies as an experiment in scientific management. It seems appropriate to note briefly the fifth anniversary. Prior to the birth, the conception was first recorded in the Marine Research Committee minutes of October 24, 1961, that the anchovy population was potentially a major resource which might be utilized for the benefit of the people of California. At that time the conclusion rested solely on population estimates derived from egg and larva surveys because no anchovy fishery large enough to permit an estimate of the total resource had ever existed on this coast. By 1964 more mature studies by scientists in the CalCOFI program based on further accumulating evidence led them to recommend that the California Fish and Game Commission establish a quota for an anchovy fishery large enough to test the estimates of the population size but small enough to safeguard the future of the population. The Fish and Game Commission, taking into account other interests, notably the need of a large population of bait and forage fish to maintain and encourage a healthy sport fishery, in 1965 set a modest quota of 75,000 tons. In the first years both fishermen and processors were cautious about making the investments necessary to take full advantage of this quota. However, experience has encouraged such investments and when the catch approached 75,000 tons, the Commission in accordance with a policy previously established, increased the quota. The catch of more than 90,000 tons in 1970 is still, according to the best scientific estimates, very conservative compared with the potential yield, but it is already a notable addition to the total catch of wetfish. The slow growth tests the patience of scientists, who feel that a meaningful use of this valuable resource is being neglected and that an annual catch of two or three times this size is conservative and also required to check their population estimates. However, the present level of the fishery is beneficial in giving fishermen, processors, and the State ample experience with the complexities of utilizing and managing this major resource in the interests of all users.—*Herbert W. Frey, John D. Isaacs, Alan R. Longhurst, Marston C. Sargent.*

AGENCY REPORTS

CALIFORNIA ACADEMY OF SCIENCES

The study of the food habits of the northern anchovy, briefly summarized in the preceding CalCOFI Report (Volume XIII, January 1969) was concluded, and the results submitted in the form of a comprehensive paper now published (see Loukashkin under PUBLICATIONS in this volume).

To recapitulate briefly, data from stomachs of 926 anchovies taken at various localities from central California to northern Baja California at different seasons over a period of nearly three years, indicate that the anchovy is strictly a plankton feeder, that it eats either zooplankton or phytoplankton, or both at the same time, but shows a marked "preference" percentage-wise for zooplankton. In a small number of cases, phytoplankton exceeded zooplankton in the stomach contents. Since the anchovy is either a particulate feeder or a filter feeder, the evidence indicates that it feeds on zooplankton when these are large enough and numerous enough to permit selective feeding; when this is not the case, it resorts to filter feeding and ingests anything that is available, including not only phytoplankton but such unexpected items as fish scales and small sand grains. On the whole, the northern anchovy may be regarded as subsisting in the second and third levels of the food web in the sea, phytoplankton being the first. Most of the empty or nearly empty stomachs were found in anchovies collected at night with the midwater trawl, supporting Baxter's (1967) view that anchovies are mainly daytime feeders.

Studies of the food habits of the Pacific and jack mackerels initiated during the period when the studies of the food habits of the anchovy were being concluded have continued during the period under report. Material collected thus far is considered insufficient for a conclusive report. Preliminary observations indicate that both are filter feeders or particulate feeders in direct relation to the size of the food in their immediate environment. Some fish and squid remains have been found. Among planktonic elements in stomach contents examined, crustaceans in larval or adult stages seem to occupy a dominant place. Thus far no phytoplanktonic forms have been found.—*R. C. Miller.*

CALIFORNIA DEPARTMENT OF FISH AND GAME PELAGIC FISH INVESTIGATIONS

Long recognizing the multi-species nature of the California purse seine fishery as well as a need to more efficiently meet our research responsibilities, we restructured the research elements of the Pelagic Fish Investigations on September 1, 1969.

Historically our efforts have been species oriented; i.e. separate sections were responsible for conducting all phases of work in Pacific sardine, Pacific mackerel, jack mackerel, and northern anchovy. All of these species are caught by the same fleet. Research objectives remain unchanged, but the basic source of data is now the California wetfish fleet rather than individual boats landing a particular species. These changes make our waterfront sampling procedures more efficient and enable us to develop a more realistic approach to catch-effort studies. With this new format, the Pelagic Fish Investigations consist of four function oriented units, each with a discrete area of responsibility but with provisions for channeling information and sharing manpower where common and overlapping interests dictate the need.

The major change was to reassign personnel of the old Anchovy, Sardine, and Mackerel Projects to the newly created Fishery Research and Monitoring Project and the Biological Studies Project. The Sea Survey Project essentially remained unchanged, but the existing Data Analysis Project (which in the past has limited itself to Sea Survey oriented work) assists all sections in program development and data treatment. In addition, we reactivated the biologist position at Monterey, which now is part of the Fishery Research and Monitoring Project.

The Fishery Research and Monitoring Project devises and carries out age composition and catch-effort studies, initially processes age composition and catch-effort data, reads otoliths, and in cooperation with the Department's Marine Fisheries Statistics Unit insures the accuracy of source documents concerning anchovy, sardine, Pacific mackerel, jack mackerel, and squid landings.

The Biological Studies Project conducts tagging programs, maintains liaison with the live bait industry, conducts various genetic, life history, and ecological studies, and gives assistance to other projects where appropriate, particularly in the joint otolith reading program that we plan to initiate.

The Sea Survey Project will continue to conduct acoustical, midwater trawl, and night light surveys of the living resources of the California Current System. Since part of the survey consists of determining the age composition of collected samples, at least one person will participate in the otolith reading program.

The Data Analysis Project not only will continue to assist the Sea Survey, but will give overall help in program development, and with the assistance of the Department's Operations Research Branch develop electronic data processing procedures and population dynamics programs for all Pelagic Fish Investigations Projects.

We feel the internal reorganization enables Pelagic Fish Investigations to fulfill its basic CalCOFI research commitment in a more efficient and effective manner while, at the same time, giving us greater flexibility to pursue other important but often postponed investigations.—*David Ganssle.*

HOPKINS MARINE STATION

The Hopkins Marine Station of Stanford University at Pacific Grove, California, conducts studies on the environment and organisms of the coastal waters off central California. Under the program, the marine station monitors the marine environment and phytoplankton of Monterey Bay, and is involved in a study of the pelagic food chains and their relations to the biological oceanography of Monterey Bay.

Approximately weekly cruises to six stations on Monterey Bay are made. At each station cruise data consist of: concentrations of dissolved oxygen, phosphate, silicate, nitrite and nitrate at 0 and 10 meters; plankton wet volumes collected in a $\frac{1}{4}$ meter net towed vertically 15 meters; depth of thermocline as recorded on a bathythermographic slide; Secchi disk extinction depth; and general comments on the weather, condition of the sea, marine mammals and oceanic birds.

At Stations 2, 4, and 6, salinities and reversing thermometer temperatures are recorded for 0, 10, 15, 20, 30, and 50 meters. At the shallow water stations, 1 and 5, these same parameters are measured at 0, 10, 15, 20, 30 meters and 0, 10, and 15 meters respectively. At Station 3, over the submarine canyon, salinities, reversing thermometer temperatures, and concentrations of dissolved oxygen, phosphate, silicate, nitrite and nitrate are recorded for the depths 0, 10, 15, 20, 30, 50, 100, 200, 300, 400, and 500 meters.

In addition, daily shore temperatures are recorded at Pacific Grove and at Santa Cruz. Both shore and cruise data are compiled and distributed to interested agencies and individuals in the form of quarterly and annual reports.

During 1969–70, studies were continued on the entry and transfer of DDT residues in pelagic marine food chains. Analyses were done on phytoplankton and detrital material collected by a net or by continuous-flow centrifugation. GLC-EC analyses were performed on samples of surface and midwater fishes and zooplankton. Experimental work with ^{14}C-DDT was done with pure cultures of phytoplankton and with a common euphausiid shrimp.

Phytoplankton samples collected in Monterey Bay from 1955 to 1969 on previous CalCOFI cruises contained compounds identified as p,p′-DDT, p,p′-DDD, and p,p′-DDE. Total concentrations of these compounds were approximately three times greater in the later samples. Lower concentrations throughout the period were associated with higher densities of standing crop.

Uptake studies with pure cultures of marine phytoplankton showed that the algal cells when exposed to low parts per trillion nominal concentrations of ^{14}C-DDT in the medium could concentrate the labelled DDT by factors ranging from 3 to 8×10^4.

GLC-EC analyses of *Triphoturus mexicanus*, a midwater fish from the Gulf of California, showed that older fish had higher DDT residue concentrations. This observation, noted by others for fresh water fish, suggests that fish accumulate DDT residues from the environment during their life span. These studies will be compared with studies in progress on *Engraulis mordax*.—*Malvern Gilmartin.*

SCRIPPS INSTITUTION OF OCEANOGRAPHY MARINE LIFE RESEARCH PROGRAM

The Marine Life Research Group (MLRG) is charged with a broad investigation of the California Current system and of other areas of the Pacific that are related to it. During the last year a number of significant scientific advances have been achieved and are briefly reported below.

The characteristics of the populations of the euphausiaceans *Euphausia pacifica, Nematoscelis difficilis,* and *Thysanoessa gregaria* in the region of a circulation gyre off Southern California have been extensively studied. Whereas these plankters reproduce seasonally in their typical subarctic habitat, here, near the southern limits of their ranges, spawning takes place throughout the year, apparently owing to the relatively constant state of the mid-latitude California Current environment, as compared with high latitudes. Size-frequency diagrams of populations sampled by CalCOFI surveys show occasional conspicuous modes in the production of young, particulary in late spring-summer. These may be traced through successive months, thus permitting an estimate of growth rate.

The extent of egg production is estimated from examination of gravid females. The appearance of cohorts of young in the plankton are related in turn to the egg production. Spawning by different size groups of adult females at characteristic times of the year appears to be partly responsible for seasonal differences in production. Biomass variability of the species shows seasonal rhythmicity, as well.

Preliminary results from two cruises in the central water masses of the North and South Pacific indicate that during the summer a certain regularity of habitat conditions prevails. There is a shallow mixed layer but a deep euphotic zone. Most of this zone has limiting nutrient levels. There is a relatively deep chlorophyll maximum and a deeper phaeophytin maximum. There are frequent blue-green algal blooms very near the surface. Zooplankters, mostly crustacea and chaetognaths, are moderately abundant considering the low standing crop of primary producers. The populations are very diverse both in species present and in relative abundances. The carnivore/herbivore ratio seems to be high. The nekton standing crop is low but it is also diverse. The species structure of the phytoplankton, zooplankton, and micronecton is now under study and will be used to determine the degree of similarity among replicate samples. This should provide some insight into the larger question: is there an orderly, predictable, climax ecosystem present in an area where advection is at a minimum? There is strong evidence that in eastern boundary currents, such as the California Current, horizontal advection may prevent a stable, orderly climax from developing. In these areas food chains are very complex, "ecosystems" quite unsystematic, and population sizes highly variable in time.

A new suite of quantitative taxonomic characters in pelagic marine copepods of the genus *Eucalanus* has recently been established. The significance of these morphological features lies in the potentially widespread research applications they afford to copepod ecology, biogeography, taxonomy, and ethology. The characters are arrays of special sensory hairs and of pores of subcuticular glands distributed in regular patterns on all of the body segments. Within the family Eucalanidae they have provided an objective, diagnostic basis for distinguishing among genera, groups of species, individual species, and geographical populations within the species. If they prove to be as useful in other copepod genera now under study, progress in calanoid systematics, life histories and the certainty of identification of breeding stocks will be significantly increased.

Most marine phytoplankters cultured in the laboratory require one or more vitamins. These vitamins are, in order of importance, vitamin B_{12}, thiamine, and biotin. In a six-month (April–September, 1967) study of the coastal plankton in waters off the coast of La Jolla it was possible to conclude that a bloom of the red tide dinoflagellate *Gonyaulax polyedra* could be correlated with a disappearance of dissolved vitamin B_{12} in the water (*G. polyedra* requires vitamin B_{12} in culture). This same study also indicated that vitamins in the sea were produced by phytoplankton, since dissolved vitamin concentrations were often high when the algal standing stock was high. This observation was verified in the laboratory where ecologically-important phytoplankters produced vitamin B_{12}, thiamine, and biotin in the culture media. If vitamin-requiring phytoplankters were added to the culture vessel containing the producers, the producers and requirers grew independently of each other. It appears that phytoplankton contributes, at times, a considerable portion of the amount of vitamins found in the sea.

Nutrification in the Sea

Nitrogen is often the limiting nutrient for phytoplankton growth in the sea. Most of the transformations of nitrogenous compounds in the sea are effected by micro-organisms. In laboratory experiments it has been demonstrated that both nitrifying bacteria (which oxidize NH_3 to NO_2^- or NO_2^- to NO_3^-) and nitrate-reducing bacteria and algae (which reduce NO_3^- to NO_2^- and other products such as N_2, N_2O, etc.) contribute nitrite to the secondary nitrite maximum found in the deeper, oxygen-poor, waters off the coast of Peru. The nitrite in the primary nitrite maximum arises mainly from the activities of nitrifying bacteria, and, in cases where standing stock is high, from excretion by various phytoplankton.

Photography of deep benthic fish populations has continued. During the year a movie camera obtained several series of ten-second strips taken at regular intervals over a period of several hours in depths ranging from 600 to nearly 4000 meters. Large numbers of sable fish, grenadier fish, and hag fish were photographed. Continued use of the still camera and bait is improving our knowledge of deep benthic fishes. Their use in conjunction with fish traps and other instruments will improve species identification and knowledge of population densities, and may possibly uncover populations of commercial extent.

The program to study the large scale oceanographic and meteorological conditions in the North Pacific continued. An array of five to eight deep-moored instrumented buoys has been moored in the North Pacific between 41°–43° N, 148°–164° W ever since September, 1968. Over a million meteorological and oceanographic data points from instrument platforms have been collected. Hourly meteorological and subsurface data recorded by the buoys have been processed and are available for analysis. Among the observed features, temperature inversions are seen to persist for months, large transient temperature changes below the surface have been recorded, and inertial periods (ca. 17.6 hours) are frequently apparent in the changes of water temperatures and other parameters. These buoys provide data on the subsurface temperature structure (unavailable previously) in addition to surface temperatures and meteorological data, for analysis of the interaction of the ocean and the atmosphere.

Instruments and buoys are continually being modified for increased usefulness. A buoy which periodically makes a continuous temperature record from the surface to a fixed depth has been succesfully tested and a plankton-sampling buoy is under development.

The study of the abyssal circulation by direct measurements of deep currents, using current meters has been extended to various parts of the Pacific Ocean. Measurements of velocity and water characteristics of the Antarctic Circumpolar Current were carried out in the Drake Passage, the strait between South America and Antarctica. The total transport of water through it was estimated to be about 270 million tons per second. This is about twice the values estimated previously, without current meters, and about three times the estimated transport of the Gulf Stream.

Similar work was done aboard the USNS *Eltanin* between Australia and Antarctica. Estimates of net eastward transport of water gave about 350 million tons per second, considerably more than the eastward flow estimated through the Drake Passage.

Further deep-current measurements were made in the Northeastern Pacific and the basins off Southern California to continue the collection of current data for an analysis of the abyssal circulation which so profoundly affects the condition and life of the deep sea floor and the intermediate waters.

Investigation of the Santa Barbara Basin in continuing to add to our knowledge of: distribution and abundance in past times of those species of plankton encountered in the sediments; sedimentation rates; history of the fishes of the California Current; and man's effects on the nearshore ocean. During this last year the water below sill depth in the Santa Barbara Basin overturned. This occurred some time between a January, 1970, cruise and a May, 1970, cruise. In January the oxygen content very near the basin bottom was 0.1 to 0.05 milliliters per liter. During the May cruise the oxygen level was up to 0.4 milliliters per liter; in June it was 0.23 milliliters per liter and in July 0.05 milliliters per liter. The overturn of the waters may have occurred very rapidly during the strong north winds in April and early May. The June and July cruise data show that the basin was quickly returning to its normal condition of very low oxygen content below the sill depth.

Several newly elucidated properties of waves are being explored for their potential in allowing the control of sea waves. It appears that wave power can be simply and substantially dissipated in deep open water and near shore by utilizing some of these properties. Usable power can be generated from a broad portion of the wave spectrum by floating devices in the open sea. Prototypes of the power device have been constructed and operation at sea has been demonstrated. A second stage prototype of this is to be designed by an outside engineering contractor.—*John D. Isaacs.*

NATIONAL MARINE FISHERIES SERVICE FISHERY-OCEANOGRAPHY CENTER

On October 3, 1970, when President Nixon's reorganization plan to consolidate various ocean- and atmospheric-oriented activities went into effect with the establishment of the National Oceanic and Atmospheric Administration (NOAA) in the U.S. Department of Commerce, the Bureau of Commercial Fisheries was among the agencies affected. Most of its functions, together with some new ones, were transferred to NOAA and it was renamed the National Marine Fisheries Service (NMFS).

In fiscal 1970, research oriented to the interests of CalCOFI continued to occupy an important part in the programs of the Fishery-Oceanography Center. As in past years, research was organized into four discipline-oriented Groups, each Group containing programs and projects related to several fisheries—temperate and tropical tunas, anchovy and sardines, Pacific and jack mackerel, marine mammals, etc. With the exception of the Fishery-Oceanography Group which is principally concerned with the relation of tunas to their environment, all of the other groups contain various elements of CalCOFI-coordinated research. The report which follows, therefore, is not intended as a comprehensive account of all research activities at the Center but only of CalCOFI research there in fiscal year 1970.

This was a year of change for the Center. Not only was our research expanded to include new programs and projects dealing with pollution of marine ecosystems, tuna behavior, tuna population dynamics, and marine mammal research but, increasingly, new tools were applied to help solve many of the traditional problems of fishery biology. This trend was particularly evident in the Population Dynamics Group which carries out most of the CalCOFI research at the Center.

Development of Hydroacoustic Techniques

An unique set of circumstances—water with a deep mixed layer, a history of military and academic underwater sound research in the area, an abundance of historical oceanographic data, a comprehensive knowledge of fish populations, and a predominant population of a single species, the anchovy—all combine to make the California Current region an ideal locale to obtain information on fish population size, availability and distribution through the efficient use of acoustic techniques.

As an alternative method to the traditional ichthyoplankton surveys for stock assessment, a decision was made in early 1968 to develop methodology for fish hydroacoustic surveys; most work in 1970 was concerned with obtaining information on the number, size, and weight of fish schools.

The use of sonar to map the size of fish schools in the horizontal plane has been developed over the past 2 years. Although it had previously been assumed from one small sample of targets that the technical specification of transducer beam width (10°) was adequate for anchovy schools, it was later found that this 10° beam angle overestimates the number of larger schools. The angle with the least error for all schools is 13°, although many of the widths of schools smaller than 25 m are underestimated by assuming a 13° beam width. Individual school sizes can be determined with certainty only after an estimate of their target strength, however.

In the continuing analysis of the 1969 CalCOFI sonar survey, it has been determined that within the CalCOFI survey area fish schools cover less than 0.2% of the surface area in most regions although some large groups of schools may cover as much as 8% of the surface. It also appears that acoustic detection of schools less than 20 m in diameter is strongly range-dependent; for schools larger than 20 m in diameter there is no detectable loss in signal return at any range from 200-450 m. A recently developed computer program makes it possible to process a 20-day acoustic survey of 100,000 square miles in about 1 week.

During a cruise on the research vessel, JORDAN, in the spring of 1970, sonar measurements were made on captive anchovy schools, one containing 142,000 fish and the other, 25,000 fish, held in a large trap constructed of monofilament mesh. Results of this study have led to a new working approximation of the weight of fish under each square meter of fish school. In 1960, Postel calculated from masthead measurements that a 20 m diameter school of *Sardinella* would weigh 30 metric tons. Estimates of biomass for the California Current area in May-June 1969, indicate a figure between 0.01 and 0.05 metric tons per square meter of fish school. Based on a tentative figure from the magnetic tape records of the sonar data, the metric tons of biomass per square meter of horizontal area of fish school are estimated to be 0.031 metric tons.

In connection with the research on fish biomass, sonar target strengths of fish schools, both wild and captive, were measured during a cooperative cruise with the Westinghouse diving vehicle, DEEPSTAR 2000. Critical measures of school compactness were made and supplemented by photographs. Thus far, it is estimated that the usual wild fish school weighs about 0.03 metric tons per m^2 cross-sectional area.

Hake

Another activity of the Population Dynamics Group has been the preparation of a report on the current status of the breeding population of the Pacific hake (*Merluccius productus*), increasingly sought by the Soviet trawl fleet in the eastern temperate Pacific. A standard procedure has been developed to scan plankton samples for hake eggs and larvae so that significant changes in hake abundance may be monitored. Early results indicate that in 1969, hake spawning was centered offshore of the southern California Bight; the amount of spawning coverage and density place 1969 in the upper half of a 17-year series for which data are available. The fact that spawning off central California was not as heavy in 1969 as in 1968 may very likely be due to oceanographic conditions caused by a 30-year record number of storms from the North Pacific, rather than to overfishing of adult hake.

Standard biochemical techniques for investigating the population structure of the Pacific hake off the coast of California and Baja California, Mexico, were developed. Techniques previously used in the anchovy subpopulation studies were modified to accord with those already used by Dr. Fred Utter in his hake work in Puget Sound, and will permit direct comparison of results with his findings on biochemical polymorphisms in hake.

The distribution in time and space of hake eggs and larvae off southern California and Baja California, taken on a January cruise of JORDAN, suggests the possibility of a separate hake stock off the southernmost portion of Baja California. Although published data on southern California hake indicate that the females mature at about 300 mm standard length, the hake collected from southern Baja California are maturing at very small sizes, 126–202 mm. Differences in four meristic characters also provide additional evidence that the southern hake are a separate stock and may be a different species. This indicates that a small but yet unmeasured portion of the total Pacific hake biomass is made up of this stock of small and presently not commercially useful specimens.

Personnel in the Population Dynamics Group provided plankton equipment, assistance and advice on sampling techniques, and the scanning and sorting of samples to scientists on the Soviet research vessel, OGON, during her egg and larva surveys of hake off California and Baja California in February-March 1970. Results of scanning of 143 plankton samples by Fisheries Service biologists for hake eggs and larvae indicated that the distribution of hake spawning had shifted northward relative to 1969 and was accompanied by a 1.3° sea surface temperature shift in the 5° square which includes San Francisco. These data were presented in a report prepared for the U.S.-Soviet fishery meetings in Moscow in September 1970.

Study of instantaneous mortality rates of hake larvae obtained from CalCOFI Cruises 6401, 6601, 6602, and 6604, indicates that some larvae less than 3 mm long escape the nets used during these cruises. The modal length of hake larvae increases as the season progresses, with peak spawning in February and March. The January cruise may thus be too early in the season to capture large, old larvae, while the April criuses occur too late in the season to capture many small, young larvae. It is also apparent that samples taken during night hours contain larger larvae than do samples taken during day hours, possibly due to an ability of larger larvae to avoid capture when the net is visible.

Anchovy

Analysis of anchovy egg and larva survey data has shown that the stocks of northern anchovy off southern California continued to increase through 1969, while those off southern Baja and central California remained relatively stable during the past decade. Data on the abundance of northern anchovy larvae obtained on CalCOFI cruises from 1950–60 were analyzed with a new statistical approach. The results are in agreement with those from other studies which indicate that the common practice of using a grid to choose locations for biological samples does not introduce serious bias into estimates of abundance derived from the samples.

Mr. Vrooman has now established that there are at least three genetically-distinct subpopulations of northern anchovies off California and Baja California, Mexico. The general range of the southern subpopulation is from the tip of Baja California, Mexico, to northern Vizcaíno Bay, Mexico; the central group from northern Vizcaíno Bay to San Francisco; and the northern group from San Francisco to at least as far north as Newport, Oregon. The northern and central anchovies are morphologically similar to each other but are distinctly different in body depth, head depth, head length, snout length, and eye diameter from the southern group.

The 1969 CalCOFI survey year was completed after 1,629 stations were made on 16 cruises which covered the 200,000 square mile area twice each season. An early summary of the samples indicated that the number of larval anchovies present during that year may be the highest yet recorded. Preliminary hake spawning biomass figures place the 1969 estimate in the upper third, in terms of quantity, for the 17 annual estimates between 1951 and 1969.

A report on estimates of spawning biomass for the northern anchovy, indicating that the anchovy population in the California Current area reached a plateau in 1962, was furnished to the California Marine Research Committee. Estimates for the biomass of anchovies placed it at 4,950,000 tons in 1970.

Wetfish Operations Pool

An objective of the Operations Research Group is to provide information to the fishing industry to be used to improve its operations. A significant step in this direction is the experiment, jointly funded by the NMFS and the California Marine Research Committee, to mechanize the wetfish purse-seine operation in California. A San Pedro seiner, SUNSET, was chartered and equipped with a 100 gal/min hydraulic system, a net drum to replace the power block, a "ring stripper" to handle the purse rings automatically, the fish pump and water separator, and an auxiliary boom to handle the corks during the brailing operation. In addition, the vessel's net was modified for use with the purse drum. Installation and field trials were completed and the vessel was ready to begin fishing tests in June 1970, with five crewmen, or approximately half the crew required by conventional seiners of the size. Tests, so far, indicate decreased time required to operate this gear and SUNSET has risen to a "high liner" in the fleet.

Local Fisheries Development

In the project to develop local fishery systems, a joint study with the NMFS Exploratory Fishing and Gear Research Base, Seattle, to investigate the saury resources off California, indicated that large numbers of medium and large saury are available off the coast. Before a viable commercial fishery can be established, however, further studies are needed on more efficient ways to catch and handle the fish.

Efforts were made to help fishermen utilize the pink shrimp (*P. jordani*) resource off California. Four days of trawling off Avila Beach with a conventional 41-foot shrimp trawl resulted in encouraging catches but sorting of fish from shrimp was laborious and time-consuming. On-board sorting with a two-man crew was impractical and consequently it was difficult to avoid landing less than the maximum 500 pounds of fish per landing of shrimp permitted by State law. To continue exploration and experimental trawling, a modified shrimp-sorting trawl is being built and will be used to determine if the separating aspect will be effective.

The "squid slurp", a method which personnel in this group helped develop, for pumping squid directly on board the fishing vessel, continued to catch squid effectively. Several modifications to the original design were made to reduce the amount of movement of the funnel and pump and to permit normal fishing even with 25 knot winds.

San Pedro Wetfish Fishery

A bioeconomic model of the San Pedro wetfish industry to permit prediction of the financial success of operations, taking into consideration condition of fish stocks, cost of fishing operations, and the market structure was also completed. The model was programmed to simulate runs of operations under varying conditions.

In this connection, "Development of the San Pedro Wetfish Fishery—A Systems Approach" was the subject of a symposium at the CalCOFI Conference in December 1969. The consensus of this symposium was that we need a systems approach to the problems of this wetfish industry with close cooperation and coordination of effort between State and Federal agencies. The points were also made that incentives to private capital, especially with respect to prospects for a constant, large supply of raw material, are required before development of the fishery can progress and that care must be taken, possibly through limited gear entry, that an expanded fleet does not become over-capitalized.

Larval Fish Ecology

The Behavior-Physiology Group studies the environmental requirements of the abundant pelagic marine resources in the California Current region. Its research is designed to obtain information on how fish respond to each other and to their environment, how they react to stimuli presented by fishing gear, how they obtain food, how much they need, and how they use the food obtained.

Working principally with larval and adult anchovy and jack mackerel, this Group has made significant advances this year. Perhaps the most important of these is the basic work which led to the first successful spawning of the northern anchovy under artificial conditions. Adult anchovies, kept in large aquaria, were subjected to 4 hours of light and 20 hours of darkness for 4 months at a temperature of about 15° C. At intervals the fish were injected with several types, dosages, and combinations of gonadotoxins. The combination which ultimately produced heavy spawning included commercial preparations of human chorionic gonadotropins (HCG) plus carp or salmon pituitary extract. It was not necessary to strip the fish in either case to obtain sexual products, as is usually done with salmon and trout, since the animals released and fertilized the eggs themselves. The percentage of eggs hatching from these trials varied from less than 10% in one trial to over 80% in others. No member of the clupeid family has ever been artificially induced to spawn before in the laboratory and the success of these experiments offers unique opportunities to study fecundity in the laboratory and provides an assured supply of anchovy eggs and larvae for physiological and other laboratory studies.

Additional information has been obtained on the requirements of anchovy larvae for growth under laboratory conditions. A rotifer, *Brachionus plicatilis,* which is being cultured in mass in the laboratory, stimulates growth in larval anchovies equal to that obtained when the larvae are fed wild plankton. The successful culture of *Brachionus* has led to numerous requests from laboratories around the country as an adjunct in mariculture.

Work also continued on swimming, feeding and other behavior of anchovy larvae. It was found that the proportion of time that larvae spend resting during the day declines from 90% for just-hatched larvae to less than 10% for 4-day-old larvae with concomitant increases in swimming. Feeding begins on the

3rd day after hatching and by the 4th day the proportion of time spent feeding is greater than or the same as at subsequent stages of development. Testing was also begun on use of an ultrasonic activity apparatus to monitor acoustically the activity of larval fish during the day and at night in the dark.

The shape and extent of the field of reactivity to prey by larval anchovies was also determined. The distance at which a prey was sighted was, in general, a function of the angular position of the prey.

Histological study of the development of sensory and motor systems in anchovy larvae has indicated that their eyes are capable of some kind of vision as early as 3 days after hatching. The retina shows an area specialized for higher visual acuity to be present as early as 7 days after hatching.

A collaborative study of the effect of predaceous copepods on fish larvae has been completed. When fish larvae are available to them, carnivorous copepods, e.g. *Labidocera* spp., attack and devour many more than they actually need for growth and metabolism. Anchovy larvae during the yolk-sac period are particularly susceptible to predation of this kind.

Behavior of Pelagic Fishes

A series of extensive experiments with jack mackerel and to a lesser degree with Pacific mackerel, Pacific sardine, northern anchovy, and a triakid shark, designed to determine the relationship among fish length, tail beat frequency, tail beat amplitude and velocity, has been completed, and the data analyzed. These data imply that fish of the same size regardless of body form or species, modulate tail beat frequency in the same manner at different velocities. Thus the velocity of any swimming fish can be estimated from either its length and the frequency of its tail beat or from the tail beat amplitude and frequency, although it is not possible to distinguish, thus far, among fish species.

Experiments to determine the maximum sustained speed of jack mackerel were completed. Preliminary results indicated that the sustained speed threshold for jack mackerel (about eight body lengths per second for a 6-hour velocity treatment) is considerably above that for other fishes studied previously.

A study was completed on the uses made by fishes of their red and white muscles while swimming. The results indicate that red muscle, like the liver, is a storage organ for nutrients and that in stressed animals failure to sustain swimming may be simply due to exhaustion of glycogen reserves.—*Alan R. Longhurst.*

REVIEW OF THE PELAGIC WET-FISHERIES FOR 1969 AND 1970

Total landings of wet-fish increased both in 1969 and 1970. This increase reflects landings of the anchovy reduction fishery which was conducted under a 140,000 ton quota during the 1969–70 season and a 100,000 ton quota during the 1970–71 season (Table 1). Landings of Pacific mackerel during 1970 were the lowest since 1926 when records of mackerel landings were first separated by species. A moratorium was placed on the take of Pacific mackerel on November 23, 1970, which limited the catch to mixed loads with no more than 15% Pacific mackerel. The moratorium on sardine catch was changed in 1969 to permit a seasonal quota of 250 tons for bait purposes only.

TABLE 1

Landings of Pelagic Wet-Fishes in California in Tons; 1964–70

Year	Sardine	Anchovy	Pacific Mack-erel	Jack Mack-erel	Herring	Squid	Total
1964	6,569	2,488	13,414	44,846	175	8,217	75,709
1965	962	2,866	3,525	33,333	258	9,310	50,254
1966	439	31,140	2,315	20,431	121	9,512	63,958
1967	74	34,805	583	19,090	136	9,801	64,489
1968	62	15,538	1,567	27,834	179	12,466	57,646
1969	53	67,639	1,179	25,961	85	10,390	105,307
1970*	221	93,805	311	22,304	157	9,933	126,731

* Preliminary

Sardine

During most of 1969, a moratorium was in effect restricting the take of sardines to mixed loads with no more than 15% sardines. A law became effective November 10, 1969, which permits 250 tons of sardines to be landed annually for bait, with the provision that no boat possess more than 3 tons any calendar day. After the quota is reached, sardines may not be possessed for any purpose except vessels may contain 15% or less by weight. Sardines so taken can be used only for canning, preserving, and reduction. Sardine landings were primarily used for dead bait in 1969 and 1970, and brought from $300 to $500 per ton to the fishermen.

Anchovy

The fifth anchovy reduction season closed May 15, 1970, with 83,473 tons of a 140,000 ton quota landed (Table 2). Monterey area landings were only 2,020 tons while southern California plants processed 81,453 tons. Fishermen at Monterey received $20.50 per ton for their catch while the price in southern California was $20 per ton. Domestic fish meal prices remained generally high during the season, providing considerable incentive to the fleet and processors.

During the 1969–70 season, the fishery, despite the record southern California catch, was not without its problems. Early in January 1970, when it seemed apparent that the southern quota would be reached, the Fish and Game Commission, at the request of the reduction industry granted an augmentation of 65,000 tons in the southern area. However, on March 20, 1970, at the request of the sport fishing and live bait industries, the Commission closed the southern area within 12 miles of shore. This action, in effect, completely shut down the fishery. Early in May the Commission, again at the request of the reduction industry, modified the regulations and opened a portion of the southern area to within 6 miles of shore. A resurgence of the fishery followed this decision and the fleet had generally good success up to the May 15 closure.

Preliminary data indicate total anchovy landings for calendar 1970 were over 95,000 tons (Table 3).

TABLE 2

Anchovy Landings for Reduction in the Southern and Northern Permit Areas; 1965–66 through 1969–70

Season	Southern Permit Area	Northern Permit Area	Total
1965–1966*	16,468	375	16,843
1966–1967†	29,589	8,021	37,610
1967–1968‡	852	5,651	6,503
1968–1969§	25,314	2,736	28,050
1969–1970¶	81,453	2,020	83,473

Seasons
* November 12, 1965 through April 30, 1966
† October 1, 1966 through April 30, 1967
‡ September 15, 1967 through May 15, 1968
§ August 1, 1968 through May 15, 1969
¶ August 1, 1969 through May 15, 1970

TABLE 3

Commercial Landings and Live Bait Catch of Anchovies in Tons; 1964–1970

Year	Reduction	Other Commercial	Live Bait	Total
1964	0	2,488	5,191	7,679
1965	170	2,696	6,148	9,014
1966	27,335	3,705	6,691	37,731
1967	32,349	2,455	5,387	40,191
1968	13,795	1,743	7,176	22,714
1969	65,210	2,429	5,538	73,170
1970*	93,805	2,186	†	95,991

* Preliminary
† Not yet available

Mackerel

Annual landings of both jack and Pacific mackerel declined in 1969 and again in 1970. Most of the jack mackerel catch during the 2 years was made at Cortes Bank. In 1969, fish 1 year old dominated the fishery, while both 1 and 2 year old fish predominated in 1970. Fishermen received $75 per ton from the canneries for jack mackerel during 1969 and 1970.

Pacific mackerel landings reached an all time low in 1970 with only 311 tons being landed. No fish were taken north of Point Conception, while Santa Catalina Island, San Clemente Island, and inshore areas off San Pedro provided most of the catch.

Most catches were mixed with jack mackerel, and the fishery was dominated by the 1968 year class during both years. A moratorium became effective in November 1970, which limited the catch to mixed loads not to exceed 15% Pacific mackerel.

Squid

Squid landings in 1969 dropped for the first time in 6 years. Squid appeared to be plentiful at traditional fishing areas, but canners had only small orders for canned squid.

Landings again were down slightly in 1970 primarily as a result of squid failing to appear in historically productive areas.—*Herbert W. Frey*

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Part II

SYMPOSIUM ON THE DEVELOPMENT OF THE SAN PEDRO WETFISH FISHERY—A SYSTEMS APPROACH

Edited by ALAN R. LONGHURST

Cambria Pines, California

December 1–3, 1969

Two of the talks presented at this Symposium are not included here. Dr. Dayton L. Alverson who gave the keynote address has asked that his presentation be withdrawn since it dealt with topical matters now largely supplanted by those recent events which resulted in the transfer of the Bureau of Commercial Fisheries into the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce as the National Marine Fisheries Service.

The editors have decided also to omit the presentation of the late Dr. Wilbert M. Chapman who discussed the subject of "Markets" informally and without notes as a substitute for an absent participant. Unfortunately, Dr. Chapman did not have an opportunity to edit his remarks before his death.

CALIFORNIA AND COMMERCIAL FISHERY PROBLEMS

A. ALAN POST
Legislative Analyst, State of California
Sacramento, California

I appreciate the opportunity to speak at this CalCOFI Conference and participate with you in discussions of California's commercial fishery problems.

In some respects my appearance here is like Jonah in the whale, I'm in strange territory. Our office has never professed to have technical expertise on the fishery problems of the state such as you represent. It is our job to point out fiscal and management problem areas and make recommendations to the Legislature that we feel are appropriate. We have merely raised certain criticisms of the Department of Fish and Game research efforts in our budget recommendations to the Legislature. We have also expressed the view that the Marine Research Committee has not been living up to its full responsibilities in resolving some of the problems of the state's commercial fisheries. Your understanding of the role of our office and the invitation to speak here today doesn't make us fisheries experts. As administrative people we are a little out of our usual territory.

We are heartily in accord with the efforts of the Bureau of Commercial Fisheries in its attempt to provide a systematic approach to fishery problems and to create a mechanism whereby the representatives of federal and state agencies and the academicians can get together to determine the problems facing the industry and work out solutions. Two years ago, we recommended to the Legislature that the Department of Fish and Game should do somewhat the same for the state.

At that time we pointed out that the state had not defined and fixed its own responsibility for meeting commercial fisheries problems. The substantial funding that had been available over the years for commercial fisheries research or related work was largely devoted to technical and academically oriented work at academic institutions and within the Department of Fish and Game which emphasized continuing collection and analysis of data on food patterns, growth factors, fish populations and other matters of special interest to the fishery biologists. In fairness to the Department of Fish and Game, it should be pointed out that from our observations of the industry's actions before the Legislature and various state regulatory bodies, the commercial fishery industry, itself, did not know what the problems were or have much in the way of suggestions. There seemed to be no effort underway to develop definitions of the problems and to initiate programs to solve them.

The Legislature in 1968 adopted our recommendation that the department participate with the commercial fishing industry in developing clearly defined statements of the problems confronting the industry and take the leadership in reorienting the state's activities to solve the problems on a priority basis.

I would like now to turn to a brief discussion of events, as we see them, that have occurred since the adoption of that recommendation by the Legislature in 1968. The department representatives met several times—I believe about six times—with representatives of commercial fishing interests. Representatives of our office did not participate in those discussions, but as we understand the results of the meetings the department presented descriptions of its programs that would be helpful to the industry. Apparently the industry representatives have been satisfied with the programs and current activities of the Department of Fish and Game. During these meetings, the department also provided data to the industry representatives which indicated that the department is spending almost $1,500,000 more annually on commercial fishing programs than it is receiving in revenue from this source. The evidence presented by the department must have been substantial because it is astounding that during the last session of the Legislature, at a time when so much emphasis was being placed on reductions in the cost of government and reductions in taxes, a bill increasing commercial fishing license fees and fish taxes by about $800,000 passed the Legislature with comparative ease.

In a report issued by the Department of Fish and Game last January responding to our recommendation for defining problems and priorities, the department indicated some problem areas confronting the commercial industry. These were:

A. Detection and capture of resource
B. Assurance or maintenance of a constant supply
C. Processing of fishery products
D. Marketing (economics)
E. Unduly restrictive laws
F. Conflict among user groups

The department identified its own role in relation to some of these problems but suggested little concerning how other governmental agencies or the industry could help. It was agreed by the department and the Legislature, however, that the department would continue its efforts to define the responsible agencies. Your efforts at this conference can help in dividing up responsibilities for a coordinated effort towards solution of commercial fishery problems.

At the last legislative session, the Governor presented a reorganization plan changing the name of the Department of Harbors and Watercraft to the Department of Navigation and Ocean Development with its primary emphasis shifted to ocean oriented activities. Simultaneously with this proposed reorganization, the Governor requested an internal reorganization within the Department of Fish and Game to permit that department to work closely with the new department in developing the Comprehensive Ocean Area Plan.

The Department of Fish and Game has commenced reorganizing to provide emphasis and separate status for its ocean activities. The department has created a separate marine region, coequal to each of the five land regions, to regulate and manage the ocean resources. The patrol, research and management activities previously divided among three of the existing land regions and marine resources operations at Terminal Island will be consolidated in this new region. In addition, the department created a new marine research branch to act as advisor and consultant on the department's marine research programs. Finally, the department has established a marine advisory committee consisting of representatives of federal, private and academic agencies interested in marine resources. These events reflect the increased emphasis the department is placing on its marine programs and the state's desire to assist in solving some of these pressing industry problems.

A word of caution. The results which can be obtained by reorganization alone are limited. Problems which we cannot identify will not disappear merely because of the establishment of a new organization or reorganization of an old department. Our commercial fishery problem remains just as much unsolved as before the reorganization. Perhaps our machinery is improved, but the problems are still with us.

I would like to turn now to a discussion of federal-state relations and some comments about the efforts of both levels of government to solve commercial fishery problems. From my comments thus far, you can see that we believe both the federal government through the Bureau of Commercial Fisheries and the state through the Department of Fish and Game are only beginning to zero in on the problems of the San Pedro Wetfish Fishery as well as other commercial fisheries problems common to each agency's interests. We hope that through the discussions and meetings held here the bureau's planning objectives will be realized and that there will be some real progress in defining the responsibilities of each agency in terms of the capability of each level of government.

At the present time both the Bureau of Commercial Fisheries and the Department of Fish and Game are engaged in planning efforts involving the same fisheries. In 1964, the Department of Fish and Game completed the California Fish and Wildlife Plan which provides a framework of programs, policies and actions recommended by the Department of Fish and Game to maintain or improve California's Fish and Wildlife resources. This plan includes data and comments on the pelagic wetfish fishery.

In addition to the California Fish and Wildlife Plan, the department has been directed by AB 564 of the 1969 session to prepare a comprehensive master inventory and preliminary master plan for utilizing all ocean fish resources based on existing scientific information, including but not limited to the biology, history, statistics, and economics of the fisheries. The purpose of this effort is to formulate programs for the management of all ocean fishery resources including the harvesting of latent stocks of fish and coordinating the efforts of state, federal and academic institutions to more effectively resolve problems involving these resources. This master inventory and plan is to be submitted to the Legislature in the 1971 session. The same bill directs the department to prepare a comprehensive inventory, from all available studies, specifically of the pelagic wetfish and related species including anchovy, hake, jack mackerel, Pacific mackerel, sardines, saury, and squid. The department is to present the first phase of this inventory to the Legislature during the 1970 session. The state is firmly committed to a planning effort.

The federal government through the Bureau of Commercial Fisheries is also developing master plans for commercial fisheries. The objective of the bureau's efforts is to create a mechanism whereby the various representatives of the federal and state agencies and the academic institutions can divide up the problems and solutions among themselves. It seems apparent that both the bureau and the department are engaged in similar, if not identical, tasks. Each organization, of course, should have its own objectives and goals and a clear delineation of responsibilities in managing and solving the problems of ocean fisheries. The industry problems, the technical activity and the geographical area covered are so large that no one agency or group can accomplish all the work to be performed. We would suggest, therefore, that the state and bureau can provide for an allocation of responsibilities and exchange of data and information required in the development of these plans to make sure that each agency does not have to cover the same ground (or I should say the same waters) or otherwise perform overlapping, duplicating or low-priority work.

At this point I would like to chide our federal friends on a matter concerning which we all could do better. You have, it seems to us, placed the cart before the horse in some of the commercial fisheries research programs. The federal government, through the Commercial Fisheries Research and Development Act of 1964 (the Bartlett Act), provides financial aid to the states for research and development of their commercial fisheries. We welcome the federal monies. But four years after the statute was enacted and after some money had been allocated to the states for commercial fisheries research and development, the Bureau of Commercial Fisheries introduced the development of its own master plans for commercial fisheries in order to solve some of the problems. It seems to us that logically the federal government should have defined its programs and objectives prior to providing the financing for the achievement of unknown objectives and goals. This same lack of defined programs and objectives has contributed to confusion at the state level and among the academic institutions. This is why we have recommended that our department of Fish and Game seek to define our commercial fishery problems.

In the development of commercial fishery programs and the delineation of responsibilities for the various agencies, we should point out that the Department of

Fish and Game is only a state agency. California certainly has a strong interest in the ocean and the department has represented that interest in the ocean fisheries in the past. But the state should leave the foreign negotiations on fishing problems to the federal government, and we hope that the Bureau of Commercial Fisheries will carry out that representation fully to represent the industries of California in relations with foreign governments.

Another frequent complaint of the industry is the presence of foreign fishing vessels off the coast of California. The presence of these vessels must indeed be painful to the fishermen who gain their livelihood from the resources off our coast. Does not the same situation hold true, however, for the American fishing vessels which appear off the coasts of Peru or even off the coast of Mexico and for the far flung tuna vessels which land their catch at San Pedro?

Finally, I would like to offer some suggestions to the commercial fishing industry and the marine sportsmen of the state concerning their role in defining and resolving problems pertaining to the marine resources. We sometimes receive suggestions from industry representatives that the state should assist in developing markets for under-utilized species. At the present time the Department of Fish and Game is not set up to carry on market development, and we suggest that the industry is wasting its time by turning to the department's fishery biologists for help in this respect. It seems to us that the development of markets is a job for private enterprise. At least it's not a job for the state even though the Bureau of Commercial Fisheries may have some capabilities in this respect. If the consumers will not buy a particular species of fish because the fish tastes bad, then it is the responsibility of industry to improve the processing and canning and preparation of the fish to meet consumer acceptance rather than involve the Department of Fish and Game in this activity. The University may be able to offer some contract assistance through its research activities.

In conclusion, some comments about the continual wrangling over the appropriate level of harvesting anchovies. In the controversy surrounding the commercial use of the anchovy, those opposed to such use point out the disappearance of the sardine and suggest an identical fate for the anchovy. We would point out that the anchovy is not the sardine and that largely as a result of the disappearance of the sardine considerable research and effort has gone into studying the anchovy and the amount of the supply safely available for use. If reasearch and monitoring efforts do not lead to resource management decisions, then these efforts are pointless, and I am not certain of the need for much additional research and study.

Again, I appreciate the opportunity to meet with you in your deliberations about the commercial fisheries of California and wish you much success in your efforts to develop a systematic approach to fishery problems.

SPORT COMMERCIAL CONFLICTS IN DEVELOPMENT OF CALIFORNIA WETFISH FISHERY

STEPHEN B. MATHEWS
Washington State Department of Fisheries
Olympia, Washington

The systems approach, according to people who claim to know what it is all about, is a methodology for attaining complex scientific, economic, or social goals by taking into account just about everything that may affect the reaching of such goals. From my distant vantage point, the desired outcome of this symposium—the development of an economically viable wetfish fishery—is strongly dependent on the existing marine sport fishery of California. There seems little question that the sport fishery will have to be taken into account and understood thoroughly—its economics, its biological interaction with commercial species, and perhaps even more important, the enthusiasm and drive of its adherents.

I have been asked to attempt to say something sensible about the economic aspects of the sport fishery, and in particular, indicate how economic analysis might help resolve the competitive interaction of sport and commercial interests which sometimes impedes management policy for obtaining the greatest total use of fishery resources. I don't wish to imply that economics should provide the ultimate answers in such disputes, but I think quite often these considerations are not given proper attention. This is probably due to the fact that it has been very difficult to satisfactorily apply economic evaluation techniques to recreational fishing, which has resulted in considerable confusion.

I am a bit at a loss as to how to approach this topic for the present symposium. The interactive issue surrounding the anchovy harvest is quite a bit more complex than, for example, a single species, such as a salmon run harvested by both sport and commercial fisheries. In this latter situation it is quite clear that the activities of one group will affect the other, and it is relatively easy to estimate changes in such things as catch per effort, value of catch, and amount of effort for both fisheries under various schemes of rationing the biologically allowable catch. In this manner one can get a handle on the kinds of restrictions to place on the two fisheries which will come the closest to maximizing the total net economic yield from the stock; that is, the sum of the net yields to the two.

This simple, single species model would seem to go out the door in the present situation wherein not only does the interaction have to pass through one step of the food chain, but also, there are a great many species involved. Let me try, however, to present a simple model for which I will ask you to stretch your imaginations a bit. That is, I will ask you to put the sport fishery in the abstract, and think of it as taking some single, generalized predator. And, think of the commercial fishery as taking a single generalized prey, and thereby adversely affecting the predator population. I don't pretend that this simple model is at all useful in itself but, hopefully, it will at least provide a conceptual framework for talking about the problem. Actually, I plan on presenting this model rather briefly, for I want to spend some time talking about the fishery itself.

Getting back to the theoretical details, I haven't yet defined the concepts of net economic yield for either sport or commercial fisheries, although I alluded to these already. For a commercial fishery net economic yield is a relatively less abstruse concept than for a sport fishery. It is simply the difference between total gross revenue from the catch and all the vessel operating and other costs of getting it, including wages for fishermen and opportunity costs for invested capital.

For sport fisheries economists are fairly well in agreement that net yield is some measure of the quantity of money which people *would* be willing to pay for their right to fish if charged for this presently free (or nominally licensed) opportunity. Behind this concept is that fact that most fisheries, unlike other useful and valuable goods and services, are unowned. Hence, people have free access to most sport fisheries. However, if someone actually owned them and charged profit maximizing fees for their use, it is plain that people would pay, perhaps not happily, a good deal more than they now pay in terms of their actual fishing costs. To repeat, because this matter is not often understood clearly, it is this extra sum of money that they *would* pay, not the money they currently pay for their fishing costs that measures the net economic yield from the fishery.

The obvious difficulty with this concept is, how do you measure it, short of simply charging people higher and higher fees to see what they would pay. Hypothetical questions have been asked on surveys and other analytical tools have been applied. None of these are totally satisfactory but they are far better than having no answers at all in making resource decisions affecting sport fisheries.

Suffice it to say, people in general would almost certainly be willing to pay more for good quality fishing than poor quality fishing. Thus, for our generalized predator sport fishery one can hypothesize a monotonically increasing function relating net value per trip to average catch per trip.

A recent study we did on sport salmon fishing indicates a relationship such as this, but no one has yet been clever enough to precisely define it. I have postulated that it must reach some upper asymptote. People reach a saturation point—they would receive as much recreational pleasure (and, therefore, value) from catching say 10 fish as 20.

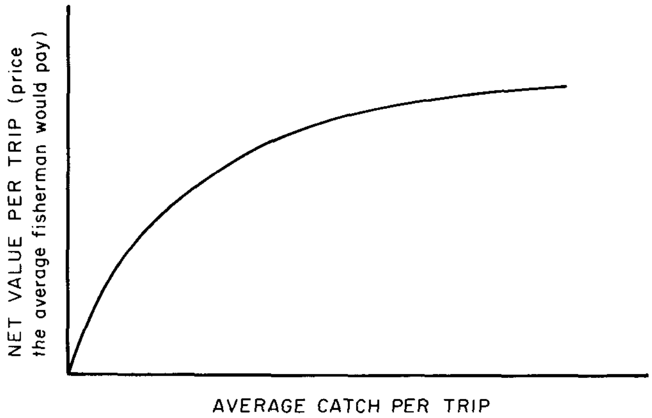

FIGURE 1

Another similarly shaped curve can be postulated relating catch per effort to total effort (Figure 2). Again, this is conjectural. It simply reflects that there is a limit, imposed by population and leisure time constraints, on the amount of sport fishing effort taken.

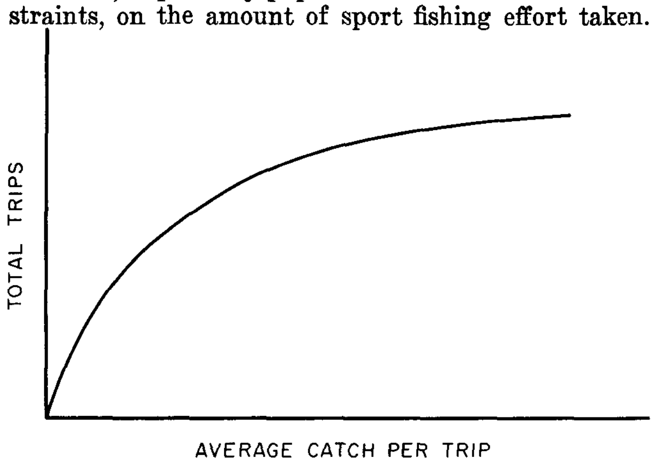

FIGURE 2

Putting these two relationships together we get the obvious one relating total net value (total trips times net value per trip) to total catch, of a similar shape to the preceding ones.

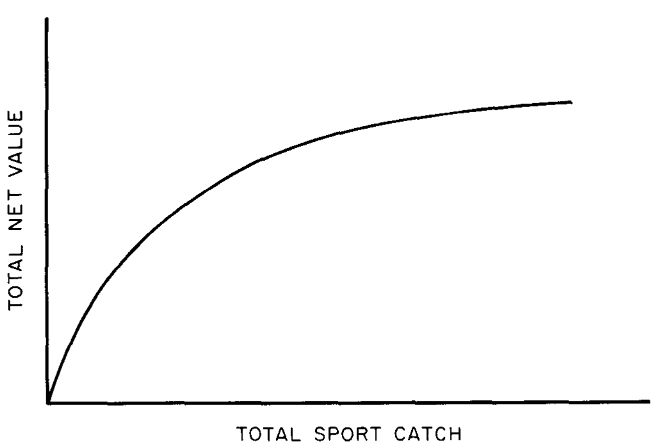

FIGURE 3

Now, a similar curve can be postulated for the commercial fishery relating net value to catch. We will assume that various quotas can be imposed, up to the maximum sustained biological yield. At some level of catch, additional units of gear become competitive with each other and existing ones. Thus, from this level of catch onward, equal increments in catch will require greater and greater increments in gear. If fishing costs are proportional to numbers of units of gear, and revenues are proportional to catch, this implies the following type of curve.

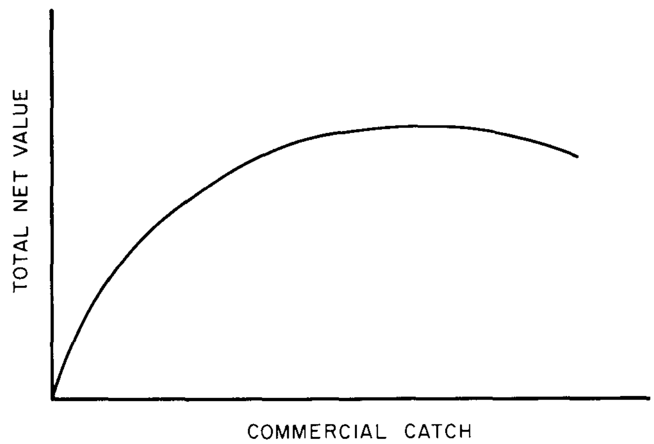

FIGURE 4

Let us now begin by assuming, as in the present case, that the sport catch is unrestricted by the commercial fishery or by anything other than the behavior and natural abundance of the fish. Fishing is good, and we are way out on the right of the curve in Figure 3. Now a commercial fishery begins, which causes the sport catch to decline. The nature of the relationship would be directly inverse in the single species situation, but less obvious, of course, in the prey-predator situation of present concern. However, we assume some cause-effect relationship between the two populations. Initially (referring to the two curves) the incremental losses in sport values will be small compared to the incremental gains in commercial value as the commercial fishery develops. We can assume a point of maximum total value where the incremental losses and gains are equal:

$$\frac{\Delta V_1}{\Delta C_1} = \frac{\Delta V_2}{\Delta C_2}$$

Note, however, that there is nothing herein implying that an optimum point can be reached only with a balance between the two (Figure 5 and Figure 6). Depending on the relationships themselves, there may be situations where total exclusion of one or the other fisheries might maximize total value.

Thus far, I have been pretty theoretical and it is tempting to continue on this line without referring to the specific fishery problem at hand, since I know relatively little about any aspects of it—the sport fishery, the biology of the many species involved, the commercial fleet, or the fish meal industry. However,

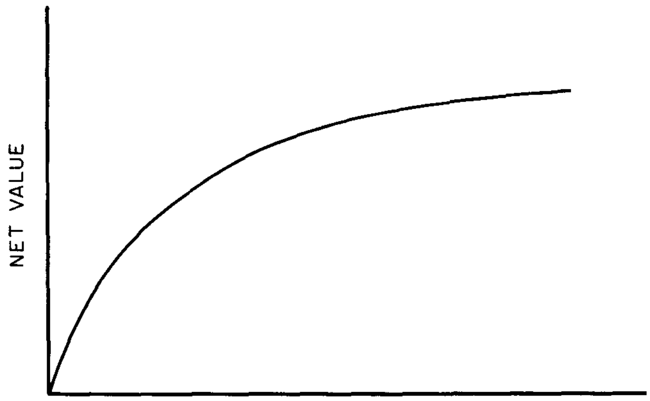

FIGURE 5

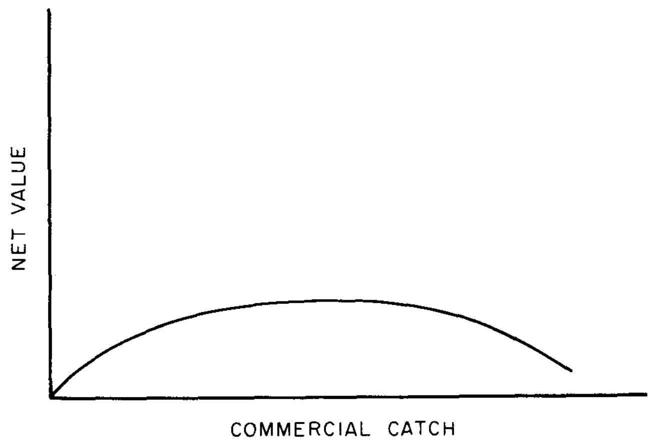

FIGURE 6

at the risk of ending up with footprints on my tongue, let me speculate on the development of the wet fish fishery per se from the economic framework presented so far. If I am wrong in some of my ensuing speculation someone will hopefully tell me, and I will go home having learned something.

First, I should comment on the implied fact that there *would* be some affect on the sport fishery from a commercial anchovy harvest at any level. I am sure that this issue is opened to question. Probably a modest catch of say 100,000 tons would have an imperceptibly small effect from what has been estimated as the standing stock. But, I don't know the level which the harvest is ultimately supposed to reach, and I would have to take the view that a commercial harvest which *did* take a significant portion of the surplus anchovy production would have a really noticeable effect on the sport fishery harvest and consequent value. Therefore, I think the possibility of a deterioration in sport fishing is distinct, and should not be dismissed. If it really can be proved there would be no negative effect on the sport fishery, and—more important—if the sport interests can be convinced of this, everything I have said becomes academic, since the problem disappears.

One of the key issues surrounding the proposed commercial fishery is whether or not a limitation on the amount of new gear to the fishery is being planned. There has been enough talk about the concept of limited entry over the past decade that I am sure most of you are aware that commercial fisheries cannot be expected to achieve high and, therefore, desirable net yields if the amount of gear cannot somehow be held below the level which tends to prevail when there is low cost, unlimited access for all who wish to fish. In the model I presented, I assumed that some positive net yield would accrue to the commercial fishery, which might justify its development even though causing some devaluation of an existing sport fishery. If, however, the expected net yield situation for a fully developed commercial fishery is low —as it seems almost certain to be without some initial planning for a legally limited but hopefully highly efficient fleet—then I see little economic justification for promoting its development beyond a modest level which might perhaps put the few old sardine boats still around back into some useful activity.

This conclusion is based simply on the economic conditions of almost all of the other commercial fisheries around the country, which you know have unlimited entry. As commercial enterprises these usually turn out to be very mediocre performers, in terms of both wages and returns on investment. I see no reason why an anchovy fishery as it developed would not follow the tired, familiar pattern of other commercial fisheries in this country. Profits may be good at first, particularly if the fishery first utilizes the old sardine vessels which have been paid off long ago. However, such profits will attract other boats as the fishery builds, and eventually the investment impetus is likely to carry the amount of gear and manpower to an undesirably high level, where average catches are too low to yield even opportunity wages and investment earnings. These situations tend to persist for a long time since it is much harder to disinvest and get out of the fishery than it was to get in.

Potentially productive men and capital become trapped, so to speak, earning less and, therefore, producing less or adding less to the overall economy, than if they had not entered the fishery in the first place. Thus, in the final analysis a nonlimited entry fishery may negatively affect the gross regional product or whatever measure of economic productivity chosen. This does assume, I should point out, that there exists an abundance of nonfishing employment and investment opportunities in the region, which I think is a reasonable assumption.

To reiterate these points, a modest increase in the quota which would allow existing, presently underutilized vessels an opportunity for a good return, would make sense economically. But without limited entry I see little economic justification for promoting the fishery beyond such a point. It would almost surely end up a loser and run the risk of devaluating the existing sport fishery, which certainly is yielding a very high, though hard to measure, economic return. However, a new fishery such as this would seem to be well suited for applying the limited entry concept, since there is no great vested interest or large fleet to worry about buying out. Extreme efficiency could be encouraged. In this way the chances for high net yields could justify from an economic standpoint the substantial development of such a commercial fishery even with some risk to the sport fishery.

So far, I have only been talking about the fish catching segment of the potential industry. Might not the potential profits in the meal processing end of the industry justify its development without having to consider the fishing segment at all? Here again, I am speculating, but my general impressions are that at present the profitability of the fish meal industry in this country is not high relative to other investment, and the future is perhaps too uncertain to give this as any economic justification for large scale promotion of the fishery.

I base this conclusion on only a casual knowledge of the current state of the industry. (1) I have seen two admittedly small scale meal operations in Washington run into financial difficulty in recent years; (2) the present industry on the coast seems to have smoldered along for several years unable to offer fishermen enough of a price on hake, for example, to get a serious fishing effort mounted; (3) from what I hear, there is not even a demand for the present low quota—though there are some arguments about economies of scale in the industry; and (4) the upper price of fish meal is limited by prices of competing plant-based meals.

No doubt if something seriously affected the world supply of fish meal such as a crash of the Peruvian anchovy fishery, the profit potential for the industry in California would greatly improve. This may be too speculative to be a reason in itself to run the risk of devaluating the sport fishery. The sport fishery, after all, is probably the most dynamic of its kind in the world, and is *currently*—not merely *potentially*—yielding some very high returns. I urge that a great deal of weight should be given this fishery even though only a gross economic analysis might be made, and that serious thought be given as to how to develop a *long term, economically viable* commercial industry before moving ahead very far on it.

THE ECONOMICS OF OPERATING A WETFISH SEINER

WILLIAM F. PERRIN
National Marine Fisheries Service Fishery-Oceanography Center
La Jolla, California

If we are going to harvest the anchovies and mackerel in the California Current region, we will have to do something about the fleet. The fleet is small, and the boats are old. With this in mind, the Operations Research Group at FOC, La Jolla decided about a year and a half ago to look into the economics of operating a wetfish seiner. We collected data on costs and earnings correlated with landings for 22 boats for the period 1963 through March 1968. Altogether I examined about 1,000 monthly settlement sheets, as well as various financial records.

Our study had three objectives: 1) to describe and document the economic condition of the fleet, 2) to construct a costs and earnings model, and 3) using the model, to examine the economic feasibility of expanding the fleet, either through recruitment of surplus vessels from other fisheries, or through new construction.

I presented a summary of the data on the financial condition of the fleet at the MRC meeting in June 1969. Suffice it to say that, as of the first quarter of 1968, the fleet was doing very poorly. Profits were very low on the average, costs were rising, and employment was falling. The data are available in a published paper (Perrin and Noetzel, 1970).

Today I will tell you very briefly about the approach we used in analyzing costs and constructing a predicting model, and I will summarize the conclusions we reached through use of the model about the economic feasibility of fleet expansion and new construction.

We wanted to predict costs, profit, return on investment, and crew earnings for various-sized vessels at various levels of revenue and various catch compositions with respect to species, and we used a straight forward reductionist approach.

We were not able to predict revenue. We could find no relationships in our data between total value of landings and vessel characteristics such as size, fish capacity, or horsepower. We can think of several possible reasons for this. More often than not, the boats are not fully loaded, or even half loaded, when they come in, especially when they are fishing mackerel, bonito, or tuna. This could be expected to reduce the effect of differential size. Most of the fishing is very local, often within 8 or 10 miles or less of port. This would reduce the effect of differential speed. Another possibility is that skill is an over-riding factor. Setting a purse seine requires a great deal of skill, and some captains are certainly better at it than others.

Still another possibility, of course, is that we had insufficient data. We had no effort data correlated with landings. California Fish and Game has now collected such data, and perhaps between-vessel differences correlated with vessel characteristics will become visible after landings have been standardized to effort.

Since we could not predict revenue, we instead predicted costs, profit, etc. at arbitrary levels of revenue over a range including all levels achieved by boats in the fleet in the past and hypothetical higher levels.

In other words, the approach we used was to say, "What would be the costs, profit, return on investment, and crew share for a 150-ton capacity boat landing $100,000 worth of mackerel? What would they be if the landings were half mackerel and half anchovies, or if it were a 100-ton capacity boat, and so on."

Since we are interested in the feasibility of new construction, we asked the questions for hypothetical new vessels, as well as for old vessels of the type now in the fleet.

First, we had to analyze costs. The costs are of two major types; so-called "trip expenses" and "owner costs." Trip expenses are deducted from the gross revenue, and include fuel, oil, salt, ice, airplane spotting, and contributions to the welfare fund, the pension fund, and the patrol agency. Rather than subdividing trip expenses in our analysis, we attempted to relate them *in toto* to amount and species composition of the landings, using the data from the monthly settlement sheets. We did a multiple regression on the data for 1967:

$$Y = 914 + 0.00103X_M + 0.00519X_T + 0.00399X_B + 0.00038X_A$$

where Y = estimated trip expenses for one settlement period, 914 is the Y intercept, X_M = pounds of mackerel, X_T = pounds of tuna, X_B = pounds of bonito, and X_A = pounds of anchovies landed. All the coefficients are significant at P = less than 0.001, and the regression accounts for 75% of the variance. Since we are concerned more with dollars than with pounds, we restated the relation for the annual case as follows:

$$Y = 8{,}052 + 0.0275\,X_M + 0.0419\,X_T + 0.0939\,X_B + 0.0380\,X_A$$

where 8,052 = the intercept for the single settlement case multiplied by 8.81, the average number of settlements per year; X_M = the value of mackerel; X_T = value of tuna; X_B = value of bonito, and X_A = value of anchovies. This says that, per dollar's worth, bonito are the most expensive to catch, tuna and anchovies cost about the same, and mackerel is the least expensive to catch.

For anchovies: $\frac{\text{cost}}{\text{value}} = \frac{\$0.00038/\text{lb.}}{\$0.01/\text{lb.}} = \frac{\$0.038}{\$1}$

So now we can estimate the trip expenses attached to a particular level of revenue and a particular catch composition.

After trip expenses are deducted from the gross revenue in a settlement, the remainder is split between the owner and the crew. In the San Pedro fleet, the owner's share ranges from 36½% to 41½%, depending on the size of the vessel. The owner pays the so-called "owner's costs" out of his share. In our analysis of owner's costs, we used the following categories: parts and repairs, netting and supplies, insurance, payroll taxes, interest, moorage, state and county taxes, depreciation, and a miscellaneous category. For some of these submodels, such as insurance and depreciation, we used deductive methods, for others, such as parts and repairs and netting and supplies, we fell back on empirical equations derived from our data. Most of the estimations are dependent on the characteristics of the vessel and on the level of revenue. Only one, that for netting and supplies, depends on the composition of the catch; it increases by $2 per ton of fish landed, which obviously is quite important when considering anchovy fishing. We had no data for repair costs for new wetfish boats, so we used data for new shrimp boats of comparable size in the Gulf of Mexico.

We then used the cost estimators and predicted profit, return on investment, and crew share for old and new boats, varying vessel capacity from 70 to 150 tons for old boats and 66 to 264 tons for new boats, the gross revenue from $50,000 to $250,000 in increments of $50,000, and the catch composition from that of the 1967 landings through 100% mackerel, ½ mackerel and ½ anchovies, and 100% anchovies. There are sample calculations and summary tables in Perrin and Noetzel (1970).

The conclusions we reached based on these calculations were pretty much what we expected. For the old boats, we found a dichotomy of interest between the vessel owner and the crew with respect to vessel size. The highest crew share at any level of revenue is with the smallest vessel, whereas the highest profit is with the largest vessel. Crew share is most affected by vessel size, but profit is most affected by composition of the catch.

For example, the maximum effect on profit at $200,000 revenue is about $13,000; this is the difference between an all-anchovy catch and an all-mackerel catch. The best situation, given existing boats, from the standpoint of profit is a 150-ton boat taking an all-mackerel catch. The best from the standpoint of the crew is a 70-ton boat taking a ½-mackerel ½-anchovy catch, by value. The break-even point for a 150-ton old vessel ranges from $65,000 for an all-mackerel catch to about $90,000 for an all-anchovy catch. These amounts are well within the range of gross revenue attained in the past. Because the market value of these old boats is very low, high return on investment can be attained with comparatively low profits. So we concluded that, given favorable market conditions, it would be feasible to expand the fleet under present conditions of catch rates and fish prices, using surplus vessels from other fisheries. This, of course, is saying nothing about stock sizes or availability, or about institutional barriers.

The outlook for new construction is a different matter. The break-even point for the optimum boat with a 50% construction subsidy, and with a catch composition similar to those of the past, is about $150,000, which is close to the upper end of the range of gross revenue in recent years. In order to make a profit comparable to the profit made by top boats in the present fleet (about $30,000), gross revenue of about $225,000 would be required. For an all-anchovy catch, the figure would be closer to $275,000. $275,000 worth of anchovies at $20 per ton is 13,750 tons. For a 100-ton boat, this would mean a full load every 3 days or less on a sustained basis all year, which probably is impossible. We concluded that unless fish prices or catch rates go up considerably, new construction is not advisable, at least under the present share-out system.

The reason for this is the high investment base. A new 100-ton boat would cost about $200,000, while the average market value for the present fleet is only about $50,000. This difference causes very high increases in insurance, depreciation, and interest, even with a subsidy.

If the share-out schedule were revised, things might be different. A 66-ton new boat could make a $20,000 profit, or about 10% return on total capital, with an all-anchovy catch worth $150,000 (about 7,500 tons), if the boat's share of net proceeds were 55%, instead of the 37½% it is now. With a crew of seven, the crew share would be about $8,600.

Looking to the future and the systems approach, we have programmed our costs and earnings model, and it is ready to integrate with a production model, being developed by Dr. Lenarz in our laboratory, and a demand model; so that we can carry out bioeconomic simulation studies of the wetfish industry.

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MODELING THE RESOURCE BASE

WILLIAM H. LENARZ
National Marine Fisheries Service Fishery-Oceanography Center
La Jolla, California

I would like to start off by giving a rough idea of the magnitude of fish populations available to the San Pedro wetfish fleet. The population of northern anchovy appears to have the largest stock in the area. Estimates based on larval surveys are in the neighborhood of 2,000,000 tons. This species is followed by the jack mackerel. Admittedly crude estimates based on larval surveys place the jack mackerel population in the eastern Pacific at 2,000,000 tons. However, the San Pedro fleet harvests only relatively young jack mackerel at the southeastern edge of the population. Pacific mackerel also occur in the area. Pat Tomlinson of the California Department of Fish and Game has been studying the population dynamics of this stock. Although the stock is currently at a very low level, he has estimated that the stock could withstand a harvest of about 20,000 tons at its optimum level. The fleet has been taking about 7,500 tons of bonito per year in recent years. The bonito population has not been sufficiently studied to place an estimate on its potential. The fleet has also taken considerable amounts of bluefin tuna in the past, but this population appears to be at a depressed level and is also poorly understood. Two other commercial species occur in significant numbers in the area, the Pacific saury and squid. Attempts presently are being made to develop a fishery for saury, and hopefully we will know more about this species in the near future. About 5,000 tons of squid are landed per year. The potential appears to be much higher. Finally, I will mention the Pacific sardine. If the population ever recovers to its previous status, Murphy estimates that it will be capable of yielding about 450,000 tons per year. Perhaps half of this figure would be obtained from this area. These tonnages are impressive but meaningless until the fish are actually landed. Changes in the structure of the industry and government regulations are needed before the potential benefits from the resource can ever be obtained. Jack Baxter of the California Department of Fish and Game will present in the next talk potential landings under current conditions. I am involved in the development of a computer simulation model of the fishery to aid us in evaluating alternative methods of developing and managing the fishery.

The first figure is a block diagram of the model. The model is composed of several sections centered about the management policies section, for the amount of profit to the fishery, the ultimate goal of any commercial enterprise, is dependent on the ability of management to estimate and interpret conditions of the fish stocks, market, and fishery. The management policies section also obtains information on external factors—for example, regulations of the northern anchovy fishery are based on strong political pressure to avoid conflicts between the commercial and sport industries. Management policies affect the fishery section and possibly to some extent the market section. The fish stocks section may be subdivided into abundance and availability sections. Abundance is defined here to be the tonnage of a population's standing stock. Availability is the portion of the population that is susceptible to the fishery. The abundance model is based on the following equation: standing stock is equal to the previous standing stock plus recruitment plus growth minus natural mortality minus yield to the fishery. Over a long period the maximum average catch for the fishery is achieved by setting each year's catch to adjust the standing stock to the level that will produce in the next season the maximum sustainable yield. The management section estimates this parameter and uses it as a factor to determine how to reach the goal of maximum profit. A simulation of availability is achieved by allowing a simulated population to migrate along shore and on and off shore. Portions of the population that are in designated areas are not available to the fishery. Again the management section uses an estimate of the availability of the population as a factor in determining how to achieve this goal. I have been talking in terms of one population, but in actuality the management policy section takes into account factors concerning several species in order to maximize profits. I plan to use linear programming techniques to do this.

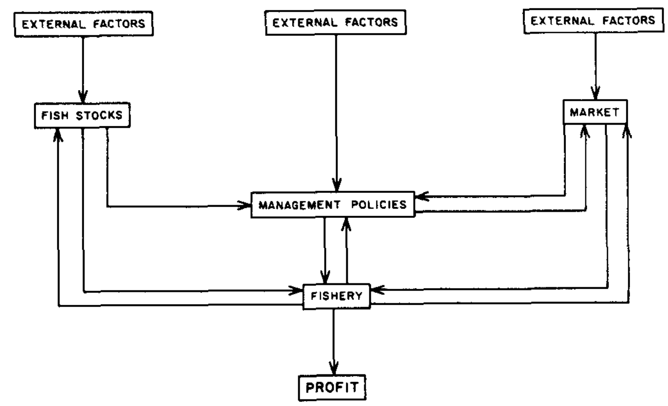

FIGURE 1. Block diagram of model of San Pedro wetfish fishery.

"Plan" is a key word in this talk. We have developed some of the components involved but still have a ways to go before we can show any results. We are very hopeful that this symposium will provide us with ideas on how to develop the remaining components and perhaps correct any misconceptions that we have.

I would now like to present some results of a simple model of the Pacific sardine fishery that I have developed using the results of Murphy. I hope that these results will illustrate some of the information that can be obtained from the use of simulation models.

This model consists only of a fish stock section, management policies section, a simple fisheries section, and an external factors section. The fish population is simulated by a production model using Murphy's estimates of natural mortality, growth, and spawn-recruitment relationship. The model is a stochastic one in that deviations from the spawn-recruitment relationship are allowed. The occurrence of strings of successful and unsuccessful spawning years is simulated by using an auto-regressive function in generation of the deviations from the spawn-recruitment relationship. The management uses estimates of the standing stocks and recruitment to determine the amount of fishing effort needed to maintain the population at its optimum level. Errors in management's estimates of standing stock and recruitment are allowed. I used this model to study the sensitivity of yield and yield-per-effort to the accuracy of estimates of standing stock and recruitment.

Figure 2 illustrates yield as a function of accuracy. The X axis is the maximum error factor expected in 95% of the observations. For example, at the point of 3 on the X axis the maximum error in the estimate of standing stock and recruitment is within a factor of 3 of the actual value for 95% or more of the observations. The Y axis is the annual yield of sardines in tons. Four management policies were investigated. The white dots connected by the solid line in the figure represent the average annual yield from a policy of varying instantaneous rate of fishing mortality from 0 to 0.8 depending on the condition of the stock. The black dots connected by a dashed line represent the average annual yield from a policy of varying instantaneous rate of fishing mortality from 0.4 to 0.8. The explanation of the two other curves in the figure

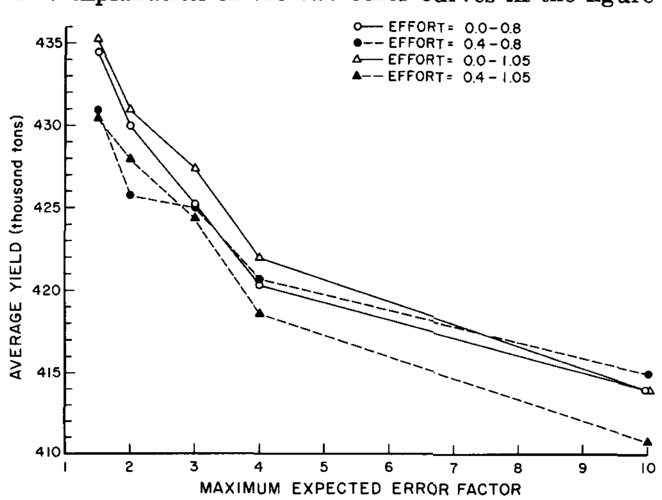

FIGURE 2. Yield of simulated Pacific sardine fishery as a function of accuracy of estimates of stock and recruitment and variability of fishery effort.

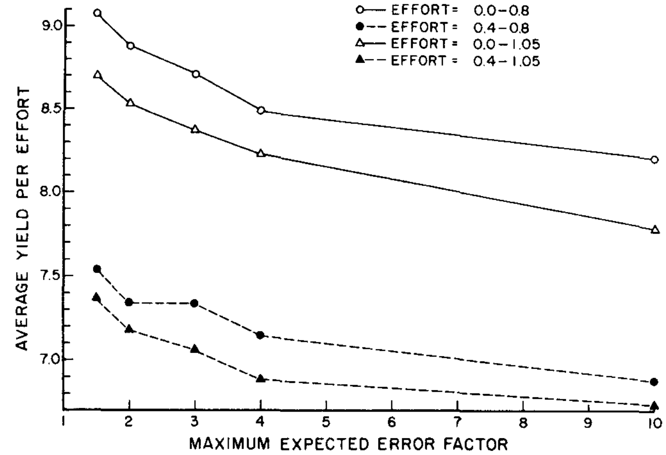

FIGURE 3. Yield per effort of simulated Pacific sardine fishery as a function of accuracy of estimates of stock and recruitment and variability of fishery effort.

is similar. In all examples, if the estimated standing stock drops below 300,000 tons, the fishery is stopped. Each point represents a value of three simulations of 200 years. As expected, the average yield is highest when management has the most accurate information and can vary the fishing effort the most. When a management policy of using constant fishing effort at the maximum sustainable rate of 0.78 is used, the yield is 390,000 tons. This is even lower than when management uses very poor information with a varying rate of fishing mortality. Under the best management policy tried, the yield is increased about 10% over the maximum sustainable yield.

Figure 3 illustrates yield per effort as a function of accuracy. This measurement is more meaningful than yield alone because it is an index of revenue per cost. Again the best results are obtained when management is well informed. The results are considerably better if the fishery is stopped when the population falls below the level of about one million tons rather than when it falls below the 300,000 ton level. The poorest result is about 40% above the result that is obtained when the population is fished at the maximum sustainable rate.

Management must take factors other than yield and yield-per-effort into consideration. One of these factors is stability of yield. Figure 4 illustrates standing stock and yield over a 200 year simulation. The maximum expected error factor was 1.5 and instantaneous rate of fishing mortality was varied between 0 and 0.8. The fishery was stopped when the spawning stock dropped below 1,000,000 tons. Even though the yield and yield-per-effort are high, very few people would be willing to accept a policy that results in such an unstable fishery. The fishery was stopped in approximately 25% of the years.

Figure 5 illustrates what happened when fishing mortality was varied from only 0.4 to 0.8 and the maximum expected error factor was 3. Yield is much more stable than in the previous case. You will note there are very few cases of when the fishery was ac-

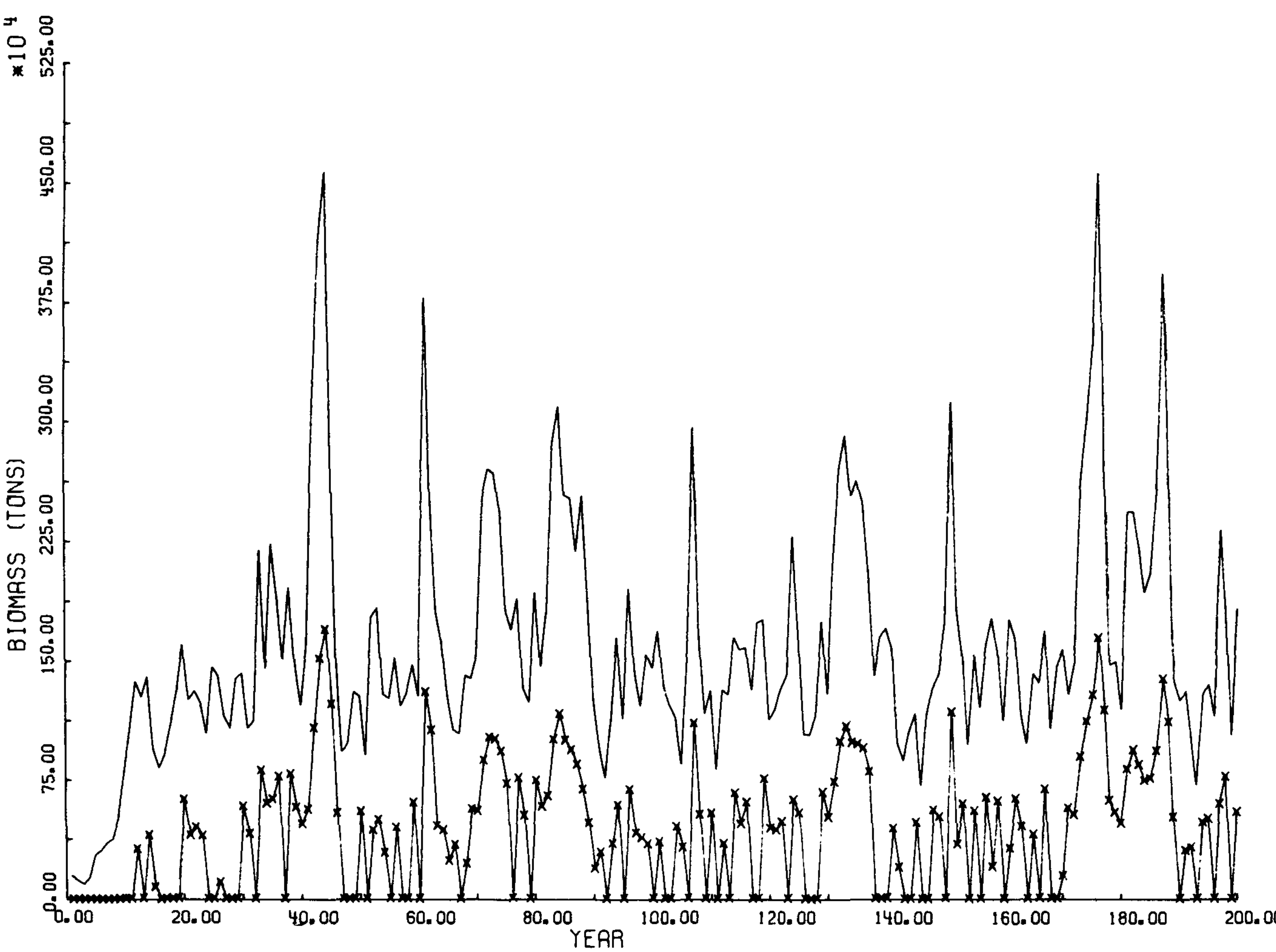

FIGURE 4. Solid line is biomass of spawning stock of simulated Pacific sardine populations. Line connecting x's is yield of simulated Pacific sardine fishery. Fishing mortality was varied between 0 and 0.8. The maximum expected error factor was 1.5. Fishing was stopped when spawning stock dropped below 1,000,000 tons.

tually stopped. In this case the fishery was only stopped when the population dropped below 300,000 tons. The average yield under this policy is only slightly less than under the previous policy.

Figure 6 illustrates the results under a policy of constant fishing at the maximum sustainable rate except when the population falls below the 300,000 tons. It is slightly more stable than the previous case. Yield is considerably less, and the yield-per-effort very much less.

Power spectra were calculated from yield under two management policies: a policy of maximum sustainable yield, and a policy of varying fishing mortality from 0.2 to 0.8. The spectra are quite similar. The power of the spectrum from the constant model is relatively slightly lower at high frequencies than that from the varied effort policy. In other words the short-term fluctuations of the yield are slightly more important in the more intensively managed fishery.

Perhaps I have stressed stable yield too strongly. As Dr. Sette has pointed out at a previous conference, we are working with a multi-species fishery. It is possible that fluctuations in profit from a properly managed multi-species fishery will be quite small. Almost all populations of fish undergo considerable fluctuations, we should strive to develop better ways of living with them.

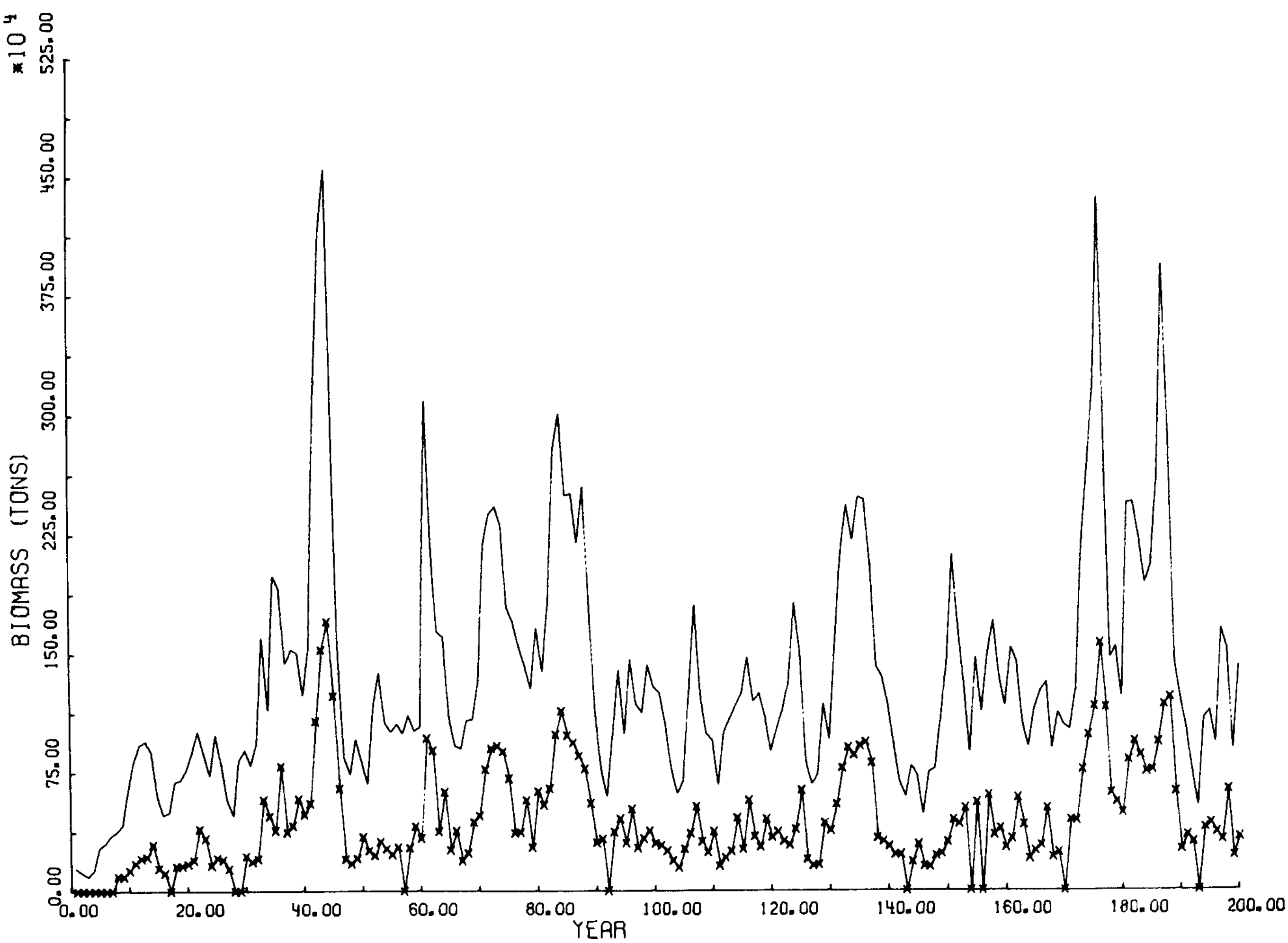

FIGURE 5. Solid line is biomass of spawning stock of simulated Pacific sardine populations. Line connecting x's is yield of simulated Pacific sardine fishery. Fishing mortality was varied from 0.4 to 0.8. The maximum expected error factor was 3. Fishing was stopped when spawning stock dropped below 300,000 tons.

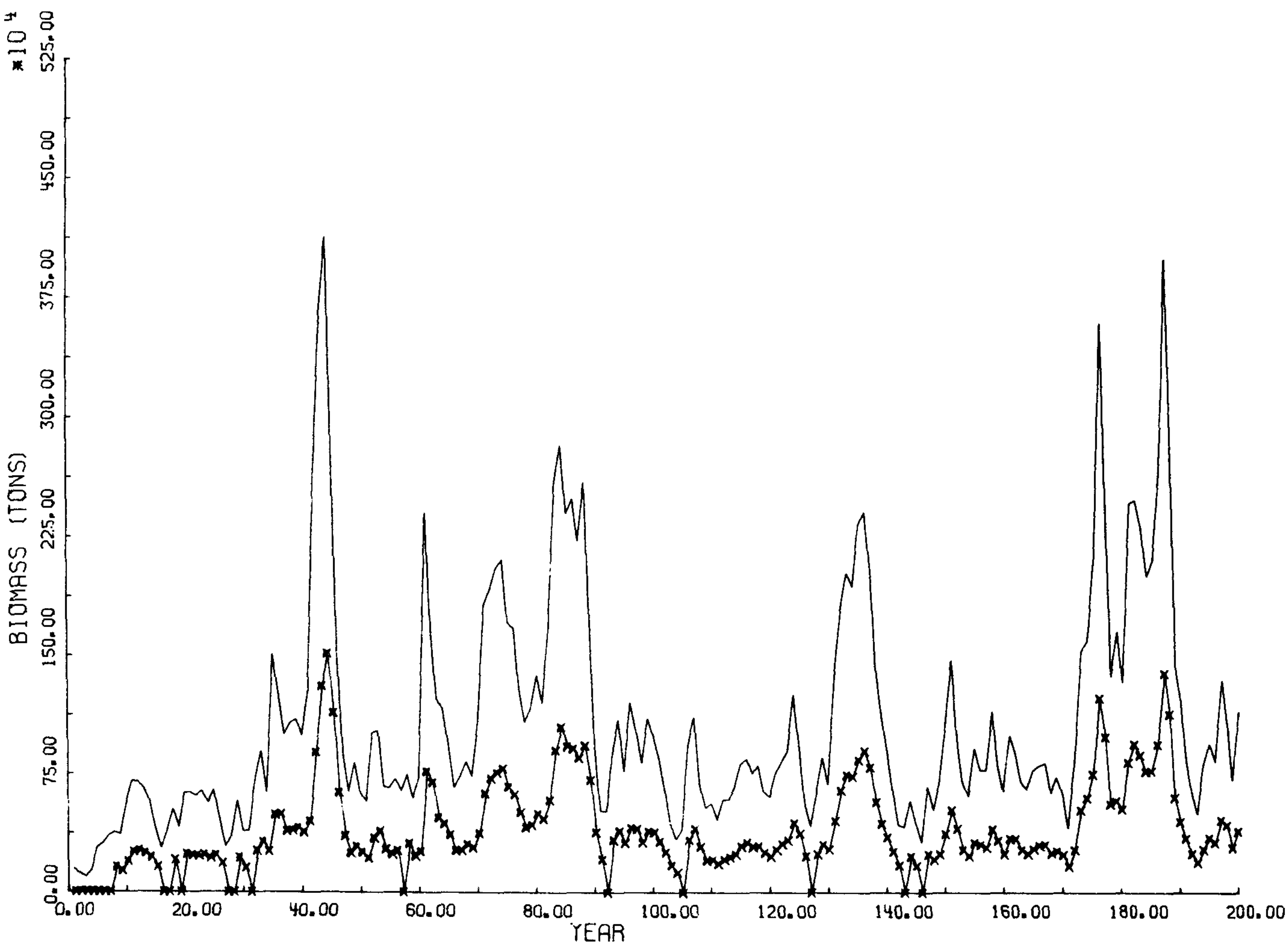

FIGURE 6. Solid line is biomass of spawning stock of simulated Pacific sardine populations. Line connecting x's is yield of simulated Pacific sardine fishery. Fishing effort was held at the maximum sustainable rate except when spawning stock dropped below 300,000 tons.

POTENTIAL CATCH OF THE PRESENT SAN PEDRO WETFISH FLEET

By

JOHN L. BAXTER[1]
Marine Resources Branch, California Department of Fish and Game
Sacramento, California

and

C. E. BLUNT, JR.[2]
Marine Resources Region, California Department of Fish and Game
Long Beach, California

INTRODUCTION

We were asked to comment on the potential catch of the San Pedro wetfish fleet as based on past performances and reflected in our catch and effort data.

After evaluation of the large amount of data available we tabulated catch and effort from each log on a weekly basis by general fishing areas. We utilized fishing log data from 1968 and most of 1969, at least as much of it as time allowed. The work we did made it quite clear that a great deal more effort will have to be directed toward the collection and processing of log interview data.

By law, vessels fishing the northern anchovy, *Engraulis mordax,* for reduction are required to submit a record of fishing operations when landing their catch. Thus, the anchovy log program reflects effort from successful trips very well but reporting unsuccessful trips, which at times may be significant, is incomplete. Our log program will also require a great deal of additional effort to ensure that unsuccessful trips for mackerel (Pacific mackerel, *Scomber japonicus* and jack mackerel, *Trachurus symmetricus*), Pacific bonito, *Sarda chiliensis,* bluefin tuna, *Thunnus thynnus,* and other species are properly reported. Therefore, the catch per unit effort figures and other data presented must be considered preliminary and subject to possible change as a result of more complete analysis.

PRESENT FLEET

In 1947 the San Pedro wetfish fleet was made up of about 250 vessels. This fleet fished primarily for the Pacific sardine, *Sardinops caeruleus.* Shortly thereafter, the sardine fishery collapsed and by 1954 the fleet had shrunk to 137 boats. Ten years later only 54 boats remained in the fleet. At present the fleet includes but 29 active vessels. These range in registered length from 39 to 80 feet and can carry from about 25 to 150 tons of fish. An additional six vessels normally fish for tuna in tropical waters but occasionally fish for bonito and tuna (primarily bluefin tuna) locally and might enter the wetfish fishery under certain conditions. These vessels are 80 to 90 feet long and have a capacity of about 120 to 180 tons.

The daily capacity of the wetfish fleet as based on loads of anchovy is 2,450 tons. Our log book data, interviews, and landing figures show that the boats operate for an average of 15 or 16 days per month. This figure takes into consideration time lost to inclement weather, repairs, and rest periods. It does not include time lost because of strikes and other economic problems. At a fleet capacity of 2,450 tons and 15 operating days per month, the monthly capacity of the fleet is 36,750 tons. The annual capacity is 441,000 tons.

ASSIGNMENT OF EFFORT

We are quite aware of the problems inherent in assigning effort in a multi-species fishery, and plan to spend a great deal more time on this problem.

For the purpose of developing estimates of the potential catch of the wetfish fleet we computed catch per hour of scouting time for the San Pedro fleet during 1968 and most of 1969. The basic catch and effort data were obtained by our log and log-interview programs conducted in conjunction with routine age and length sampling at the waterfront. Skippers fishing for anchovies are required to make out a fishing log when landing their catch. Fishing and scouting information pertaining to jack mackerel, Pacific mackerel, sardines, bonito, and bluefin tuna are obtained each day through interviews with vessel skippers as they unload their catch or when they dock at San Pedro after an unsuccessful trip. Due to lack of manpower we have not been able to follow completely the daily activity of each vessel in the fleet; however, we believe that in most months we have obtained logs for about 90 percent of the fleet activity, especially during 1968.

Log catch and hours of scouting were summarized on a weekly basis for each month by general fishing areas. Fishing effort was assigned as either being (i) jack and Pacific mackerel, (ii) anchovy, (iii) bonito, and (iv) tuna (bluefin and albacore, *Thunnus alalunga*). We established 12 general areas off southern California and 1 for northern Baja California. Fishing effort was assigned on the basis of the species composition of the catch in a general area during the weekly summary. For example, if only mackerel were taken in an area, all effort in that general area was classified as mackerel effort. If only bonito were taken, the effort was classified as bonito effort. Occasionally both bonito and mackerel were taken in a general area, and when one or the other did not dominate by at least 80 percent of the weekly catch, the effort was not utilized in the catch-effort summation. During 1968 very little effort had to be eliminated for this

[1] Present address: National Marine Fisheries Service, Washington, D.C.
[2] Present address: Department of Fish and Game, Eureka, California.

reason simply because the tuna, mackerel, and bonito fishing areas were distinct during most of the weekly periods. Anchovy fishing areas are also distinct in that generally they are well outside the 50 fathom isobath as opposed to mackerel fishing which is well within it. During 1969 the fisheries were not as distinct with bonito being caught more often in mackerel areas, and bluefin tuna being taken closer to land masses in usual mackerel catch areas. In the case of tuna we were able to classify many trips as tuna trips by detailed information on the logs which the skippers supplied.

RESOURCE BASE

The species normally considered as the resource base for the San Pedro wetfish fleet are Pacific mackerel, sardines, jack mackerel, anchovies, squid (*Loligo opalescens*), bonito and bluefin tuna. The populations of sardines and Pacific mackerel are at extremely low levels. There is a moratorium on sardine fishing (15 percent tolerance allowed with mixed catches), and Pacific mackerel are caught in only small quantities in conjunction with fishing for the other species. Therefore, these species are not regarded as part of the resource base *at this time.*

Biomass estimates for northern anchovies and jack mackerel have been published based on egg and larva surveys by the U.S. Bureau of Commercial Fisheries (now National Marine Fisheries Service). These show a biomass of 4 to 6 million tons of anchovies (50 percent off California), (Messersmith et al, 1969), and 1.4 to 2.4 million tons of jack mackerel in the CalCOFI area (Blunt, 1969). The proportion of jack mackerel off California has not been estimated. We have no estimate of squid biomass; however, it has been generally acknowledged as very large. The squid catch off California has ranged between 4,000 and 12,000 tons per year since 1961.

The amounts of bonito and bluefin tuna that might be harvested off California under the right conditions are indicated by California Department of Fish and Game catch records. These data show that as much as 9,000 tons of bonito have been caught in California waters. During the mid-1930's the California catch of bluefin tuna was about 9,000 tons per year. In recent years the bluefin tuna catch reached a high of 8,500 tons in 1962.

POTENTIAL CATCH

For this symposium we are interested in the potential catch of our present fleet, fishing in their normal areas and with current gear and operating methods. We are confronted with the imponderable question "What species do you want to base the estimates on, and how much effort do you want to spend on each?" We know full well that economics and institutional problems have direct consequences upon what the fishermen catch. In 1969 the anchovy catch increased to about 50,000 tons as compared to 15,500 tons for 1968, generally because more effort was put into the anchovy fishery.

Based on the catch rates of the fleet during 1968 and most of 1969 (Table 1), and assuming complete effort toward anchovy fishing except during the

TABLE 1

Southern California Wetfish Fleet

Preliminary Log Catch, Effort, and Catch per Effort Data

Year/ Month	Log Scouting Hours				Total Scouting Hours	Log Catch (Short Tons)				Catch per Effort (Tons/Hour)			
	Mackerel	Bonito	Anchovy	Bluefin Tuna		Mackerel	Bonito	Anchovy	Bluefin Tuna	Mackerel	Bonito	Anchovy	Bluefin Tuna
1968													
Jan.	733	1,496	--	--	2,229	1,454	583	--	--	1.98	.39	--	--
Feb.	1,057	804	--	--	1,861	1,051	203	--	--	.99	.25	--	--
Mar.	388	242	--	--	625	282	80	--	--	.74	.33	--	--
Apr.	788	189	9.5	--	987	2,062	82	20	--	2.62	.43	--	--
May	1,201	145	--	--	1,346	3,057	118	--	--	2.55	.81	--	--
June	952	--	--	--	952	3,194	--	--	--	3.35	--	--	--
July	459	--	--	862	1,321	1,304	--	--	81	2.84	--	--	.09
Aug.	253	830	--	1,516	2,599	997	1,135	--	365	3.94	1.37	--	.24
Sept.	577	1,228	--	724	2,529	992	1,123	--	180	1.72	.91	--	.24
Oct.	778	--	128.	261	1,167	2,254	--	2,309	191	2.90	--	18.0	.73
Nov.	1,034	--	370.5	--	1,405	3,619	--	5,005	--	3.50	--	13.5	--
Dec.	795	98	237.5	--	1,131	3,558	363	3,051	--	4.48	3.70	12.8	--
1969													
Jan.	716	667	202	--	1,585	1,613	438	1,358	--	2.25	.66	6.7	--
Feb.	756	--	69	--	825	2,088	--	322	--	2.76	--	4.7	--
Mar.	809	--	136	--	945	2,973	--	1,767	--	3.7	--	13.0	--
Apr.	651	--	589	--	1,240	1,560	--	7,855	--	2.40	--	13.3	--
May	845	--	328	--	1,173	1,515	--	3,753	--	1.8	--	11.4	--
June	1,384	--	--	--	1,384	2,029	--	--	--	1.5	--	--	--
July	1,194	408	--	467	2,069	3,041	199	--	110	2.5	.5	--	.2
Aug.	--	--	231	--	--	--	--	1,979	--	--	--	8.6	--
Sept.	--	--	942	--	--	--	--	14,808	--	--	--	15.7	--
Oct.	--	--	693	--	--	--	--	10,011	--	--	--	14.4	--
Nov.	--	--	--	--	--	--	--	--	--	--	--	--	--
Dec.	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 2

HYPOTHETICAL EFFORT ALLOCATION

Based on 1968 and 1969 Log Data
(Assumes availability and catchability equivalent to 1968 and 1969, also assumes good economic conditions and demand for fish)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
						Percent Allocation						
Mackerel	50	50	50	50	50	90	30	30	30	35	45	45
Bonito	20	20	20	20	20	10	30	30	10	10	10	10
Anchovy	30	30	30	30	30				20	35	45	45
Tuna	--	--	--	--	--	--	40	40	40	20	--	--
						Hours of Scouting						
Mackerel	1,015	943	1,015	1,015	1,160	2,506	1,114	1,114	835	812	979	914
Bonito	406	377	406	406	464	278	1,114	1,114	278	232	218	203
Anchovy	609	565	609	609	696	--	--	--	557	812	979	914
Tuna	--	--	--	--	--	--	1,484	1,484	1,114	464	--	--

Fleet gross 2,450 tons/day
36,750 tons/month
441,000 tons/year
Ave. 15 days fishing/month
Ave. 5 hours scouting/day
29 purse seiners

summer closure, the present fleet could conceivably catch approximately 210,000 tons of anchovies per year. If they fished for mackerel and tuna during the May 15 through September 14 period (closed to anchovy fishing for reduction) they could potentially catch 12,000 tons of mackerel and 700 tons of tuna. In conjunction with mackerel scouting they could bring in 2,300 tons of bonito. As based on 1968 data this would assume complete effort on mackerel in June and 60 percent effort on mackerel and bonito and 40 percent effort on tuna during July, August, and the first half of September. These estimates, of course, assume equivalent availability as occurred in 1968 and 1969.

A more realistic situation would be to assume the effort allocation itemized in Table 2. This resembles the fleet's effort allocation during 1968 and 1969, and assumes good demand for the northern anchovy. It also assumes equivalent abundance and availability as in the base period. The potential catch under this situation would be 32,000 tons of mackerel, 4,000 tons of bonito, 75,000 tons of anchovies, and 1,200 tons of tuna. The tuna catch could very well reach 2,000 and 3,000 tons, or higher, in some years since the abundance, availability, and catchability of this transoceanic migrant may change significantly from year to year. (Table 2.)

These estimates of potential catch are somewhat hypothetical since their attainment depends on a number of assumptions. These are:

1. Good economic demand.
2. All vessels fish approximately 15 days each month, and average 5 hours of scouting per day.
3. Allocation of effort is as indicated in Table 2.
4. Availability and catchability of the exploited fish stocks is equivalent to the base years.
5. Catch per unit of scouting effort observed during months of base years will be maintained with higher fishing intensity.

COMMENTS ON FISHING STRATEGY

During the process of examining individual logs it became evident that the allocations of effort by certain vessels appear not to have been the most prudent decisions. For example, during August 1968 vessels were spending days scouting for tuna with no catch. A total of 1,520 log hours was spent scouting with a subsequent catch of only 0.2 tons of tuna per scouting hour, or $60 per hour. Meanwhile, mackerel and bonito received only 1,080 hours of effort combined. Mackerel and bonito catch rates were 3.9 and 1.4 tons per hour respectively. At the prevailing prices paid to the fishermen, this amounts to $295 per hour of mackerel scouting and $140 per hour of bonito scouting. Some vessels departed areas of apparently good mackerel fishing (2 to 4 tons per scouting hour) where they had made catches in order to search for tuna with the hope of a bonanza catch. After spending 20 to 40 hours scouting with no success, they returned to quickly make 30 to 50 ton sets on mackerel.

TABLE 3

Dollar Return per Hour of Scouting During 1968
Anchovy—$17 per ton
Mackerel—$75 per ton

	October	November	December
Anchovy	306	229	218
Mackerel	217	262	336

It is also of interest to note that the dollar return per hour of anchovy scouting in 1968 (as based on the price of fish to the fishermen) rivaled the return for mackerel (Table 3).

During 1969 (anchovy price increased to $20 per ton), the return per hour of anchovy scouting was $172 for September, $314 for October, and $288 for November.

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VESSEL TECHNOLOGY

FRANK J. HESTER
National Marine Fisheries Service Fishery-Oceanography Center *
La Jolla, California

I am going to talk about technological innovations for the San Pedro wetfish purse seine operation that can perhaps increase the efficiency and reduce the cost of the operation. I would like to begin by going into the general problem of making money with a fishing boat or for that matter with any production business. In order to remain competitive, that is stay in business, one has to, if it is in an expanding economy, manage to increase productivity in line with the increase in cost of operation in order to cover the increase in labor costs that have to go up in an expanding economy. This increase in labor cost has to be offset either by reducing the operating costs of the business, by increasing the dollar value for its product per man hour, or by raising the prices.

Before we look at the fishery, let's look in general to what has happened in the American economy over the past decade. In general, the indices of the agricultural product have gone up some 15%. The wholesale price indices have risen similarly; these are, I believe, something on the order of 20%. In general the cost of living has gone up some 30–35%. Now if we look at a fishery, it is obvious that the vessel operator is going to have to keep his unit producing fish at a price in keeping with the levels of the wholesale price indices. The fishermen, however, have to increase their wages someplace in keeping with the cost of living index.

The high seas tuna fleet has in general followed this type of tendency. Productivity in fish/man hour and boat year has risen in the last decade allowing an increase in the crewmen's wages and owner's profit. However, if you look at Bill Perrin's data on the San Pedro wetfish fleet, you will see productivity in this fleet has stayed essentially level over the last decade.

If the position of the San Pedro wetfish fleet is to improve, somehow or other, the productivity of this fleet is going to have to go up. Jack Baxter showed that it is possible to pull about $5 million worth of fish out of the southern California ocean without any major changes in the fleet. Right now it is only about 2½ million. We have a pretty good chance to increase the landings if we can overcome some of the obstacles that, in the past, have kept the production down to about half of what it could be.

Increasing the productivity of the fishing fleet can be done in two ways, or a combination of these two ways. You can increase the value of the catch or you can cut cost. Some of the problems that must be overcome in these two areas are legal problems: some deal with management in an economic sense—as in operating a fishing boat—and some with economics in the marketing sense—that is developing markets for these products. But also, some of these problems are technological in nature, that is, they require the application of engineering and science. It is these latter problems that I am going to discuss, but since there is some interaction between these categories, I will probably touch on all of these problems.

To start with, let's look at those actions that will affect the value of the catch. The most obvious way to increase the value of the catch is to raise the price of fish. This is, however, a marketing problem and one that technology cannot do very much about.

Another approach, you might use, would be to increase the volume of the catch; here we run into a number of subproblems. A portion of the cost of operating a vessel is "fixed" cost. Regardless of whether the vessel goes to sea or not you have to pay interest on your loan, you have to pay moorage, and insurance, etc. It is obvious that the more fish you catch the less the fixed costs will affect the production cost; but to catch more fish means that some existing obstacles must be overcome. For example, our San Pedro fleet has a list of, I believe, some 90 port rules that are mostly holdovers from the sardine days which say you cannot fish on certain holiday days, weekends, and during the full moon periods as well as other restrictions. The boats also are faced with certain periods of bad weather when they cannot fish. The overall result is that they are only fishing on an average of about 100 days a year. It would be desirable, when you are operating a vessel, generally to have it operate for 200 to 250 days a year. Unfortunately, technology cannot do anything about port rules or about labor problems, and at present we cannot do anything about the weather. There are however some things technology can do about increasing the volume of the catch by increasing the days of fishing per year. Part of the problem is that some of the fish are available at only certain times of the day. For example, there is a tendency for the fish to come up at night, disperse, go down deep during the day. They are only available to the fishing gear for a short portion of the evening and a short portion in the morning. If it were possible, for example, to fish during the daytime when the fish are still deep, this would essentially increase your time on the fishing ground and fishing time by probably twofold. It is possible in other parts of the world to fish deep schools using sonar and deep nets. Both sonar and net technology are well developed and there is no reason why they could not be applied here.

We have a third problem which restricts the volume of the catch and this is the legal barriers, the institutional barriers, that control seasons, fishing areas, the size limit of the fish, and in some instances the

* Present address: Honolulu Laboratory, Southwest Fisheries Center, Honolulu.

type of gear. Institutional barriers, in general, are not open to technological solution.

A fourth problem affecting the value of the landings is, what you might call, the dockside bottleneck. Generally in a fishery there is an optimum vessel size which makes the most money. This is not true, as you have just heard from Bill Perrin, in the San Pedro fleet. In a large part, I believe it is due to the limited capacity of the processing plants. In the tuna industry when fishing is good and you have a lot of vessels coming into port, you may have to wait several weeks to unload; since the high seas tuna vessels are refrigerated they can tie up at the docks and act as freezer plants for the canners. In the wetfish fleet, however, the vessels are mostly unrefrigerated and therefore, you cannot have them setting around more than a couple of days or someone will complain. So the processors are forced to put limits on what the boats can bring in; this is so they will not bring in more than the plant can handle. This often means that the vessel is allowed less than a full load and probably tends to hurt the bigger boats more than the smaller boats. This problem of limits may be a matter of marketing in that the processor can sell only so much of that species and that he wants no more. This may be a matter of economics; it may not be worth the money for the processor to increase his processing capacity or to meet some of the new standards of pollution control that have been put into effect in the San Pedro area. But I think it is also likely that partially it is just a matter of poor plant utilization—that there is a bottleneck at dockside. This is open to analysis and technological solution. For example, it is possible to hold fish in refrigerated sea water for periods of up to 10 days without appreciable loss in quality. It might be feasible to prepare several large refrigerated sea water barges that could act as accumulators for fish so that when fishing is good the vessels could unload at the barges and the plant could then spread out its capacity over a period of time. That might cover weekends when the vessels are not allowed to fish and it might cover bad weather periods. This type of accumulator system might have some additional benefits. It might be that these barges could also be used to transport some plant effluents offshore and dump them instead of the plant now being required to run a pipeline out past the Long Beach breakwater. It also might be that by providing this type of storage for the fish it would allow a continuous monitoring of the catch, for example, for some of these pollutants, pesticides, residues, and the processor could have time to decide whether or not a load of fish went into the can or whether it had to go to the reduction line. I don't know who would pay for this or how effective it would be, but it is a problem that can be studied and one can come up with some answers.

Finally, we can get into this concept of managing the vessels themselves, that I hoped Mr. Douglass would talk about. If the processors only want so much of each species and it costs so much to catch a pound of this fish at a certain time of year, and a pound of that fish at some other time of year, or if there is only a little bit of one species available and a lot of any other, it might be interesting to see if you could change the strategy of fleet operation. For example, you could assign different vessels to different species to meet the market demands. During the times when there is a small run of tuna, instead of allowing the entire fleet to go out and waste their time searching for these tuna you could assign the majority of the fleet to mackerel and let only a few boats fish for tuna. Then perhaps you could develop a management system whereby you could pool profit in part so that the boats that are fishing for the low value species would not necessarily have to suffer. Such an approach is open to modeling; it is part of the Lenarz/Perrin economic model and I think it will prove very interesting. I don't think, however, that it is a solution that is very easy to implement.

Besides increasing the value of the landings the second obvious way to improve the vessel productivity is by reducing the operating costs. Although this cannot be potentially as profitable as increasing the volume of the catch, I think it is a little easier to obtain at this point. It is certainly very important in a business sense. I can think of three ways to cut down costs: you can cut manpower, you can speed up the fishing operation, or you can reduce the overhead. With a fishing boat all of these are open to technological solutions.

To cut manpower you can mechanize the operation. Right now we have a subcommittee of the Marine Research Committee which is evaluating the cost effectiveness of mechanizing wetfish purse seining using a fish pump rather than the mechanical brail, operating the vessel without using a power skiff by using a side thruster or bow thruster instead of the seine skiff and by using a storage drum for the net rather than stacking the net in the net pile by hand. We hope that by using these three innovations these boats will be able to operate with a five-man crew rather than the nine or 10 men that are used now. We also hope that the capital cost of this mechanization can be recovered from the labor cost saving realized by reducing the number of men in the crew and taking some of the increased crew earnings, and applying it to the vessel share.

Speeding up the operation is in part a matter of technology and in part an institutional barrier problem. If the drum seine and the fish pump are successful, a considerable savings in the actual operating time in making the set should result. However, the biggest waste of time, in this and about any other fishery, is in finding fish. It should be possible to reduce search time by using sonar and by improving the forecasting and fish spotting services but I don't want to develop this theme any further.

Now we come again to the institutional barriers. In our area we have a problem in that the vessels are denied the right to fish inside the 3-mile limit and they are not allowed to fish in some other restricted areas. At present this results in considerable increase in running time. We have to live within these restrictions right now but in the future if they were somehow modified or changed I think it would probably do more to increase the profit to the wetfish vessels than any of the technological innovations.

The last item I want to develop is the reduction of overhead. One overhead item in the San Pedro fleet or in any fishing fleet is the cost of paying off your vessel. For the modeling purposes, we have used cost construction estimates in the quarter to half million dollar range from some of the new vessels that are being constructed. However, I recently talked to a couple of fishermen who felt that they could build a boat for our local conditions for less than $100,000. This would be essentially a flat bottom power barge which would pack 200–300 tons of fish. I think that this idea has some merit. The question is, is it economically sound and is it legally possible to build a vessel for wetfish that might not be sea worthy or readily adaptable to another fishery? But again, the question is open to study.

Well we have looked at most of the major problems that are holding back the productivity of the San Pedro wetfish fleet.

In summary, we want to accomplish two things: we want to increase the value and volume of the landings and we want to reduce the cost of catching fish. Increased value and volume through technology might be achieved by increasing the time a vessel can spend at sea, by using sonar and deeper nets, by increasing the plant capacity using this refrigerated sea water accumulation system and by developing a vessel operations strategy for a multi-species fishery.

I have left out institutional barriers since this is a people problem, and I left out prices because that is a marketing problem.

We also have three ways we can apply technology to reduce operating costs. We can do this by cutting the crew size by mechanization; by cutting the search time with sonar, and forecasting and fish scouting services; and by developing low-cost vessels designed specifically for this fishery and the weather conditions we have off the California coast.

I have not tried to put any dollar values on these proposals mainly because to do so would require more data than I have available. I think you will agree that each and every proposal is open to analysis and it should not take too long to establish an order of priorities for implementation.

MARKET POTENTIAL OF THE SAN PEDRO WETFISH FISHERY: A DEMAND ANALYSIS APPROACH

DARREL A. NASH
National Marine Fisheries Service
College Park, Maryland

How can profits be improved in the San Pedro wetfish fishery? I think that is the central theme in the proceedings today. There are several facets of this problem. The resource base, vessel and gear efficiency, access to the resource, all are factors. Another most important consideration is the market potential for these products in terms of expected growth of the market, how variations in total landings affect prices and profits, and how the prices of one product affect another. This paper shows how profits are expected to be affected by changes in landings, prices, and changes in the general economy.

We all recognize that there have been several drastic changes in this fishery which are only loosely, if at all, related to economic forces. Therefore, some of the associations found between the fishery and these economic factors may be only apparent. Prices received by the fishermen and the amount sold to canners, at least in the short run, are not entirely a free market. Prices are generally set before the start of the fishing season and the canneries set quotas on purchases from the fishermen. Ideally, for an economic analysis, data are available which have been generated by prices and quantities which adjust freely to market forces.

Having expressed these cautions, we were pleasantly surprised at the results of a price and demand analysis of this fishery. The economic and statistical tests applied to the results show that several demand relations have been successfully estimated. The interpretation of the results, however, must be somewhat guarded.

I would like to cover briefly why demand analysis is undertaken and what we hope to accomplish by such efforts. Demand analysis is done to determine what factors — what economic forces—cause prices and quantities purchased to be at certain levels. Fishermen are well aware of price variations for fish and probably have a fairly good understanding of why prices behave as they do. Demand analysis attempts to isolate and quantify the net effects of the major factors affecting price and quantity. There are implications to be drawn as to profit potential based on the particular characteristics of the results. Armed with this knowledge, fishermen and processors can do several things. One is that by knowing what factors affect price and quantity purchased they can see the future courses of the market potential for their product. Secondly, revenue changes resulting from changes in amount sold can be determined. Finally, the results may indicate opportunities for changing demand through advertising, product development, and similar market expansion activities.

If you will permit, I will take a few minutes to review the general approach to demand analysis and discuss the expected outcome. According to economic principles, we expect that the amount of a product which is purchased is determined by price, consumer income, population, and prices of other products which are substitutes for the one under consideration.

The direction of the effect is also specified by these principles. As prices increase, we expect the amount purchased to decrease. Looking at it from another direction, as more is offered for sale, price must decrease in order to clear the market. Population and income increases are expected to increase the amount purchased. These are the two "growth variables" in most of the world today, and those products which are greatly affected by population and income are in an extremely fortunate position since both population and income are increasing steadily. On the other hand, there are some products which diminish in consumption as income increases. These are the losers, you might say, in the competition for the consumers' dollar. Consumption patterns differ by various socioeconomic characteristics of the population. Thus as these characteristics change over time, consumption of certain products will also change. Prices of substitute products tend to cause the amount of the product under consideration to move in the same direction. If the price of a good substitute goes down, you are likely to buy it, and therefore the quantity sold of another product goes down.

The next step is to put these theoretical economic relationships to work in obtaining statistical estimates.

The means used to derive the statistical estimates in this case is multiple regression analysis. This method, as you probably know, fits a functional relationship among the several variables in the analysis. Tests are applied to the estimates, both economic and statistical, to determine if our estimates can be accepted as valid.

I want to go directly to the estimates of demand and market potential which were estimated for the San Pedro wetfish fishery. This was done at two market levels—the landing and the wholesale level (that is sales f.o.b. the canners).

At the landing level, prices and quantities were analyzed using California data from 1950 to 1966 based on *Fishery Statistics of the U.S.* The species were Pacific mackerel, jack mackerel, anchovies, sardines, bonito, and bluefin tuna. Since the future resource availability of sardines is in question, the sardine analysis may be merely a study of history, however, the results are interesting.

A series of equations were run treating quantity landed as affected by all other variables, and a second set considers price as affected by the others. Other variables included were the prices of the other wetfish species and annual consumer income in the U.S. At the landings level total annual income was used, rather than per capita income. In this way the variable measures the effect of both population and income increases.

Mackerel

I think the best way of showing the results is to present one product at a time and discuss various analyses of each. So let's look at table 1 which shows the results of the mackerel analysis.

TABLE 1A

Price and Demand Analysis of California Mackerel (Landings Level)

Prob. No.	Dependent Variable	Statistic	Independent Variable: Price of Jack Mackerel	Price of Pacific Mackerel	Landings of Jack Mackerel	Landings of Pacific Mackerel	Consumer Income	a	R^2	D.W.
1	Jack Mackerel Landings	b	−3.86	2.95			−.33	8.18	.40	1.75[1,3]
		t	(2.66)[4]	(1.88)			(.21)	(.90)		
2	Price of Jack Mackerel	b		.79	−.10			.74	.89	2.36[1,3]
		t		(9.70)[4]	(2.88)[4]			(3.38)[4]		
3	Pacific Mackerel Landings	b	.26	−1.94				77.31	.68	1.87[3]
		t	(.311)	(2.72)[4]				(7.94)[4]		
		e	.21	−1.69						
4	Price of Pacific Mackerel	b	.75			−.0002		14.00	.87	1.74[3]
		t	(4.53)[4]			(2.72)[4]		(2.52)[4]		
		e	.69			−.22				

[1] logarithmic equations
[2] no autocorrelation 5 percent confidence level
[3] may or may not be autocorrelation at 5 percent confidence level
[4] significant at the 5 percent confidence level
e = percentage change in the dependent variable for a one percent change in the independent variable

TABLE 1B

Price and Demand Analysis of California Mackerel (Canners Level)

Prob. No.	Dependent Variable	Statistic	Independent Variable: Price of Canned Mackerel	Price of Tuna-Like Fishes—Canned	Price of Canned Alewives	Pack of Mackerel	Consumer Income	a	R^2	D.W.
5	Pack of Mackerel	b	−3.56	.79	.134			.43	.46	1.72[3]
		t	(3.27)[4]	(1.34)	(.05)			(1.46)		
		e	−2.22	1.34	.06					
6	Price of Canned Mackerel	b		.131	.39	−.00008	.00001	.05	.56	1.45[3]
		t		(1.22)	(.88)	(2.18)[4]	(1.41)	(.81)		
		e		.36	.26	−.13	.13			

[3] may or may not be autocorrelation at 5 percent confidence level
[4] significant at the 5 percent confidence level
e = percentage change in the dependent variable for a one percent change in the independent variable

At the landings level, the first step was to determine which of the other products of the wetfish fleet affected the price or sales of mackerel. This showed that only the two types of mackerel are related. Problems 1 through 4 show the relationships.

Table 1A will be discussed in some detail to explain the meaning of the various figures. The first row in each problem shows the coefficients of each variable, or the units of change in the dependent variable associated with a one unit change in the independent variable. For the logarithmic equations (problems 1 and 2), the changes may be considered to be in percentage terms, while the linear equations (problems 3 and 4), are in the units (pounds and dollars) used to make the estimates. For example, problem 1 shows that for a one percent change in the price of jack mackerel, landings change a net amount of 3.86 percent in the opposite direction, and that for a one percent change in the price of Pacific mackerel, jack mackerel landings change 2.95 percent in the same direction. The figures in parentheses—the second row—indicate how much confidence can be placed in the estimate directly above it. As a rule of thumb, if the t-value is greater than 2.0, we can be confident our results are accurate within a statistical tolerance. Even if some do not pass this test, our feeling is that in many cases these should be used rather than saying we have no information at all. The D.W. (Durbin-Watson) statistic tests whether the equation has been properly formulated. Generally, D.W. statistics between 1.5 and 2.5 indicate an acceptable equation.

The "e" values of problems 3 and 4 have the same economic meaning as the "b" values in problems 1 and 2. A logarithmic equation gives results directly in percentages, while for the linear equations, this must be computed. The percentage change is very important as it measures how profits are affected by changes in quantity and price. The relative percentage change between dependent and independent variables is known as the elasticity.

The four problems on mackerel taken in total, I think, give us quite a bit of understanding of the price-making forces in these markets. The strongest relationship is between the two prices (note the t-values in equations 2 and 4). As we expect according to our reasoning above, there is an inverse relation between price and landings (a negative sign), and a direct relation between the price or quantity of a product and the price of the substitute. All four of the equations show that for each of the two species the price and landings are definitely related. Although the relationships are quite strong, prices do not show great *percentage* changes in response to changes in landings. For example, in equation 2 a one percent increase in landings of jack mackerel would result in a .1 percent decrease in the price of the product.

A similar analysis was done at the canners (or wholesale) level shown in table 1B. First, prices of other canned fish products which may affect the products canned from the wetfish fishery were included. There is some indication of a relationship between "tuna-like fishes" and mackerel in both problems 5 and 6. As in the problems at the landings level, the strongest relationship in both equations is between price and quantity of the same fish. Again prices do not respond very much to a change in pack. There is a weak positive relation of mackerel price to consumer income. However, this cannot be considered as a major price determinant.

Mackerel Imports

A continuing factor of concern to U.S. fishermen is the effect of imports on the domestic fishery. Equations 5 and 6 were rerun including imports as a variable. We can report that this analysis came out about the same as most other attempts so far to measure the effects of fish imports—that is, the results were inconclusive. There is some evidence from the analysis that imports change in the opposite direction to domestic production, and change in the same direction as domestic price, indicating that a price increase attracts imports. This should not be considered as a conclusive analysis but does show what a preliminary look revealed.

Anchovies

After mackerel, which currently is the mainstay of the fleet, the most interest lies in anchovies, which may become an important resource for the wetfish fleet. The anchovy equations are shown in table 2. These also show a strong relationship between price and quantity and that prices change considerably less percentagewise than do landings. In this case, a one percent increase in landings results in a .14 percent decline in price (problem 8). The t-values again confirm that these two factors are strongly related. Jack mackerel prices seem to affect anchovy landings and prices, probably reflecting a tendency for buyers to use the major product of the fishery as a basis for establishing price offers. The price effect of Pacific sardines can be safely discounted. The negative relationship between consumer income and prices is attributed to the decline of the resource more than to a lowering of demand for the product.

Bonito

Again in table 3 we find a strong relationship between price and landings of bonito. There is also a very strong association between sardine price and bonito price and landings. There is also a weak relationship shown from price of Pacific mackerel, however, this can probably be safely discounted. There is a strong *negative* association between consumer income and bonito price. We feel this mainly represents a concurrent downward trend in price and upward in income, without any causal relationship between the two.

We did not learn very much about the demand for bonito at the canners' level. As an attempt to analyze this market, data on "tuna-like fishes" were used. Probably due to the conglomerate, statistical measurement is difficult. Problem 11 is shown as an example of several tried. Price and quantity packed seem to move in the same direction, which runs counter to the principle set out earlier.

TABLE 2

Price and Demand Analysis of California Anchovies (Landings Level)

Prob. No.	Dependent Variable	Statistic	Price of Anchovies	Landings of Anchovies	Price of Jack Mackerel	Price of Pacific Sardine	Consumer Income	a	R^2	D.W.
7	Landings of Anchovies	b t	−2.91 (2.15)		4.44 (3.09)[4]	−.67 (1.15)		2.49 (1.40)	.48	.77[1]
8	Price of Anchovies	b t		−.14 (3.60)[4]	.61 (2.84)[4]	.02 (.21)	−.58 (2.72)[4]	4.07 (3.33)[4]	.67	1.11[1]

[1] logarithmic equation
[4] significant at the 5 percent confidence level

TABLE 3

Price and Demand Analysis for Bonito (Landings Level)

Prob. No.	Dependent Variable	Statistic	Price of Bonito	Price of Sardines	Price of Pacific Mackerel	Bonito Landings	Consumer Income	a	R^2	D.W.
9	Bonito Landings	b	−.17	.14	.16		−.05	18.00	.85	2.07[2]
		t	(2.32)[4]	(4.07)[4]	(1.25)		(1.78)	(1.75)		
		e	−2.34	1.57	.14		−4.25			
10	Price of Bonito	b		.53		−.04	−2.32	13.77	.97	2.13[1,2]
		t		(9.63)[4]		(1.77)	(19.81)[4]	(23.30)[4]		

(Canners Level)

			Price of Tuna-like fishes		Price of Canned Mackerel		Price of Canned Tuna			
11	Pack of Tuna-like fishes	b	.33		.091		−.01	−.07	.66	1.94[2]
		t	(3.79)[4]		(1.94)		(.18)	(2.44)[4]		
		e	2.19		.71		−.09			

[1] logarithmic equations
[2] no autocorrelation 5 percent confidence level
[3] may or may not be autocorrelation at 5 percent confidence level
[4] significant at the 5 percent confidence level
e = the percentage change in the dependent variable for a one percent change in the independent variable

Sardines

Table 4 shows that Pacific sardines at the landings level are affected by the same market forces as bonito. Prices, as in the case of all other products analyzed, are very strongly related to landings. The percentage change in price (.13) is quite low for a one percent change in landings. In problem 13 an upward trend in sardine prices accompanies an increase in consumers' income. Sardines were not analyzed at the canners' level.

TABLE 4

Price and Demand Analysis of Pacific Sardines (Landings Level)

Prob. No.	Dependent Variable	Statistic	Price of Sardines	Price of Bonito	Landings of Sardines	Pack of Sardines	Consumer Income	a	R^2	D.W.
12	Sardine Landings	b	−2.63	.99				6.89	.87	1.88[1,2]
		t	(8.47)[4]	(2.92)[4]				(8.54)[4]		
13	Price of Sardines	b		1.25	−.13		2.80	−15.39	.94	2.56[1,3]
		t		(5.77)[4]	(2.96)[4]		(4.82)[4]	(4.14)[4]		

[1] logarithmic equations
[2] no autocorrelation 5 percent confidence level
[3] may or may not be autocorrelation at 5 percent confidence level
[4] significant at the 5 percent confidence level

TABLE 5A

Price and Demand Analysis for Bluefin (Landings Level)

Prob. No.	Dependent Variable	Statistic	Price of Bluefin	Price of Jack Mackerel	Bluefin Landings	a	R^2	D.W.
14	Bluefin Landings	b	−5.25	1.87		12.80	.46	1.42[1,3]
		t	(3.45)[4]	(2.32)[4]		(4.67)[4]		
15	Price of Bluefin	b		.33	−.08	2.04	.65	1.69[1,3]
		t		(4.02)[4]	(3.44)[4]	(13.44)[4]		

[1] logarithmic equations
[2] no autocorrelation 5 percent confidence level
[3] may or may not be autocorrelation at 5 percent confidence level
[4] significant at the 5 percent confidence level

TABLE 5B

Price and Demand Analysis for Bluefin (Canners Level) [5]

Prob. No.	Dependent Variable	Statistic	Price of Tuna	Price of Salmon	Price index of meat, poultry and fish	Consumer Income	a	R^2	D.W.
16	Per capita consumption of tuna	b t	−.99 (7.19)	.15 (.94)	−.22 (.73)	1.41 (6.78)	−2.40	.97	1.28[1]

[1] logarithmic equations
[5] from Bell, Frederick W., "Forecasting World Demand for Tuna to the Year 1990, "*Commercial Fisheries Review*, Bureau of Commercial Fisheries, U.S. Department of the Interior, December 1969, p. 24.

Bluefin

Bluefin prices and landings are strongly related to jack mackerel price (table 5A), although the reverse was not shown to be true. As in the case of anchovies, this probably reflects the tendency to base prices on the major product. The price and landings as before, are highly related.

At the canners' level (table 5B) bluefin is undoubtedly affected by the same factors affecting all tuna. Equations for all types of tuna combined have been previously derived. One such equation is problem 16. This can be considered to show the factors affecting bluefin sales. In this case we find that in the present market the relation between per capita consumption and price is such that the cost to the consumer is constant. Note also that rising incomes will cause tuna consumption to increase about 1.4 percent for each 1 percent increase in income.

Implications

We have some idea now of how the various products of the fishery are related to each other in a statistical sense. Most of these results also find support in economic expectations. As for any analysis, the question is "So what?"

One very important finding, which we might say is "bad news," is the lack of any strong relationship between landings or pack and consumer income except in the case of tuna and sardines. Therefore, we cannot count on rising income to cause growth in the size of the market for the major species of the fishery. At the landings level the income was total income—not per person or per capita—so even population increase cannot be counted on to increase market size.

The other major finding we may classify as "good news." This is the matter of how sensitive prices are to landings, or vice versa. In every case analyzed, it was shown that prices change percentagewise very little in response to changes in landings. From the standpoint of the seller (the fisherman and canner) this means that they probably should produce more because gross receipts will increase. That is, the receipts from added landings will more than compensate for a price fall due to more products available on the market.

Note that I said, "Should probably produce more." The reason for the uncertainty is that it is not the gross receipts that make the difference on the profit and loss statement—it is the net earnings after expenses are covered. Fortunately in this case, we have information we can use to determine the effect of quantity increases on the net returns of the wetfish fleet (Perrin and Noetzel 1970).

If it is possible from the standpoint of available resources, fishing capability, and catch quota regulations, any one boat could increase catch at any time without affecting the price noticeably, and therefore increase profits. The question here is, what happens if the whole fleet increases catch? According to the price equations discussed previously, this would cause a price decrease. As noted, however, this would result in a total revenue *increase*.

TABLE 6

Effect of 10 Percent Catch Increase on Gross Revenue, Crew Earnings and Return to Vessel Owner

Vessel size, capacity in tons	100 percent mackerel				50 percent each of mackerel and anchovies			
	Gross revenue (dollars)	1 crew share (dollars)	Profit (dollars)	Return on investment (percent)	Gross revenue (dollars)	1 crew share (dollars)	Profit (dollars)	Return on investment (percent)
70	100,000 108,841	6,080 6,791	7,328 9,935	26.0 35.3	100,000 108,876	6,157 6,754	4,576 6,670	16.2[a] 23.7[b]
100	100,000 108,841	5,340 5,966	8,341 11,089	29.6 39.4	100,000 108,876	5,408 5,933	5,604 7,840	19.9[a] 27.8[b]
120	100,000 108,841	5,297 5,917	8,745 11,540	31.1 41.0	100,000 108,876	5,365 5,884	5,917 8,289	21.0[a] 29.4[b]
150	100,000 108,841	4,656 5,201	10,071 13,146	35.8 46.6	100,000 108,876	4,715 5,172	7,361 9,885	26.1[a] 35.1[b]

[a] as shown in Perrin and Noetzel (1970)
[b] above source with 10 percent increase in landings adjusted for price change

To see how this may affect an individual boat, selected cases in the Perrin and Noetzel study were rerun. It is assumed that the average increase in catch by all boats in the fleet is 10 percent. According to our demand equations, price will drop. But total revenue goes up for all boats whose increase in catch is greater than the average increase for the fleet. Table 6 shows this and the effect on vessel and crew earnings. Computations were made for each of the four sizes of boats for two cases: 100 percent mackerel fishing, and 50 percent mackerel, 50 percent anchovy fishing. The $100,000 gross revenue cases shown in table 22 of Perrin and Noetzel were recomputed. If landings increased in each case by 10 percent, gross revenue would be $108,841 and $108,876 respectively. As can be seen, crew shares, profits, and return on investment would all increase significantly on each vessel whose catch increased by at least the average increase of the whole fleet. A vessel which did not increase catch, naturally would experience a decline in total revenue because the same catch would be sold for a lower price per pound.

The fact that profits can go up by increasing the amount sold should be of major interest to canners. Table 1B shows that gross profits increase at higher amounts sold for the canners as well. Although the profit picture of canners cannot be analyzed as was done for the vessels, it is highly likely that net profit would also increase. An analysis similar to the one done by Perrin and Noetzel should be done at the canners level. If net profit increases with sales increases, then catch quotas should be liberalized.

The effect of the elasticity on profits is a two-edged sword. The relationship also works in reverse in that a decrease in landings decreases total profits and in this case net profits. This probably explains a good share of the difficulty the fleet presently finds itself in.

Conclusions

It has been demonstrated by the Perrin and Noetzel paper that there can be profits in the wetfish fishery given sufficient volume of landings. This paper shows that increasing the catch, in contrast to increasing the supply of many food products, will increase total revenue to the fleet and net revenue to any vessel which increases its catch by a percentage equal to or greater than that by which total fleet catch is increased. Therefore, there is considerable hope for a profitable fishery. Rising population and income on the other hand, probably will not cause any growth in the market.

One final note. Except for canned tuna and the luxury shellfish, the only fish products that have made significant advances in per capita consumption in the U.S. during the past two decades are those with new product forms—the convenience items. These are fish sticks and portions, breaded frozen shrimp, and other shellfish with shell removed and highly processed. The losers are the smoked, cured, many canned items (except tuna), and the traditional fish market forms. I am not suggesting what might be done to improve the market form of the wetfish fleet. It does present a problem and room for someone to generate and test some ideas.

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SUMMARY

DAVID PARKINSON
CONSULTEC Inc.
San Diego, California

To summarize this very briefly, as I have listened to the proceedings here today, the basic question is "Do you or do you not want to preserve the wetfish fleet?" If the answer to that question is yes—I think I have heard evidence here that would indicate there is a market and need for this fleet—then I would hope the basic decision could be made, perhaps within this group. Say yes we do want to preserve the wetfish industry, and then let's get on with trying to solve the problems and bring together a management plan. I would like to close this on the theme that it was started out on; and that is, a piecemeal approach—as we are going at it now—is not a real solution. We have ample guidelines both at federal and state level to say that we should try to master plan this thing. Here is a marvelous opportunity for a group such as this, who would be comprised of the various interests in the fishing industry, to get together and solve the problem instead of making excuses as to why we can't solve it—or it's too hard or we've got institutional constraints or this type of thing. What I would recommend is that, if possible, you establish some sort of standing committee or group within this organization to set about the task of developing a planning guideline. This doesn't mean that the people here, necessarily, have to do the work; but they should be able to specify the objectives, identify the problems, and identify the holes, if you will, in areas where we need more data. Then you can develop a master plan for this industry which could serve as a prototype for any future fishing industry in the United States. You would have a chance to answer the questions from a total system aspect; you would be in a position to go to the Bureau of the Budget, sit across the round table from these people, and say "Yes, we considered that, and here is what our results show." Now, you have a basic trade off, and that is to note we have a very large deficiency as far as data are concerned. Do we wait until we get more data or do we try and go ahead today with what we've got? There is a middle ground there somewhere, but it seems to me we do have quite a bit of data. From a final point of view, this is truly a systems type problem and I doubt if the piecemeal approach is going to produce any conclusive or substantial results. I agree with Dr. Chapman when he says we ought to start all over with the new processing plant; maybe we should even think about the processor owning the fleet of boats. That has a lot of advantages: he could buy them in a group of six or ten, he gets a lower price, he's got a standardized ship, he's got common repair parts, maintenance procedures, etc. All this helps to optimize or make a more efficient operation. This again, of course, assumes that some of these institutional problems can be solved. If we can get a master plan, and if we can prove that this industry is worth developing and pursuing, we can get the help either from the federal or state government to develop it. We can also go to people, such as the present processors, and say "Look, here are the facts, now will you or won't you invest in this industry?" Hopefully our case will be strong enough that they will. I think personally, that in today's economic environment, conglomerates, if they were more interested in developing their own business—internally in their own resources—instead of worrying about picking up some unrelated industry—that they know nothing about, but looks good on the balance sheet—we would all be in a lot better shape.

Part III

SCIENTIFIC CONTRIBUTION

BIOMASS OF THE SUBPOPULATIONS OF NORTHERN ANCHOVY *ENGRAULIS MORDAX* GIRARD

ANDREW M. VROOMAN *and* PAUL E. SMITH
National Marine Fisheries Service Fishery-Oceanography Center
La Jolla, California

During the California Cooperative Oceanic Fisheries Investigations (CalCOFI) anchovy larvae have been collected by standard methods described by Ahlstrom (1948, 1953) on a standard station plan (inside back cover) in waters off the west coast from Oregon to the tip of Baja California every year 1951–1966 and in 1969. The data from 1951 through 1958 is shown by year, month, station and size group of larvae in 269 charts of the area in CalCOFI Atlas No. 9, 1968, which also includes a brief account of methods, with references. The total number of larvae each year in the known range of the northern anchovy *Engraulis mordax,* calculated by methods discussed in Ahlstrom (1968) and Messersmith, Baxter and Roedel (1969) is shown in the last column of Table 1.

TABLE 1

Numbers × 10^{12} of anchovy larvae (regional census estimates, Smith, MS) in four geographical areas.

Year	Northern subpopulation	Central subpopulation		Southern subpopulation	
	Central California	Southern California	Northern Baja Calif.	Southern Baja Calif.	Total
1951	111	1,474	1,525	3,394	6,504
1952	76	879	3,301	3,876	8,132
1953	2	4,446	3,774	5,410	13,632
1954	1,164	6,041	2,671	8,657	18,533
1955	24	4,864	9,249	2,963	17,100
1956	247	3,294	6,071	5,603	15,215
1957	130	11,799	4,257	3,854	20,040
1958	3,930	11,655	7,003	5,684	28,272
1959	3,506	12,439	4,729	2,789	23,463
1960	637	8,791	10,748	11,238	31,414
1961	1,054	7,518	5,357	18,609	32,538
1962	979	23,102	21,324	18,353	63,758
1963	1,577	32,745	16,763	10,448	61,533
1964	5,221	34,046	5,330	7,656	52,253
1965	1,256	49,634	13,631	14,771	79,292
1966	4,001	35,360	6,947	5,892	52,200

The biomass of spawning anchovy adults was calculated from $B_a = 98.2\ L_a$ where B_a is the biomass in millions of tons and L_a is the number of larvae times 10^{12} (Smith, MS). The standard error of prediction is about 9%. The biomass each year for the entire region survey area is shown in Figure 1 and given in the last column of Table 2. The biomass increased from about 640,000 tons in 1951 to over 6 million tons in 1962. Since 1962 it has remained high, fluctuating between about 5 and 8 million tons. The preliminary estimate for 1969 based on those collections which have been sorted and counted to date is 5.4 million tons.

These figures represent all the northern anchovies which spawn off the coast from San Francisco to Cape San Lazaro, Baja California, Mexico. McHugh (1951), from a study of variations in certain meristic characters of *E. mordax,* concluded that three geographic-

TABLE 2

Spawning biomass in thousands of tons of anchovies in each of the three subpopulations (Smith, MS).

Year	Northern subpopulation	Central subpopulation	Southern subpopulation	Total
1951	11	294	333	639
1952	7	410	381	798
1953	0	807	531	1,388
1954	114	855	850	1,820
1955	2	1,386	291	1,679
1956	24	919	550	1,494
1957	13	1,576	378	1,967
1958	386	1,832	558	2,776
1959	344	1,686	274	2,304
1960	63	1,918	1,103	3,084
1961	103	1,264	1,827	3,194
1962	96	4,362	1,802	6,260
1963	155	4,861	1,026	6,041
1964	513	3,866	752	5,130
1965	123	6,211	1,450	7,785
1966	393	4,154	578	5,125

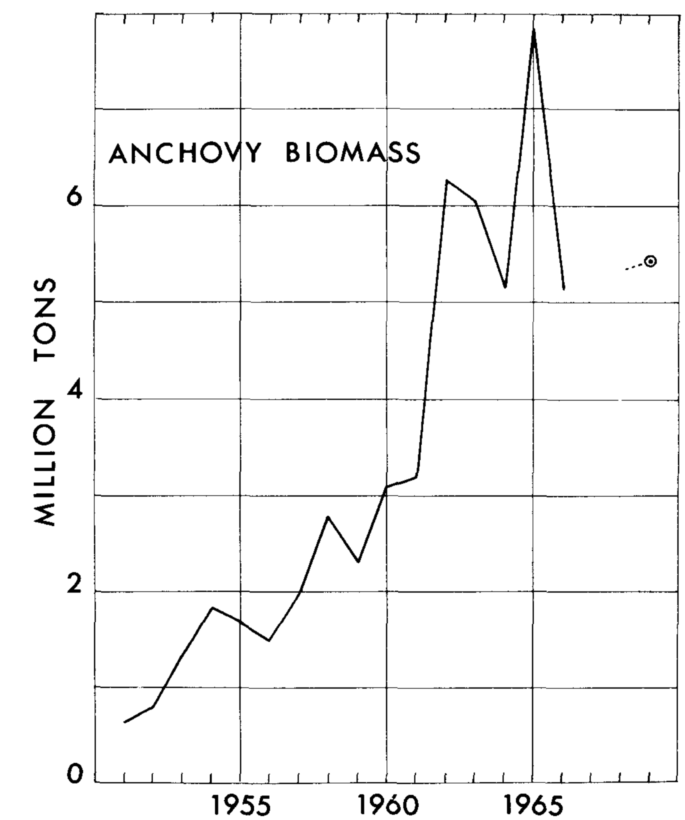

FIGURE 1. Total spawning biomass of anchovies in the CalCOFI survey area, calculated from the numbers of anchovy larvae collected each year.

ally separate subpopulations could be found over this range and suggested as approximate boundary markers Point Conception on the California coast and Cedros Island off Baja California. Genetic studies on adult anchovies, using serum transferrins (Vrooman and Paloma, MS), confirm McHugh's findings of three subpopulations and also show that the winter distribution of the three groups generally fits his description. Figure 2 is a schematic representation of the distribution of the subpopulations.

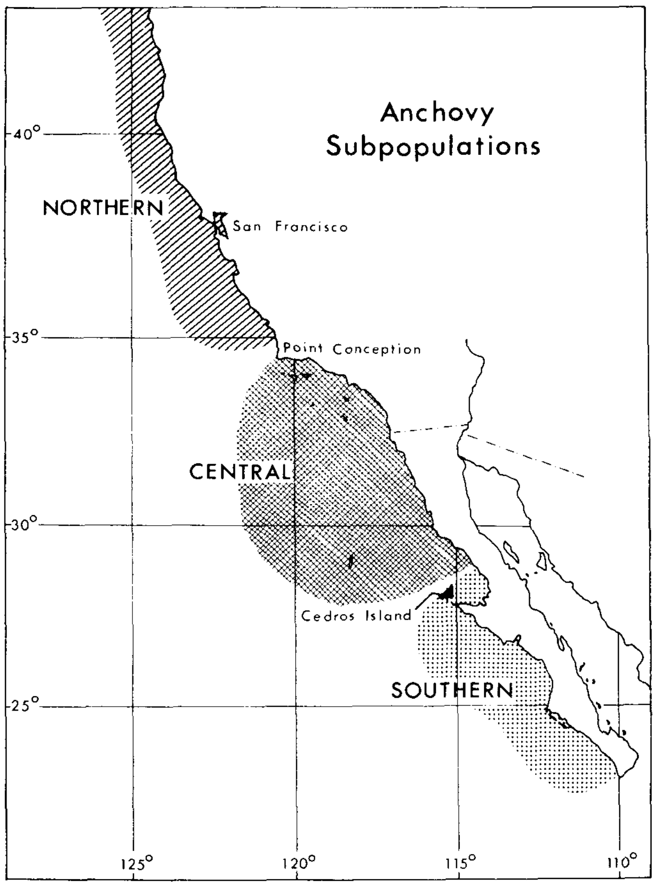

FIGURE 2. Schematic diagram of the winter distribution of the three subpopulations of the northern anchovy, *Engraulis mordax*.

When the CalCOFI grid is divided into four areas and the numbers of anchovy larvae in each is used as an index of abundance, geographical differences in changes of biomass with time may be seen. The four areas are 1) Central California—all CalCOFI station lines between San Francisco and Point Conception, 2) Southern California—Point Conception to Ensenada, Baja California, 3) Northern Baja California—Ensenada to Cedros Island, and 4) Southern Baja California—Cedros Island to Cape San Lazaro. From this data (Table 1, Figure 3) it can be seen that the greatest increase by far has taken place in the Southern California area.

By combining the Southern California and Northern Baja California areas the larvae are divided roughly into the three subpopulations (Figure 4). Table 2 shows the biomass of spawning adults as calculated from this data. From these representations it is apparent that although during 1960–66 the biomass of the southern subpopulation was on the average twice as great as during 1951–59, the ratio for the same periods in the central subpopulation was three and a half. The ratio for the northern subpopulation was intermediate.

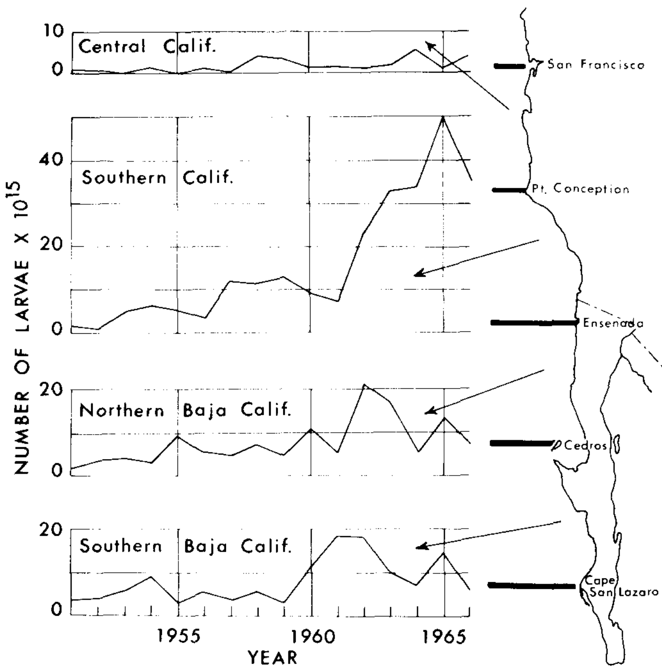

FIGURE 3. Regional census estimates of northern anchovy, *Engraulis mordax*, for the years 1951–1966 (Smith, MS).

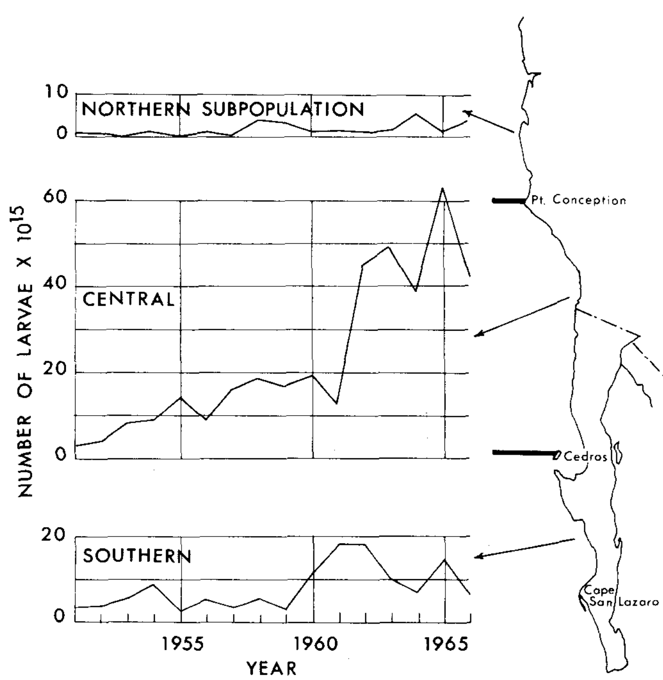

FIGURE 4. Regional census estimates of northern anchovy larvae for each of the three subpopulations in the CalCOFI area, 1951–1966.

The number of larvae may be used as a fair approximation of the total biomass of adult anchovies in the central subpopulation because the cruise pattern covered essentially their whole range at all seasons in all years. In the northern region collections of larvae have been made as far north as the California-Oregon border, but not with sufficient regularity and geographic coverage to make a satisfactory basis for calculating the total biomass of the northern subpopulation. The situation is the same for the southern subpopulation south of Cape San Lazaro. Details of the area covered and the stations occupied are given by Ahlstrom (1966).

Vrooman and Paloma (1c) observed a considerable shift of the central subpopulation north in the summer and south in the winter. These authors noted that in winter and early spring when most of the anchovy spawning takes place, the boundary between the northern and central subpopulations is as shown in Figure 3. Also, Haugen, Messersmith and Wickwire (1969) observed that a few of the anchovies tagged in the central California region were recovered in southern California and vice versa. These findings we believe do not impair the evidence of an essential distinction between the northern and central subpopulations.

Within the CalCOFI area between San Francisco and Cape San Lazaro, the mean total biomass of anchovies for the five year period 1962–66 was 6.1 million tons. The central subpopulation amounted to 4.7 million tons or 77.3% of that total. The southern subpopulation, with about 1.1 million tons, made up 18.5%, while the northern subpopulation contributed only 0.26 million tons or 4.2% of the 5-year mean.

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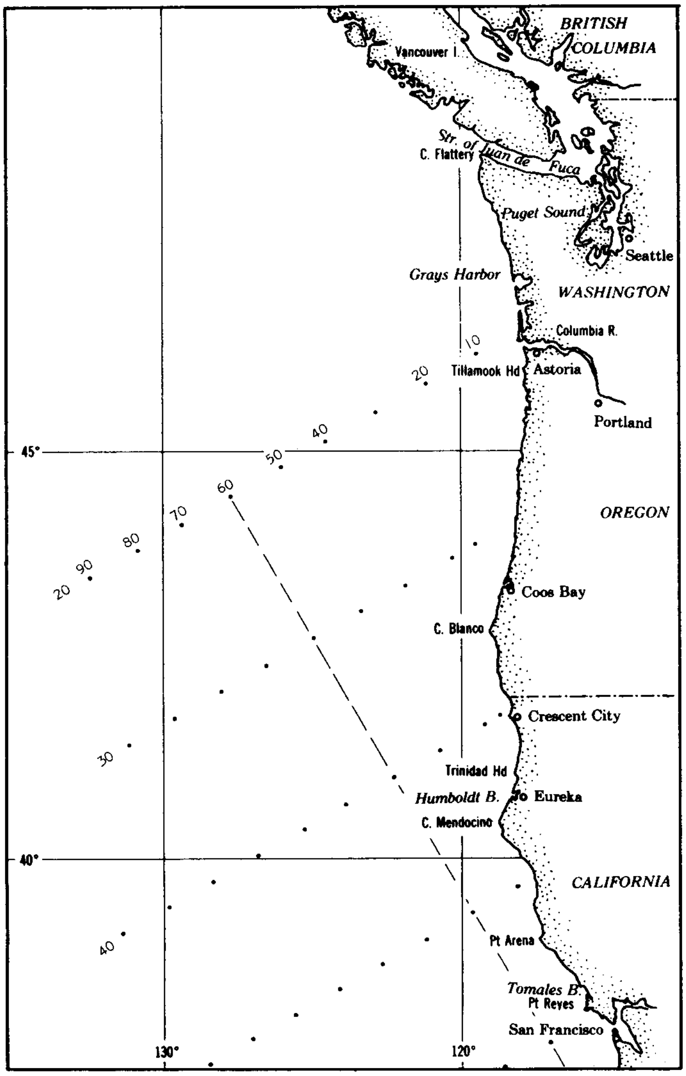

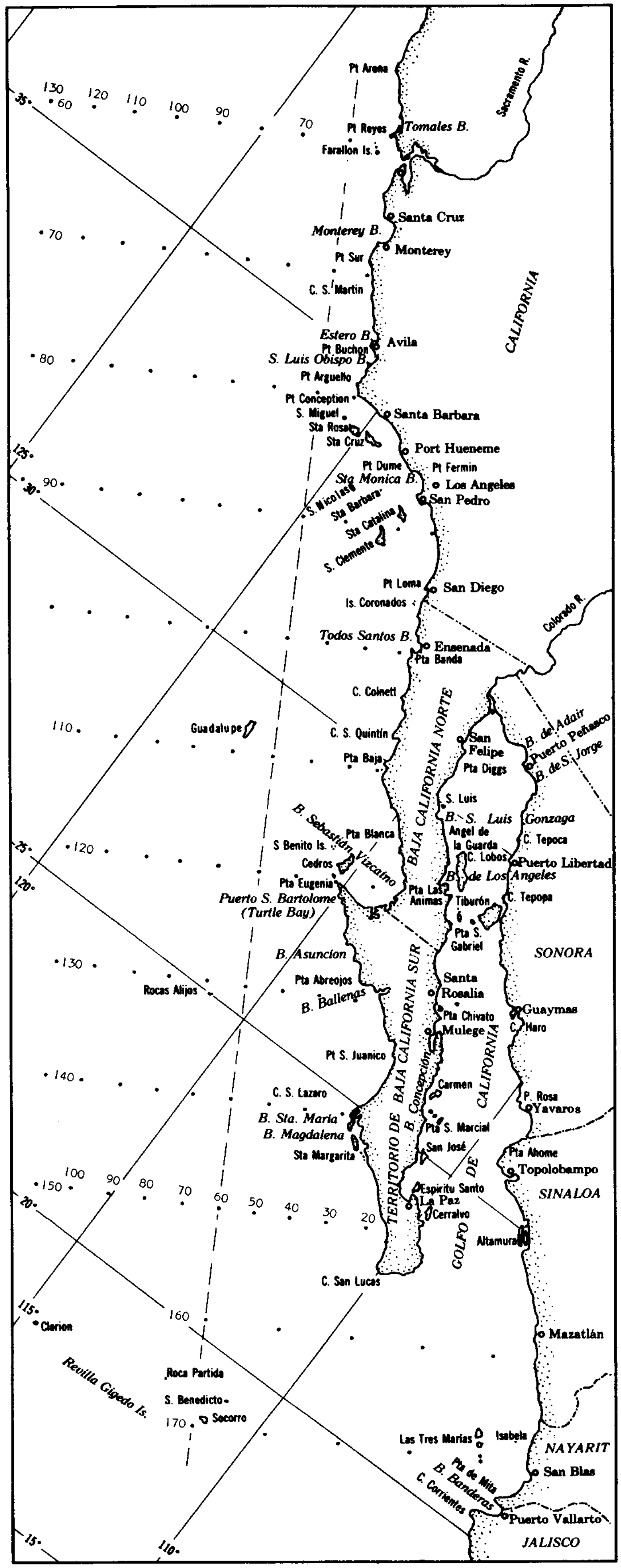

These maps are designed to show essential details of the area most intensively studied by the California Cooperative Oceanic Fisheries Investigations. This is approximately the same area as is shown in color on the front cover. Geographical place names are those most commonly used in the various publications emerging from the research. The cardinal station lines extending southwestward from the coast are shown. They are 120 miles apart. Additional lines are utilized as needed and can be as closely spaced as 12 miles apart and still have individual numbers. The stations along the lines are numbered with respect to the station 60 line, the numbers increasing to the west and decreasing to the east. Most of them are 40 miles apart, and are numbered in groups of 10. This permits adding stations as close as 4 miles apart as needed. An example of the usual identification is 120.65. This station is on line 120, 20 nautical miles southwest of station 60.

The projection of the front cover is Lambert's Azimuthal Equal Area Projection. The detail maps are a Mercator projection. Art work by George Mattson, National Marine Fisheries Service.

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