AGENCY REPORTS

CALIFORNIA ACADEMY OF SCIENCES

July 1, 1973, to June 30, 1974

During this fiscal year, investigations have continued on market squid and on species of fish previously under investigation. It was originally postulated that about 1000 specimens of each species, with a reasonable geographic distribution within its range, would be necessary to establish a pattern of feeding. This however did not take account of the fact, later discovered, that in a considerable number of cases the stomachs are found completely empty, and thus yield no information at all. It is necessary, therefore, to alter this objective to numbers of stomachs containing food. It should be noted also that consistency of feeding patterns among a substantial number of specimens from different localities and at different seasons is more important than analyzing the stomach contents of a large number of specimens from one locality, or at one period of the year.

Study and identification of stomach contents were made by Anatole Loukashkin.

Market Squid. Stomachs of market squid, *Loligo opalescens,* from Monterey Bay collected in June 1973, were examined and the contents recorded as follows: 87 stomachs (46%) contained food or food remains. Among three dominant items, crustacean remains occupied first place, polychaetes second place, and fish remains third.

Hake. From the same area, taken at the same time, 70 stomachs of the Pacific hake were examined. 57 stomachs (74.3%) contained food. Of this, 77% consisted of euphausid crustaceans and their parts, 11.5% lantern fish, 3.8% squid, 1.9% sergestid shrimps.

Forty-six stomachs of Pacific hake collected by Kenneth Mais from the Channel Islands off southern California were examined. Of these, 42 stomachs were filled with food, of which 91.5% consisted of euphausids and their remains, and miscellaneous material (unidentifiable) 4.7%.

Saury. A collection of 100 frozen Pacific saury from central California waters, made in 1972, was received from Kenneth Mais in October 1973. Of these, almost all contained food, ranging from full to about ⅛ capacity. Two stomachs were empty.

The identifiable food items found consisted, in the order named, of crustacean flesh and fragments, hyperid amphipods, crustacean larvae (mostly megalopa larvae of crabs), fish remains, euphausids, jellyfish and parts of same, and one isopod. There was a considerable amount of unidentifiable fleshy material, probably of crustaceans and/or fish. It is noteworthy that no phytoplankton was found.

Anchovy. A collection of 427 stomachs of northern anchovy taken in central California waters by Jerome Spratt in May–June 1973, were studied early in 1974. One hundred eighty-nine stomachs were filled with copepods of several species as the dominant food item. The remaining 238 stomachs were filled exclusively with diatoms—*Chaetoceros, Skeletonema, Coscinodiscus, Rhizosolenia,* and others.

During the period November 15–30, 1973, Loukashkin participated in a research cruise of the ALASKA for observation of feeding behavior and collection of market squid and fishes assigned to the program by the Marine Research Committee. In cooperation with Raymond Ally of the Department of Fish and Game, 159 squid, 42 jack mackerel, and 58 saury were collected. The weather was stormy and collecting difficult.

Robert C. Miller

CALIFORNIA ACADEMY OF SCIENCES

July 1, 1974–June 30, 1975

Investigations in 1974–75 have been largely a continuation of those of the preceding fiscal year, as additional material has become available.

Market Squid. One hundred fifty-nine stomachs of market squid, *Loligo opalescens,* from the Channel Islands region, were collected by Raymond Ally and Anatole Loukashkin in November 1973. Eighty-eight stomachs (55.3%) contained food, while 71 (44.7%) were empty. Quantities of food in stomachs varied from full to less than ⅛ of stomach capacity. Dominant identifiable food items were crustacean remains (25%), polychaete remains (24%), fish remains (17%), and euphausids (1%). The remainder consisted of indeterminable fleshy material.

Of 143 stomachs of market squid collected by Raymond Ally in central and southern California waters in June 1974, 72 stomachs contained food and 71 were empty; 22 stomachs were filled to capacity, and 50 contained food in amounts from ¾ capacity to less than ⅛. Dominant food items were fish remains (41.6%) crustacean remains (45.7%) polychaetes (8.4%) and young squid remains (6.9%). The remainder consisted of indeterminate fleshy material.

Saury. Fifty-eight stomachs of saury collected by Ally in the Channel Islands area in November 1973 (from the same area and season as the squid mentioned above) were examined. Of these 45 contained food in small amounts (⅛ or less of stomach capacity). Dominant forms were siphonophores and their remains, copepod remains, 12 pteropods (intact), and small amounts of fish remains, crustacean fragments and eggs, euphausid remains, polychaete remains, and amphipods, along with a certain amount of indeterminate material

(unidentifiable because of the advanced state of digestion).

Anchovy. Four hundred anchovy stomachs were examined (the remainder of those obtained by Jerome Spratt in central California waters in May–June 1973). As in those previously examined from this area at this season, phytoplankton was predominant, with copepods taking second place. Among diatoms the most abundant forms were *Skeletonema costata, Rhizosolenia* sp., *Melosira varians, Ditylum* sp. *Navicula* sp., *Nitzschia* sp., *Thalassiosira* sp., *Chaetoceros curvisetus* and *C. affine.* A few protozoa that leave visible remains were noted (Coccolithophoridae and a possibly amoeboid form resembling *Arcella*).

The unexpected dominance of phytoplankton in this sampling bears out the necessity of obtaining numbers of specimens from as many areas and seasons as possible in order to determine the total spectrum of feeding in a given species of fish.

Pacific and Jack Mackerel. We now have records of stomach contents of 1092 specimens of Pacific and 792 specimens of jack mackerel, including some 200 specimens of each obtained by Loukashkin on voyages in Mexican waters in 1958, 1961, and 1962. It would be desirable to have 200 or 300 more jack mackerel from California waters in order to write up for publication the data on food of these species.

Robert C. Miller

CALIFORNIA DEPARTMENT OF FISH AND GAME

July 1, 1973, to June 30, 1974

The Marine Resources Region underwent reorganization during the latter part of this period. The purpose of this action was to separate management and research activities. Management responsibilities remained with the Marine Resources Region while the major research responsibilities were transferred to Operations Research Branch. Since the Pelagic Fish Program was involved in both activities, the Sea Survey and Fisheries Monitoring Projects remained in Marine Resources Region while the Biological Studies and Data Analysis Projects were placed in Operations Research Branch.

In 1972, the California State Legislature passed a management bill that requires a moratorium on the commerical take of Pacific mackerel until the spawning biomass between Point Conception, California, and Punta Eugenia, Baja California, reaches 10,000 tons. This tonnage estimate is to be determined by the California Department of Fish and Game. Similar legislation was passed in 1973 for managing Pacific sardines. A moratorium on this fishery became effective January 1, 1974, and will remain in effect until the spawning biomass north of Cape Colnett, Baja California, reaches 20,000 tons. Legislation also was passed in 1973 directing the department to conduct a 2 year study as a basis for managing Pacific herring stocks in Tomales and San Francisco Bays.

Sea Survey

Nine sea survey cruises were conducted during the year. The anchovy resources of northern Baja California and southern California were acoustically surveyed on four cruises, and those of central California during one cruise. Nearly 5,600 nautical miles of echo ranging and sounding were completed. Two cruises were devoted to developing methods of estimating anchovy school biomass from acoustic records. An exploratory survey for market squid was made in central California, and a survey was made using night-light and blanket net to monitor Pacific mackerel and Pacific sardine populations in southern California waters.

The increase in the anchovy population off northern Baja California and southern California, as indicated by acoustic surveys in 1972, has continued through 1973. Surveys this year indicate a larger population than at any time since acoustic surveys were initiated in 1966. Very conservative estimates of biomass for this region range from 1.7 to 2.5 million tons. Highly successful recruitment during 1973 should result in a continued increase.

Progress was made toward more accurate assessment of anchovy school biomass which is the key to more accurate estimations of population size. Target strength, volume back scattering strength measurements, and simultaneous underwater visual observations have added to our knowledge of acoustically assessing school sizes and densities.

Data Analysis

Several different methods of determining Pacific mackerel population size were investigated as mechanisms for estimating the spawning population size of Pacific mackerel stocks north of Punta Eugenia, Baja California. The estimate of Pacific mackerel spawning population size obtained by a tagging procedure was 5,480 tons. Three additional methods were used to estimate spawning biomass. These estimates were 4,730 tons, 6,210 tons, 6,970 tons. All of these estimates were less than the 10,000 tons required to initiate a commerical fishery under the Pacific mackerel management regulation (Section 8388.5 of the California Fish and Game Code).

Analysis of Pacific mackerel maturation and growth data reveals spawning can occur from March through October, but the majority takes place from April through August. During this April through August period, 22.5%, 65.5%, 75.1%, 84.7%, 84.2%, and 87.5% of the female fish were mature or maturing for Age Groups I, II, III, IV, V, and VI+ respectively.

Examination of past Pacific mackerel data and estimated parameters has raised serious doubts about the reliability of historical estimates.

Analysis of 18 years of the jack mackerel cannery fishery has shown an almost 10 to 1 variability in year class strengths occurring in the past.

Intensive investigations of sardine data for population estimates were initiated with the passage of the sardine management bill.

Mackerel Tagging Program

The Mackerel Tagging Program was initiated in August 1971 under contract with the Marine Research Committee. By the end of 1972, program personnel had tagged 11,215 jack mackerel and 1,898 Pacific mackerel. During 1973, a total of 4,640 jack mackerel and 1,509 Pacific mackerel was tagged. These fish were tagged and released from Departmental research vessles and cooperating commercial fishing vessels in the San Pedro purse seine fleet. Additional fish have been supplied by local southern California live bait operators.

Tagged fish have been recovered at a rate of 1% for jack mackerel and 3.75% for Pacific mackerel. Jack mackerel recoveries primarily come from cannery personnel while tagged Pacific mackerel are most frequently returned by sportsmen. Tag return data from the jack mackerel are being utilized to chart the inshore movements of the population off southern California and to supplement electrophoretic, morphometric, and meristic data concerning the racial characteristics of this stock.

Tag and recovery data from the Pacific mackerel are used in estimating the spawning biomass of this species between Punta Eugenia, Baja California, and Point Conception.

Herbert W. Frey

CALIFORNIA DEPARTMENT OF FISH AND GAME

July 1, 1974, to June 30, 1975

Sea Survey

Acoustic surveys indicated a slight decrease in the anchovy population over the record high of 1973. Spring and fall surveys found fewer schools and a more patchy, less widespread distribution than the previous year. The bulk of the population was located in the northern half of southern California where large concentrations and high availability produced good fishing.

A cooperative purse seiner charter cruise with National Marine Fisheries Service and operation of our sonar in conjunction with purse seine fishing operations have greatly improved our capabilities to estimate anchovy school biomass from acoustic records. Underwater photography of anchovy schools also has enhanced this capability. Results of this work indicate we have been making reasonably accurate estimates of schools up to 25 tons and underestimating the larger ones.

An anchovy acoustic survey of northern Baja California and southern California in February 1975 detected a total of 10,527 anchovy schools over 1,671 miles of transects.

A new program for the Wang desk computer enable us to produce biomass estimates by 20 minute grids within 1 week of cruise completion.

The most successful Pacific mackerel spawning in more than 7 years was indicated by relatively numerous catches of young fish by midwater trawling and night-lighting in southern California young mackerel were received from bait haulers and scuba divers. No evidence of change in the depressed condition of the sardine population was detected by sea surveys. Unusually large concentrations of Pacific sauries were present in the offshore areas of southern California during the fall of 1974. This is the largest and most extensive concentration seen in this area in the last 10 years.

Pacific Herring Studies

In 1972, Japan removed their import quota on herring roe. This action immediately established a lucrative market for Pacific herring in California. Consequently a resurgence of the herring fishery developed in California in 1973. This fishery is conducted primarily in San Francisco and Tomales Bays, and just-ready-to-spawn fish are the targets. Nearly all of the catch is frozen and exported, ultimately reaching the specialty markets in Japan.

As a result of this harvest of spawning herring for the production of "kazamoko," the department was requested by the California State Legislature to carry out a 2 year study on the Pacific herring resources in San Francisco and Tomales Bays. The study was conducted during the 1973–74 and 1974–75 spawning seasons, and was designed to (1) estimate the spawning biomass of herring in Tomales and San Francisco Bays; (2) determine if Tomales Bay and San Francisco Bay contain separate stocks; and (3) determine size, age, and sex composition of the landings.

The study indicated that current spawning populations of Pacific herring in San Francisco and Tomales Bays are larger than prior estimates indicated. Spawning biomass in San Francisco Bay is estimated at nearly 20,000 tons while that in Tomales Bay approximated 5,000 to 6,000 tons.

A comparison of sampling data from the two bays indicates each contains a spawning population that is not freely interbreeding.

Analysis of age-length data indicates a difference in mean length at age exists between Tomales Bay and San Francisco Bay herring. In 1973–74 Tomales Bay age classes were from 4 to 14 mm SL larger than corresponding age classes from San Francisco Bay. In 1974–75 Tomales Bay age classes were again larger by 3–11 mm SL. The fact that Tomales Bay herring are consistently larger at every age group is strong indication that herring from Tomales and San Francisco Bays are not freely interbreeding. Except during the short spawning season, the herring

population from both bays probably occupies the same area of the Pacific Ocean off California. The fish feed and grow in the same areas and their total environment may be considered the same once they leave the bays. It is unlikely that environmental factors in the ocean, except for spawning, would favor herring from Tomales Bay over herring from San Francisco Bay. The faster growth exhibited by Tomales Bay herring probably is genetic in origin.

The overall age composition of both bays is comparable with 2, 3, and 4 year old fish combined accounting for 68%to 80% of the catch during the study.

Market Squid Study

In order to facilitate an expanding harvest of *Loligo opalescens* and provide a scientific basis for its management, a study was initiated in 1974 on the market squid. This is a cooperative California Department of Fish and Game and Sea Grant program. The goals of the program are to assist management agencies and the fishing industry in:

1) Devising methods for increased harvest of squid, including improved gear, better knowledge of squid spawning areas, and correlation of oceanographic conditions with the appearance of squid on the spawning grounds.
2) Determining acceptable levels of harvest to insure that squid are utilized on a sustained yield basis by developing techniques for assessing the size of the population and investigating the possibility that this population is divided into reproductively isolated subpopulation, stocks, or races. This work includes ascertaining the age at which market squid mature sexually and the number of times they are capable of reproducing.
3) Assessing the impact of an increased squid harvest upon other living resources of the California Current by investigating what squid consume, what they compete with, and the extent to which other species are dependent upon squid as a food resource.

The Department of Fish and Game is involved in several of the research activities mentioned above.

Two research cruises have been completed, one from La Jolla to Santa Cruz and one from Monterey to the Oregon border. The first cruise revealed the existence of fishable concentrations of squid at three heretofore unknown locations south of Monterey. Few squid were observed on the second cruise, a condition reflecting their general scarcity off northern California during the spring of 1975.

Gross morphometric data obtained by sampling commercial catches during 1974 were analyzed. They indicate the occurrence of localized populations in northern and southern California. These results by themselves, however, are inadequate to verify the existence of actual subspecies. Biochemical research was conducted on blood proteins and more than 23 squid enzyme systems in an effort to establish the feasibility of electrophoresis as a tool for revealing genetic isolation, should it exist. Blood serum proteins and two enzyme systems, phosphoglucomutase and the acid phosphotase esterases, have demonstrated polymorphism. As a result, we feel electrophoretic analysis of squid proteins is an acceptable technique. An extensive sampling regime has been devised to produce statistically reliable results, and morphometric analyses have been extended to beak and sucker disc anatomy.

Modal length frequency progressions utilizing samples from Monterey Bay indicate that the market squid achieves maximum size in 1 to 1.5 years. Microscopic observation of hard parts revealed growth increments in the beak, pen, and statolith. The statolith appears to be the most promising organ for age determination. Over 100 have been read to date, and daily and monthly growth rings have been discovered. Preliminary calculations based on these rings indicate that market squid spawn when 1.5 years old.

Herbert W. Frey

MARINE LIFE RESEARCH GROUP SCRIPPS INSTITUTION OF OCEANOGRAPHY

July 1, 1973, to June 30, 1974

Biological Studies

Edward Brinton in collaboration with Margaret Knight and Tarsicio Antezana has studied euphausiid crustaceans and has extended their research to include life histories and details of larval development of important species occupying the region of the California Current and corresponding coastal waters of western South America. The near shore part of the California Current System appears to sustain a more homogeneous and self-sufficient biota than had been generally supposed, as evidenced by geographical continuity in populations of the temperate species *Euphausia pacifica* and *Nematoscelis difficilis*. Rates of recruitment, growth, and production of euphausiids are associated with 6 to 12 month life cycles which, even to the south of Point Conception, remain strongly geared to the seasonality of environmental processes. There is increasing evidence connecting the degree of success of a cohort to the timing of its initiation in relation to timing of habitat events, e.g., perturbations in temperature, speed, and direction of transport. Further, it has appeared possible to learn something about the extent and direction of population mixing by means of a series of comparisons among size-frequency diagrams of euphausiid populations derived from the different localities in a given CalCOFI grid survey.

With literature now available, it is difficult to identify single larvae of most species of Euphausiacea. As

part of a project to provide identification and eventually a key to larvae of the California Current euphausiids, the larval development of *Euphausia gibbodies* Ortmann, a major species of this current system, has been described and illustrated. The larvae of two very closely related species, *E. sanzoi* and *E. fallax* from southeast Asia and the Indian Ocean, are now being studied. The close relationship of the three species, determined on the basis of adult morphology, is substantiated by the study of the larval phases of their life histories. The fine details of larval morphology are now being analyzed with much interest as they appear to demonstrate unsuspected affinities within this group of species.

Krill Expedition lead by Brinton to South America on AGASSIZ during May–September 1974 studied the distribution of plankton in relation to the conspicuous oxygen minimum layer of the eastern tropical Pacific. *Euphausia mucronata,* the abundant krill of the Peru-Chile Current, and a biogeographical homologue of *E. pacifica,* was the object of a population analysis by Antezana, an SIO graduate student from Chile. Numerous South American scientists participated in the cruise.

Study of southeast Asian euphausiids centers on South China Sea and eastern Indian Ocean material, particularly from the Naga Expedition. Five new volumes of Naga Reports are in press this year, these dealing with physical oceanography of the area and plankton biology and taxonomy.

Abraham Fleminger and Kuni Hulsemann continued their investigations on evolution and biogeography of planktonic copepods, concentrated on questions of range, habitat, speciation, and geographical variation on tropical to subtropical epiplanktonic calanoids belonging to the predaceous Pontellidae and the herbivorous Calanidae.

An analysis of geographical distribution relative to hydrography in the Indian and Pacific Oceans now in manuscript indicates that the habitat of the copepod *Pontellina* is equivalent to surface waters overlying the thermocline. Each species appears to be genetically adapted to migrate vertically only within the prevailing depth of regional surface water masses and it is proposed that the habitat and geographical range are determined by the semiclosed circulation of the surface water mass and the availability of suitable food within the depth range limits of the species.

Patterns of geographical distribution in American coastal zone zooplankton were examined by Fleminger and Hulsemann and a comparative analysis of character divergence relative to geographical overlap was made of the indigenous species of *Labidocera.* The extent of morphological divergence in secondary sexual characters and in feeding appendages was estimated relative to geographical relationship among sets of sympatric and allopatric species. The results show strong positive selection for reproductive isolating mechanisms but little or no evidence of selection pressures affecting the morphology of feeding appendages or body size among co-occurring species.

In tropical plankton the ecologically important family of primary consumers, Calanidae, is represented by the genus *Undinula.* As with its temperate-to-polar counterpart, *Calanus,* identification of species of *Undinula* has persistently confused plankton workers. During their ongoing survey of integumental organs in the family Calanidae, Fleminger and Hulsemann found evidence that these morphological features could be used to unravel the taxonomy of *Undinula,* the key being the integumental organs of females located at body sites utilized by the male in mating and in spermatophore placement. The results show an interesting biogeographical pattern of two sets of sibling species varying in geographical contact and in extent of polytypy in females as well as adding support to the tropical-subtropical biogeographical patterns in the world's oceans, previously demonstrated by means of other genera.

The scanning electron microscope was used to explore various morphological features difficult to examine by conventional light microscopy and to develop a systematic collection of diagnostic illustrations of American copepods in the California Current. Initial results are very satisfactory and, as time permits, at least all of the common species of the region will be catalogued photographically. In addition to obtaining a remarkably informative permanent photographic record for analysis, the survey revealed a number of features of considerable systematic potential.

Lanna Cheng is studying some of the special adaptations of *Halobates,* the only pelagic marine insect, to its unique environment. These insects have a very efficient mechanical gill—the plastron—which enables them to breathe when accidentally submerged, for instance, during storms. In collaboration with Richard Lee, she also has investigated the lipids of these insects. They are able to store food in the form of triglycerides in much larger quantities than do their freshwater relatives, thereby enabling them to survive without food for 2 weeks.

Daniel M. Brown has developed four new systems for sampling marine organisms. One is a conversion of the Isaacs-Kidd midwater trawl into an opening-closing net. Another is a closing vertical towed net built to reduce the handling and "scaring" problems of this style of sampling. The third is a trap which can capture live fish at great depths, hold them in their own cold water, and keep them under pressure. The fourth is a low cost free-vehicle drop-camera system developed to photograph schools of fish detected on sonar, providing a simplified method of identifying pelagic fish stocks.

North Pacific Central Gyre Studies

Under the direction of John A. McGowan, several studies are being conducted in the North Pacific Central Gyre. A historical review of the scientific

information about the hydrography, population and community biology, and fisheries of the area (25–35°N, 145–160°W) is nearly completed.

Until 1968 very few studies were devoted specifically to attempts to understand processes and events taking place within the gyre itself, and the gyre was thought of as being a rather homogeneous environment with clear warm water, a deep permanent thermocline, and very low standing crops of phytoplankton, zooplankton, and fish. The only controversial aspect of this area concerned the assertion of Sverdrup, Johnson, and Fleming in 1942 that there was actually a double anticyclonic circulation system in the area.

In the last decade it has become apparent that much of the weather (and to some degree climate) is strongly influenced by air-sea interaction and because the North Pacific Central Gyre is so large and shows such pronounced long term but migrating surface temperature anomalies, the gyre is thought to be very important. The central gyre best approximates a closed biological system, an essential assumption in ecosystem theory. The fisheries potential, although small on a unit area basis, is fairly large because of the large total area. For example, the commercial fisheries catch from the area (25–35°N, 145–160°W) has been tabulated by species for the years 1967–71. These are tuna, swordfish, marlin, and skipjack (nine species total). The value of this catch to the fishermen (in 1973 prices) was $7,356,062.

The large vertically-stable low-productivity central gyre has boundary zones which are much less vertically stable than the gyre itself. The exact locations of boundary zones, however, are not well documented. There is physical and biological evidence from the upper few hundred meters that the northern boundary, whose axis is centered about 40°N, does fluctuate latitudinally and may reach as far south as 37°N. Thus this zone of increased vertical mixing may be rather close to the locales being studied. There is new evidence for a double gyre system in the central North Pacific. This evidence is biological, physical, and theoretical. If there is a double gyre system, then the meridional boundary zone between the two gyres (main axis about 170°W) could be an area of enhanced vertical mixing.

The initial field program in the North Pacific Central Gyre concluded with six expeditions to the vicinity of 28°N 155°W. These completed the series of samples for seasonal coverage as well as providing opportunity for special projects. Elizabeth Venrick is examining the phytoplankton samples for differences in the composition and seasonal development of the deep shade-adapted layer, which characteristically occurs during the summer at 120 m, and the very distinct low nutrient populations which occur at shallower depths. These observations have been supplemented by concurrent studies on phytoplankton dynamics conducted by the Food Chain Research Group (FCRG) in the Institute of Marine Resources. Analysis of 9 years of field data on the distribution of the nitrogen fixing bluegreen alga *Richelia intracellularis* in the North Pacific was concluded. There is strong evidence that this may represent a significant source of new nitrogen to the euphotic layer, at least on a local scale, and blooms of *Richelia* are correlated with increases in phytoplankton standing stock and productivity in the upper 60 m.

Present studies led by McGowan in collaboration with members of the FCRG include the distributions of chlorophyll-*a*, primary productivity, and zooplankton standing crop.

Chlorophyll-*a* is a very good measure of the standing crop of plants. Variations in plant standing crop, in time and space, are an integral part of the ecological dynamics of the system and can, in a nutrient limited situation, provide clues as to the input of deeper, nutrient rich water in the recent past. A very large set of chlorophyll-*a* data from the central gyre has been processed and is being analyzed. One outstanding result is the discovery of the deep chlorophyll maximum at 110 to 120 m.

Variations in plant growth where light is adequate for photosynthesis are directly related to the rates of input of inorganic compounds of nitrogen and phosphorus. The outstanding feature of the central gyre is that the rate of input of nutrients to the upper zone (<150m) appears to be inadequate to support the observed rate of photosynthesis. Apparently vertical mixing in this area is not yet understood.

A phosphate trial-balance sheet which includes uptake by phytoplankton, recycling by zooplankton, and vertical eddy diffusivity does not balance. One implication is that there is more vertical and/or horizontal mixing of nutrient rich water into the area than we can account for with orthodox knowledge. There are strong reasons to believe that it is vertical mixing rather than horizontal mixing. Perhaps vertically migrating creatures also transport significant nutrients.

The primary productivity (photosynthetic rate) is an instantaneous measurement of rate which depends on nutrient input, light, and the "history" of the plant population. A most interesting result is that the summer of 1969 had twice the productivity rate of previous or subsequent summers. Apparently some significant mixing event was taking place or had taken place the previous spring or winter.

The zooplankton standing crop is a mixture of herbivores and first-stage carnivores. Their abundance is strongly dependent on the immediate and previous productivity regime. But because of their rather slow turnover rate (weeks to months), they tend to integrate, over time, the productivity dynamics. The major reason for this, other than their length of life, is that they tend, by their excretory processes, to recycle nitrogen and phosphorus compounds thus increasing the residence time of these nutrients. In accord with the productivity data, the standing crop of zooplankton in the summer of 1969 was twice that

of previous or subsequent summers, indicating a greater than usual upward mixing of deeper nutrient rich water sometime in the previous few months.

Data have been obtained on two size-categories of actively swimming organisms (= nekton), the 1–15 cm fish and the much larger commercial fish of the area. The smaller fish are mostly mesopelagic, living at depths of over 300 m during the day and migrating to or near the surface at night. These migrators are the major predators on zooplankton and are thus an important part of the system. They, along with the diurnally vertically migrating zooplankton, could serve as an active vertical transport vehicle for nutrients and other substances such as radioactive compounds.

A very large number of hydrographic measurements exists in the central gyre data set. These have been only partly processed. Most of them cover depth ranges of 0–700 m but a substantial number go to 2000 m and a few to the bottom. Temperature curves from 1969 indicate an unusual hydrographic event.

Deep Circulation

Studies of the circulation of the Pacific Ocean and the South Atlantic Ocean have been carried out by Joseph L. Reid. Published results of the Boreas expedition, carried out in January–April 1966 in the Northwest Pacific, the Bering Sea, and the Okhotsk Sea, have shown that convective overturn extends to no more than 150 m depth even in midwinter, and in much of the area to less than 100 m. The characteristic low temperature and salinity at the surface are transmitted to greater depths (and then laterally throughout the North Pacific as Intermediate Water) by mixing through the pycnocline rather than by convective overturn.

At somewhat lower latitudes, a shallower salinity minimum is found in both the North and South Pacific above the Intermediate Water salinity minimum. These shallower salinity minima originate in the equatorward eastern boundary currents along both North and South America and extend westward with the extension of these currents north and south of the equator, and can be detected as far as the Philippine Islands north of the equator.

Measurements of flow and water characteristics in the abyssal Pacific made near Samoa have shown not only an abyssal northward flow of water near 5000 m in the deep and narrow Samoa Passage, but a southward return flow of water near 3000 m. This suggests that some of the deeper waters of the North Pacific may leave the Pacific by passing southward along the Tonga-Kermadec Ridge into the Antarctic Circumpolar Current.

William Patzert is working with Reid to describe the circulation of the various water masses found in the southwestern Atlantic Ocean. Among the new findings as a result of the Cato Expedition of 1972 are the relationships between the deep high-stability layers found in the water column and large scale circulation.

The results of Patzert's earlier studies on the seasonal variability in the circulation of the Red Sea and its relation to the monsoon oscillations over the Indian Ocean have been reported, and two studies of the flow around midocean islands have been published.

During April–May 1974 Patzert was Associate Chief Scientist aboard the MELVILLE for GEOSECS-Leg J expedition and is currently analyzing two long sections of closely spaced XBTs from the expedition for evidence of baroclinic instability as a mechanism for mesoscale eddy formation.

A preliminary study of sea surface temperatures from coastal and island stations was just initiated. Initially, the amplitudes and phases of anomalies will be viewed to understand the coherence along the eastern oceanic boundary and out to the island stations. The results from these continuous records should indicate a plan to analyze the offshore data from the CalCOFI cruises. The ultimate objective of this work will be to describe and understand the longer term fluctuations at the eastern boundaries, in general, and along the California coast, in particular.

Anaerobic Sediment Investigations

The study of marine sediments is a means of extending the historical perspective of oceanic events. Not only does sediment provide access to material characteristic of past times but, due to effective horizontal dispersion of sediment particulates, the material is also characteristic of broad areas.

Marine anaerobic sediments are particularly valuable in that they can be resolved on time intervals approaching 1 year. Using techniques including box coring methods that consistently obtain the present sediment surface, verification of sediment surface recovery by the presence of excess Th-228, and stratigraphic dating by varve and Pb-210 chronology, John D. Isaacs, Andrew Soutar, Stanley A. Kling, and Peter A. Crill have been able to perform detailed historical studies.

In the Santa Barbara, Santa Monica, and San Pedro Basins these studies include such elements as common lead and its isotopic ratios, mercury, and a suite of metals. Many substances show a systematic increase in concentration over the past few decades and record the magnitude of the effect of man on the geochemical balance in the coastal sea off California.

A detailed investigation of fish debris in the sediments of the Santa Barbara and the Soledad Basins has provided insight into the historical abundance of pelagic fish of the California coast. Correlation between fish populations, as determined by fishery statistics and fish scale deposition in sediments, has shown that the interpretation of past abundance levels is probably reliable. The historical perspective suggests the past 30 years have been characterized by considerably high levels of anchovies, and that the

sardine passed through a protracted period of low abundance in the last part of the 19th century, as it had during a number of other occasions during the last 15 centuries.

Soutar and Kling are presently developing their investigations to include climatological and ecological factors in the sea of California and in other areas such as the Gulf of California and coastal Peru.

Joseph L. Reid

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES CENTER LA JOLLA LABORATORY

July 1, 1973, to June 30, 1975.

The federal commitment to CalCOFI coordinated research has continued through several major reorganizations as a central element in the research program of the NMFS Southwest Fisheries Center's La Jolla Laboratory for the past 28 years.

CalCOFI related activities are carried out in the Coastal Fisheries Resources Division, headed by Reuben Lasker. The Division was organized at the La Jolla Laboratory to perform the research and analyses required for management of the coastal recreational and commercial fisheries of the California Current. Some of the fish resources of concern to this division are the anchovy, the Pacific and jack mackerels, Pacific sardine, barracuda, and white seabass. Among the studies conducted by this division are laboratory and field work to help determine the basic causes of larval fish mortality. This information, being developed for the northern anchovy, as well as earlier work on the physiology of fishes, is being incorporated into computer models for increasing the understanding of the process of recruitment to fisheries. In turn, the results of recruitment studies are being incorporated into the stock assessments of the coastal recreational–commercial fishery resources that are being undertaken in cooperation with the State of California.

In addition to stock assessment, the requirements for research and management information with respect to these fisheries are being explored with the State of California and with Mexico. The stock assessment efforts are based on a broad range of techniques open to fishery scientists and include ship surveys involving collection of fish eggs and larvae, acoustic assessment techniques, catch and effort analysis, and the analysis of existing fishery and biological data. Considerable efforts have been devoted to developing the 25 year CalCOFI data base to achieve computer analysis capability.

Because of space limitations, the report which follows is not a complete account of CalCOFI research activities conducted at the La Jolla Laboratory but does present highlights of significant research progress and accomplishments.

Life Studies: Larval Fish

At the La Jolla Laboratory, the conduct of larval fish studies is directed toward specific problems of the varying factors which affect the survival/mortality of the larvae of coastal pelagic and recreational fishes.

Studies continued on the refinement of techniques and methods for inducing the spawning of selected commercial and recreational fishes to obtain laboratory materials, with particular attention to the Pacific mackerel and northern anchovy. A successful method has been developed by Roger Leong to mature Pacific mackerel in the laboratory throughout the year under different light–temperature conditions and to spawn them on demand with gonadotropic agents. In nature, the Pacific mackerel spawns off the southern California coast only during May through August. It has been found that temperature is far more important than the photoperiod in regulating maturation and a high temperature, 19° C or more, accelerates ova development. However, prolonged exposure to high temperatures also has a debilitating effect and the state of health of the fish begins to decline in about 4 months with eventual death in about 6 months. The fish develop more slowly at 16° to 17° C, but the mackerel remain healthier and a few are ripe the year around. The ripe fish can be detected through a biopsy technique and can then be spawned with a combination of hormone injections. The combination now being used is 1 mg of crude salmon pituitary followed 24 hours later with 100 units of gonadotrophin from pregnant mare serum.

Plankton Microstratifications in Coastal Waters off California

Considerable effort has been devoted to an investigation of plankton microstratification in the coastal waters off California. This information is essential for an understanding of the survival of anchovy larvae and other larval fish. Food studies in the sea and in the laboratory indicate that the average food density in this area will not support life of larval fishes. Consequently, the survival of larval fishes depend on the patchiness of the food distribution, that is, on plankton microstratification.

Several meetings were organized by Robert Owen to plan a multipleship effort scheduled for March 1976, to measure small scale plankton distributions and mechanisms of phytoplankton and zooplankton patchiness, co-patchiness of species, and association of fish larvae with higher density zones of food sized particles.

Starvation as Cause of Mortality in Jack Mackerel Larva

A project began in April 1975 to evaluate starvation as a cause of mortality in mackerel larvae. Jack mackerel are of major importance in the California wetfish fishery. The major objective of the study is to

establish histological criteria for estimating the extent of starvation in sea-caught jack mackerel larvae. Once these criteria are established, sea-caught larvae will be examined to determine the incidence of starvation. The work should greatly improve the understanding of causes of larval mortality and, therefore, relationships between stock size and recruitment. As a first step, starvation criteria are to be established through laboratory experimentation. Subsequently, jack mackerel eggs will be collected at sea and the larvae reared in the laboratory under controlled conditions. Histological techniques will be employed to determine normal cellular growth in larvae at various stages of development to compare with that of larvae that have been starved.

Histological Study on Effects of Starvation on Anchovy Larvae

The study of developmental anatomy of larval marine teleosts was begun by Charles O'Connell at the La Jolla Laboratory to describe the differentiation of sensory and other organ systems in respect to variations in the laboratory-rearing environment.

Detailed descriptions of organ system development are used in conjunction with laboratory behavior studies to evaluate the changing capabilities and requirements of the marine fish larvae as they grow. Variability in organ system development has been examined for possible symptoms of early mortality.

Work was also undertaken to ascertain the effects of starvation on the histological condition of early post yolk sac anchovy larvae. The ultimate purpose is to identify particular histological features, or combinations of features which are indicators of the starving and/or dying condition. Results of histological examination of anchovy larvae reared to the age of 10 days in the laboratory with and without food have been assembled. About 2 days after final yolk absorption, the histological changes that signify severe emaciation are evident. The changes in muscle, notochord, cartilage, pancreas, and midgut are progressive and constitute indicators for judging whether larvae are slightly, moderately, or severely emaciated. It was noted by O'Connell that while 6 and 7 day old larvae tend to be robust if food has been available and severely emaciated if it has not, 3 and 4 day old larvae show the reverse. Those larvae without food appear to be robust, while those reared in the presence of food and who have been feeding, show signs of slight to moderate emaciation.

Transfer of Chlorinated Hydrocarbons through a Marine Food Chain

Sponsored by the International Decade of Ocean Exploration–National Science Foundation, a study was completed by Ed Scura and Gail Theilacker on the transfer of chlorinated hydrocarbons (CHC) through a marine food chain. This work was unique because for the first time a study of this kind was made at the low concentrations of CHC pollutants usually found in the sea, i.e., in parts per trillion, and with a food chain using northern anchovy larvae. The results were surprising since in experiments using the C^{14} labeled CHC, it was found that larvae who were not feeding took up approximately the same amount of C^{14} CHC as those fed algae containing relatively high levels of CHC. Furthermore, CHC uptake seems to be intimately related to the amount of lipid in the tissue of the algae cells or animals. Anchovy larvae, therefore, must take up CHC directly from sea water.

Two major technical advances were made during the course of the study. A method was discovered for introducing CHC into sea water to attain the parts per trillion levels desired by simply bubbling laboratory air into sea water and a method was devised for analyzing parts per trillion of CHC in 1 liter samples of sea water.

Field Criteria for Survival of Anchovy Larvae

Laboratory work of long duration at the La Jolla Laboratory has led to the hypotheses that survival of fish larvae depends on particle size, density, species composition, and distribution (vertically and horizontally) of their food. Preliminary tests of this hypothesis bore out the further assertion that laboratory derived information could be used to set the criteria for threshold density levels and the kind of food needed by fish larvae to survive.

In a striking new approach to one of the major problems in fishery biology—that of predicting recruitment failure—a study was begun by Reuben Lasker to show how laboratory spawned fish larvae can be used to detect larval feeding grounds at sea and to point out some of the ways this technique might be used to provide the link between marine food chain research and stock and recruitment predictions in fisheries; the latter by determining what the environmental conditions at sea must be with respect to larval fish food to result in a good or bad survival year for particular species of fish larvae.

Northern anchovy larvae, provided by laboratory spawned fish, were used to detect concentrations of larval fish food *in situ* along the California coast. First feeding larval anchovies, whose development was controlled by temperature manipulation aboard ship, were placed in samples of Los Angeles Bight water taken from the surface and from chlorophyll maximum layers. The following information was thus accumulated in the California Current:

Food particles of the right size for larval anchovy feeding (i.e., ca 40 microns diameter) occur above threshold levels needed for feeding (i.e., more than 30 particles/ml) chiefly within the first 5 miles of the shore. In California waters dinoflagellates, e.g. *Gymnodinium splendens* and *Gonyaulax polyedra,* have been the dominant food organisms.

Threshold concentrations and higher of larval food are most often found in chlorophyll maximum lay-

ers about 15 m deep, but frequently there are above threshold concentrations near the surface. Vigorous storms and upwellings have been observed to break up the chlorophyll maximum layers and to reduce the number of food particles below the threshold number needed for first feeding anchovy larvae to survive. Anchovy and a variety of other fish larvae are found within and above these inshore layers.

Cruises held from September 1974 through April 1975 showed that a chlorophyll maximum characterized by a dominant species of dinoflagellate, *G. polyedra,* extended from Point Conception to San Diego, California, and persisted through January. In January, numbers of the 30 to 50 micron diameter particles increased generally over the entire survey area and spread seaward beyond the usual 5 mile extent of the 15 meter chlorophyll maximum.

In February, a major upwelling on the west coast of California dispersed the chlorophyll maximum and by early March the characteristic concentration of 30 to 50 micron particles in the Los Angeles Bight had dropped well below the larval fish feeding threshold, i.e., to 1 to 5 particles per ml over the entire Los Angeles Bight.

In early 1975, particle counts in the same region (approximately 3 weeks after the previous cruise) show particle counts have increased above threshold within 2 miles of shore from at least Santa Monica to Del Mar, California, or about 150 km. Sampling was restricted to this area because of ship time restrictions.

Marine Environmental Assessment

Basic to the objectives of CalCOFI is the assessment of stock levels and the estimation and prediction of recruitment of fish into the fishery. Historically, these have involved egg and larva surveys which are one of the basic tools in fishery science for evaluating the kinds and amounts of fish resources. Since the inception of CalCOFI, a group of researchers at the La Jolla Laboratory has been devoted to increasing the efficiency of such surveys by increasing the number of larval marine fish that can be positively identified and by training persons in their identification and description.

Investigators in this project headed by Elbert Ahlstrom have developed the so-called "dynamic approach" in describing the early life history stages of marine fishes. Series of specimens of a species are selected by size from newly hatched larvae to juveniles, and these are studied for developmental changes in body form, in pigment patterns, fin development, ossification, etc. Although for the majority of developmental series being studied, specimens are selected from the extensive CalCOFI collections of fish eggs and larvae, for some many-species groups, such as rockfishes, it is necessary to use a different approach—rearing of eggs and larvae obtained from identified parents to obtain developmental series.

Among the contributions of this group are the preparation of identification handbooks of marine fish eggs and larvae. An identification guide to the larvae and pelagic juveniles of rockfishes and scorpionfishes was completed and in its final form treats seven genera and 20 species of the family Scorpaenidae. Three of these genera and 11 of the species have not previously been described or illustrated. The paper includes species of rockfish from all oceans in which they occur and provides a basis for comparison of the early life histories of these commercially important fishes. Also in progress is a handbook of early life history stages of pelagic marine fishes of the California Current. Information on the pelagic stromateoid fishes has been separately prepared for publication. Ten kinds of stromateoid fishes occur in the CalCOFI area. One member of this group is a choice food fish for human consumption, the Pacific butterfish, *Peprilus simillimus.*

Neuston Net—Supplement to Standard CalCOFI Net Hauls

Almost all of the fish eggs and larvae taken on CalCOFI cruises have been collected with the standard net hauled obliquely from 200 m to the surface. In May, 1972, 115 neuston net hauls were taken on regular CalCOFI stations from off Puget Sound to below Cape San Lucas, Baja California. In contrast to the standard net, the neuston net is towed at the surface, with only about half of the net immersed. These samples have now been analyzed and it has been found that larvae occurring in largest numbers in the neuston collections were those of the northern anchovy, *Engraulis mordax,* and of the Pacific saury, *Cololabis saura.* Interestingly, a much higher percentage of large anchovy larvae were taken by the neuston net than are proportionately taken in standard net tows—a difference of about 15 times. Most of the large collections of anchovy larvae were obtained in night hauls. Another species that occurred in exceptionally large numbers at one station off the Columbia River was the sablefish, *Anoplopoma fimbria.* A rockfish larva-juvenile which is possibly that of *Sebastes alutus* occurred in large numbers in two collections. This appears to be another species that concentrates at the surface during its rarely found larval stage.

The neuston hauls contained larva-juveniles of 28 families. Over the same CalCOFI grid one would expect to take larvae of at least double this number of fish families. Thus, only a portion of the species are represented in neuston hauls. However, for certain species, such as the Pacific saury, it appears that the neuston net is an indispensable tool for establishing distribution. The number of saury larvae taken on this one cruise was equivalent to the number taken in 2 decades of CalCOFI collections made with oblique plankton hauls.

A subsequent comparison made of fish samples in the neuston nets versus regular oblique plankton

hauls revealed that the family of fishes best represented in both types of hauls was the myctophid lanternfishes. Several kinds of fish from this group were predominant in neuston hauls, while other lanternfishes, common in oblique hauls, were absent from neuston collections.

CalCOFI Atlas—Flatfish Larvae

Another in the series of CalCOFI atlases dealing with the distribution of fish larvae on CalCOFI cruises was prepared for flatfish larvae. Two genera and six species were included in the atlas. The 6 year period, 1955–1960, the period for which individual status records for these species are most readily available, is covered in the atlas. The atlas presents monthly distributions for the several flatfish that are taken most commonly in CalCOFI collections, and for less common forms, distribution was compiled by quarters. Following previously established procedures, illustrations for each species and a brief description of its distinctive larval features are presented.

Twelve kinds of fish larvae (10 species, two genera) contribute about 90% of the larvae taken on CalCOFI cruises. With the completion of the flatfish atlas, distribution charts of 11 of these 12 kinds of larvae will have been covered in CalCOFI atlases.

Fourth Fish Egg and Larval Identification Course

With the objective of training NMFS personnel and others in identification of fish eggs and larvae, an intensive course on this subject was given in the spring of 1975. Participants included 21 persons, 13 from foreign countries. During the course, a total of 204 life history series was studied, belonging to 92 fish families. About 10% of the series were based on Atlantic material, 90% on Pacific. This was the fourth time that this course was presented at the Center.

Analysis of Potential Invertebrate Predators of Anchovy Larvae

Work also continued on an analysis of the potential invertebrate predators of anchovy larvae in the CalCOFI plankton collections by Angeles Alvariño. The numerical abundance of Chaetognatha, Siphonophorae, Medusae, Chondrophorae, and Ctenophora is being determined as well as information on a number of other zooplankters. This detailed study is basic in evaluating the potential predatory impact of the various species and determining corresponding variations in relation to the different stages of the life cycles of species in these zoological groups.

To provide population dynamicists and environmental scientists with information which can be used to monitor the environment more efficiently and to predict the variation in stock size and recruitment in marine fish populations, the approach at the La Jolla Laboratory is to rear coastal pelagic and recreational fishes from eggs through metamorphosis on artificial diets, determining the essential nutritional factors needed for larval survival. A description of the temporal events in larval fish development is in progress with emphasis on systems essential for capture of food and avoidance of predators.

Among the major advances made in these areas during the past 2 years was the successful rearing of the northern anchovy through metamorphosis on laboratory cultured foods. This was the culmination of a series of rearing studies at the La Jolla Laboratory designed to develop culture procedures for rearing anchovy larvae; in the past, anchovy could not be reared past about 20 days on cultured foods.

In 1970 Kramer and Zweifel recorded the growth of anchovy larvae at 17 and 22° C for periods up to 35 days, at which time the larvae reached an average length of 17 mm. In their experiments, larvae did not reach metamorphosis which occurs at about 35 mm. The larvae were fed wild plankton supplemented by brine shrimp nauplii, *Artemia salina.* In the ensuing years culture techniques using laboratory cultured foods for larval anchovy gradually developed: the dinoflagellate, *Gymnodinium splendens,* for the first 5 days (Lasker, et al.); the rotifer, *Brachionus plicatilis* (Theilacker and McMaster), to about 20 days during which time the fish grew to about 10 mm. During the last year, John Hunter and Carol Sanchez were successful in culturing the copepod, *Tisbe furcata,* which supplied the missing link, that is, provided a food other than *Artemia* for larvae older than 20 days (greater than 10 mm). In all previous attempts, larvae gradually died when fed *Artemia* (the so-called "*Artemia* syndrome") and what remained to be done was to find a cultured food that could be used for larvae larger than 10 mm. Foods used to rear anchovy larvae to metamorphosis included *Gymnodinium, Brachionus, Tisbe,* and *Artemia.* Metamorphosis occurred 72 days after hatching at a rearing temperature of 16° C.

The Pacific mackerel, *Scomber japonicus,* was also successfully reared from the egg through metamorphosis by Hunter and Sanchez. This is the first time mackerel have been reared through metamorphosis on a laboratory cultured food, under controlled conditions. At the age of 18 days the larvae had become juveniles and had an average length of 17.8 mm. Eggs were obtained from a laboratory population of mackerel brought to breeding conditions by Roderick Leong.

In a related study, Hunter also conducted a starvation experiment designed to determine how long newly metamorphosed anchovy larvae can survive without food. The experiment demonstrated that newly metamorphosed anchovy can withstand a starvation period of 12–15 days whereas those that had not completed metamorphosis cannot. Lipid content of the fish during starvation declined 30% of dry weight to 12% of dry weight but recovery for surviving fish was rapid as they returned to the 30% level after 5–8 days of feeding. The fat content of newly metamorphosed anchovy was comparable to that of

adult anchovy during the summer and fall when gonadal fat is low. Hunter concluded from this study that the extreme vulnerability to starvation characteristic of the larval phase is over by the time the fish pass metamorphosis.

Possible Energy-Sparing Mechanism Discovered for Larval Anchovy

Mechanisms that reduce activity and thereby conserve energy are probably important in the survival of larval fish. Two such mechanisms have been studied on the northern anchovy: 1) kinetic behavior which results in reduced swimming speed in areas of high food concentration, and 2) the effect of temperature on activity. The reduction in activity associated with lower temperatures, however, may be offset by slower growth rates which may increase the exposure to predation. Another possible energy sparing mechanism was discovered by Hunter and Sanchez when they examined in the laboratory the extent of inflation of the gas bladder as a function of time of day and larval length.

They found that northern anchovies 12 mm long inflate the gas bladder at night and deflate it in the day. At night larvae were found to have greatly distended gas bladders which often were so large that they partially constricted the gut, whereas by 2–4 hours after the onset of light the bladders were deflated. At night an obvious gas bubble was present in the bladder; during the day it was absent. At night larvae appeared to be suspended motionless in the water, whereas during the day they were continually swimming and feeding. The most tenable explanation for this diel change in the inflation of the gas bladder is that it permits the larva to adjust its buoyancy to neutrality at night and consequently to conserve energy. The work of a Japanese scientist on another species of anchovy demonstrated that anchovy show the same behavior in the sea.

Also in progress are studies on the effect of prey size on the feeding behavior of larval anchovy and Pacific mackerel. These studies are designed to determine the relationship between size of mouth of the larva and the maximum prey it can ingest and the prey size it can ingest in quantity. Laboratory and field work indicate that the size of food required by a larva increases as the larva grows, and if food is less than the optimal size, growth slows and mortality occurs. Preliminary data indicate that anchovy and mackerel larvae require a prey having a width of about ¼ to ⅓ the mouth opening at the time of first feeding and one about ½ to ⅔ the mouth opening thereafter. These data also suggest that larvae after the first few days of feeding are able to capture prey that are nearly as wide as their mouth but do not take them in quantity unless the prey width is ⅔ the mouth opening or smaller.

CalCOFI System Review and Analysis

Data collections by CalCOFI have been made for many years in the California Current Region (15–40 years, depending upon particular time series). These include catch and age data on specific wetfishes; sea survey data on juveniles and adults; spawning surveys; physical and chemical oceanographic data; plankton surveys, temperature, and tidal data; and upwelling and transport data. At year's end computer runs of 25,000 CalCOFI time series (1951–1969) of sized larvae of northern anchovy and Pacific sardine were completed. A second series of tables is being created which is corrected by current estimates of the known biases in the collection technique. Specimens of recent data are also available for jack mackerel, Pacific mackerel, and Pacific hake. These data are used for determining mortality rates and spawning biomass of these pelagic fishes.

Manual of Methods for Pelagic Fish Egg and Larva Surveys

A 350 page manual of methods titled, "Standard Techniques for Pelagic Fish Egg and Larva Surveys", edited by Paul Smith has been completed under contract with the FAO of the United Nations in Rome. The text of the manual, based on materials presented during a training course on larval fish at the La Jolla Laboratory, includes two sections—one on the practical aspects of conducting an egg and larva survey and one on the theoretical basis for interpreting the survey data. The recommendations include use of a simple bongo net in a slow, oblique tow for optimum economy of operation and capture and retention of fish larvae. A bibliography of surveys and larva and larval identification has been assembled, as part of the manual. The bibliography has been indexed to taxonomic groups and geographic regions.

Automated Hydroacoustic Data Acquisition and Processing System

A technical need exists for the development of an operational hydroacoustic tool for assessing pelagic fish stocks. The collection of large amounts of sonar target data, necessary for the isolation of sampling errors and biases associated with acoustic assessment methods, has meant subjective logging by hand, accounting and processing procedures aboard the NOAA research vessel, JORDAN, and at the laboratory in La Jolla, following a sonar cruise. During the present reporting period, an automated sonar data acquisition and processing system was developed at the La Jolla Laboratory by John Brown and Rodger Hewitt, with the cooperation of the Naval Undersea Center in San Diego.

The ship's speed and time are recorded with each target and used to calculate the area surveyed. It is used in the data collection program to determine when an oceanographic station has been reached and to suspend data recording while on station. Start pulses continue to be counted, however, and the time at the beginning and end of the station is recorded.

In shipboard operation, the system requires no attendance. Prior to departure, the computer is started, and the hour counter preset to the current time. The sonar system is then started and may be left in operation 24 hours a day or turned off at night. At the end of the day (1600 hours), the data collection program is replaced by a general computational program. This program change is accomplished automatically from a prerecorded magnetic tape cartridge. The stored target data are reduced, summarized, and dumped into peripheral mass storage capable of holding the entire trip's collection.

The system was successfully used at sea during the first two in a series of six survey cruises conducted in 1975 (the CalCOFI station grid is occupied every 3 years on a monthly or bimonthly interval). Acoustic dimensions on 5,000 targets were tabulated over an area ranging from Point Conception, California, to Magdalena Bay, Baja California, and seaward typically 150 miles. While 50% of the schools detected are less than 50 m, it is believed that the northern anchovy is the predominant species sampled by the horizontally directed sound waves.

Photo analysis, using a method developed by John Graves, is also expected to yield independent information relating sonar measurements to school compaction. The development of a free-vehicle drop camera by D. Brown of the Scripps Institution of Oceanography has provided a new tool for fish school species identification.

Various system improvements are being planned which include an automatic variable threshold based on integrated volume reverberation, peripheral data storage, and a towed body transducer array. From the progress made thus far, however, it now appears that the goal of obtaining real time, biomass estimates of pelagic fish schools in the California Current region is feasible.

Cooperative CF&G–NMFS Research on Status of Fish Stocks

Strong State of California/Federal cooperation presently exists in the research, analysis and management of fisheries of common interest. Although past state/federal cooperative research in CalCOFI has developed a large amount of data on marine fish eggs and larvae, little is known about the factors that control survival from egg to recruitment. As an initial approach to this overall problem, a study and analysis of the current status of such California coastal recreational and commercial fish stocks as yellowtail, anchovy, bonito, and mackerel was undertaken in 1974 in cooperation with the California Department of Fish and Game. The principal researchers, Alec MacCall of CF&G and Gary Stauffer of NMFS concluded from their preliminary stock assessment work that the northern anchovy and jack mackerel are lightly exploited and should be able to sustain larger catches; the Pacific sardine and Pacific mackerel stocks are extremely depleted and show little indication of recovery; California barracuda is depleted and is now subject to a length restriction conducive to rehabilitation; conflicting evidence indicates that the white seabass resource is fully to over exploited; the California yellowtail is lightly exploited. This information is being used as a guide for future work and to determine if any of the stocks are in need of immediate management action.

Cooperative Fisheries Research with Mexico

The NMFS was represented by Reuben Lasker, Chief of the Coastal Fisheries Division at the La Jolla Laboratory, at the meeting of CalCOFI scientists who met in Mexico in June 1975 to discuss areas of mutual interest and possible collaboration in the study of anchovies in the California Current area. As a starting point, the establishment of four working groups was approved:

a) status of the anchovy stocks
b) acoustic surveys
c) egg and larva surveys
d) catch per unit effort

Other types of collaborations discussed at this meeting included FAO Fellowships at the NMFS Southwest Fisheries Center and scientific consultation by La Jolla Laboratory scientists in Mexico.

Lending urgency to these informal cooperative research efforts was the announced intention at year's end of the Mexican government to take 500,000 tons annually of northern anchovy for processing into fish meal.

Brian J. Rothschild

REVIEW OF THE PELAGIC WET-FISHERIES FOR 1973

Commercial landings of pelagic wet-fish species increased both in 1972 and 1973, due mostly to the growth of the anchovy reduction fishery (Table 1). Anchovy landings in 1972 were the second highest total since the inception of the fishery, and preliminary figures for 1973 indicate that a new record may be set. Although jack mackerel and squid landings were down slightly both years, they were about equal to the average tonnage for the previous 10 years. In accordance with the 1969 legislation which limits the sardine catch to 250 tons for bait use, only 186 tons were landed in 1972, and even fewer in 1973. The Pacific mackerel catch, also limited by law, has declined to its lowest level since the Department of Fish and Game began keeping records.

TABLE 1

Landings of Pelagic Wet-Fishes in California in Tons; 1964–1973

Year	Sardine	Anchovy	Pacific Mackerel	Jack Mackerel	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	96,243	311	23,873	158	12,295	133,101
1971	149	44,853	78	29,941	120	15,756	90,897
1972	186	69,101	54	25,559	63	10,081	105,044
1973	76	131,919	28	10,308	1,410	5,959	149,700

During 1972 there were 37 purse seiners and 10 lampara boats (not including those solely involved with live-bait fishing) which landed wet-fish species at California ports, although some were only occasional contributors. One purse seiner sank in November's rough weather with a full load of anchovies on board. All but one of the purse seiners were based in San Pedro or Port Hueneme; the remaining purse seiner and the majority of the lampara boats were based in Monterey.

The wet-fish fleet of 1973 was larger than that of the previous year, both in number of boats and in carrying capacity: 42 purse seiners and 11 lampara boats were involved in the fishery. Three of the new additions to the fleet have relatively large (200 ton) carrying capacities: two are converted tuna bait boats and one is a former Peruvian anchovy purse seiner built in the U.S.A. The overall increase in number and size of boats reflects the optimism with which the future anchovy fishery is regarded.

Northern Anchovy

For the 1972–73 reduction season the California Fish and Game Commission authorized a 110,000 ton quota: 10,000 tons for the northern permit area (from Pt. Conception north to the Oregon border) where the season opened on August 15; and 100,000 tons for the southern permit area (from Pt. Conception south to the Mexican border) where the season opened on September 15. When the season closed in both areas on May 15, 1973, almost 75% of the total quota had been filled: 75,520 tons had been landed (Table 2).

TABLE 2

Anchovy Landings for Reduction in the Southern and Northern Permit Areas in Tons From 1968–69 Through 1972–73

Season	Southern Permit Area	Northern Permit Area	Total
1968-69	25,314	2,736	28,050
1969-70	81,684	1,803	83,487
1970-71	81,420	608	82,028
1971-72	52,440	986	53,426
1972-73	73,176	2,352	75,528

As the season opened, fishermen were receiving $21.00 per ton of unprocessed fish. The price rose steadily all season and closed at $47.50, reflecting an increase in world fish meal prices. This increase was attributed to the drastic reduction of the Peruvian anchovy catch which, prior to 1972, had been the world's largest source of anchovy meal. Peru's anchovy population has dwindled considerably recently due to rapidly increasing fishing pressure coupled with the appearance of El Niño conditions.

A warm water influx also affected California in 1972 by bringing in great numbers of Pacific bonito and bluefin tuna. Hence the anchovy season got off to a slow start since fishermen concentrated their efforts on the more profitable large fish. But beginning in late December and continuing to the end of March, the weather was sufficiently rough to cause all fishing efforts to come to a standstill. An abrupt reversal took place in April: good weather prevailed, and the anchovies formed large, dense, readily available schools close offshore. During the last 6 weeks of the season, more than half the entire season's catch was landed at southern California ports. The canneries found it necessary to impose daily limits on the tonnage landed by each boat, in order to prevent accumulation of too many fish for the plants to process.

The 1973–74 season got off to a rousing start as anchovies remained plentiful and easily obtained. The 10,000 ton quota for the northern permit area was filled within 3 months, so on October 5, 1973, the Fish and Game Commission added an extra 5,000 tons to the quota, and moved the boundary between the northern and southern permit areas approximately 50 miles northward to Pt. Buchon.

At the beginning of the season, the price for anchovies was at an all-time high of $57.50 per ton. It declined gradually towards the end of the season to $41.00.

TABLE 3

Commercial Landings and Live Bait Catch of Anchovies in Tons; 1966–1973

Year	Reduction	Other Commercial	Live Bait	Total
1966	27,348	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	65,204	2,435	5,538	73,177
1970	92,955	3,288	6,105	102,348
1971	43,652	1,200	6,387	51,239
1972	66,617	5,868	5,850	74,949
1973	130,547	1,372	6,216	138,135

Live Bait

The live-bait fishery had a very successful year in 1972 (Table 3), with anchovies readily available to meet an increase demand for bait from sportsmen due to the unusual abundance of yellowtail. However, the 1973 season was less favorable. Although anchovies were present in sizeable numbers, their behavior was erratic, making them difficult to catch. There was a large proportion of "pinheads" (small fish-of-the-year) which are unsuitable for hook bait. Bait haulers agree that there were more young fish this year than in any previous season, an indication of a healthy anchovy population to be utilized in the near future.

Pacific Sardine

Protective legislation for California's sardine population remains in effect, prohibiting the take of sardines except under two circumstances: (1) as incidental catches (less than 15% by weight), or (2) as dead bait, since the law allows 250 tons to be landed each year for this purpose. Only 186 tons were caught in 1972, and less than 76 were landed in 1973. Most of these fish were found close to shore between Port Hueneme and La Jolla.

A new law will go into effect on January 1, 1974, which completely prohibits the taking of sardines for any purpose, except as incidental catches which may be used for canning or reduction only. Besides providing a moratorium on the commercial fishery, the law also sets forth a management plan for the recovery of the sardine population. When the spawning population of the northern stock reaches 20,000 tons (as determined by the California Department of Fish and Game), 1,000 tons may be taken, with increases as the spawning stock increases.

Jack Mackerel

Jack mackerel landings were down in 1972 mainly as a result of a shift in effort from mackerel to Pacific bonito and bluefin tuna. The fleet landed the major part of the year's mackerel catch between July and September when mackerel were plentiful around Cortez Bank. For the rest of the year jack mackerel landings were poor due to (1) scarcity of fish, (2) bad weather conditions, and (3) the abundance of bluefin and Pacific bonito which are more profitable catches for the fishermen. The year 1973 was an extremely poor jack mackerel year. Landings were scattered throughout the year, with only a few weeks of solid mackerel fishing.

The price paid to the fishermen by the canneries held steady at $80–85 per ton throughout 1972, and for most of 1973 it remained at $90–95 per ton. Late in the year, however, the price rose to $100. The fresh fish market price varied greatly both years though, fluctuating between $80 and $240 per ton.

Pacific Mackerel

A moratorium which went into effect in November 1970 limits the taking of Pacific mackerel to a 15% incidental catch in mixed loads of fish. The Pacifc mackerel catches for both 1972 and 1973 were quite small: 54 tons in 1972 and 58 tons in 1973. All the fish were from mixed loads of jack and Pacifc mackerel, usually caught at Cortez Bank. The 1972 year class seems to be a weak one, as in the preceding year, and although the strength of the 1973 year class is as yet unknown, it could be strong since part of the most recent good-sized year class (1970) has now reached spawning age.

Market Squid

Squid landings declined in 1972. Monterey reported very limited landings except in July, while southern California experienced a relatively good squid season. The year 1973 was an extremely bad year for squid fishermen since Monterey landings were minimal and southern California landings were poor.

Pacific Herring

Herring landings experienced a great upsurge in California in 1973. This was not due to any change in the status of the population, but rather to the introduction of a new market for herring. The fish are shipped frozen to Korea where the eggs are stripped from the fish and sold as a delicacy in Japan.

Of the 750 ton quota authorized for Tomales Bay during the 1972–73 season, 588 tons were landed before the California Department of Fish and Game closed the herring fishing season in that area. San Francisco, which had a 1,500 ton quota, reported landings of 434 tons. A new law has now gone into effect which allows 450 tons to be taken from Tomales Bay, and 500 tons from San Francisco Bay during the 1973–74 season.

Vickie Wine