AGENCY REPORTS

CALIFORNIA ACADEMY OF SCIENCES

July 1, 1975–June 30, 1976

In previous reports we have dealt with the major food items found in the stomachs of a number of species of fish of present or potential interest to fishermen along the California coast. Rather commonly, fishes large enough to enter the commercial fishery feed on marine organisms large enough to be identified by macroscopic observation, although owing to maceration during digestion, individual organisms may have to be identified through microscopic study of fragments (legs, eyes, antennae, or other recognizable parts).

However, in identification of the fish and macroplankton ingested by the commercial fishes under study, no attention has been directed specifically to a search for very small plankton (nannoplankton) which might have been ingested along with larger food. Murray and Hjort suggest in their classic book *The Depths of the Ocean* (p. 356) that these hard-to-get small plankton species may, because of their numbers, play a more important role than all of the others combined. It was accordingly decided to make a detailed restudy under the microscope of the stomach contents of the fishes involved in this investigation.

Briefly it may be stated that no nannoplankton was found, and with two exceptions, no phytoplankton whatever. The exceptions were two Jack Mackerel caught south of Catalina Island in May 1969; each contained among other items found in the stomach, one diatom *(Chaetophora* sp.). One of them also contained part of a blade of eel-grass.

The re-examination of stomach contents is not, however, considered fruitless. Negative information has a value of its own; and further, some additional organisms were found in the stomach contents of three species of fish from which they have not previously been reported by us, as follows:

Jack Mackerel (735 stomachs re-examined). Protozoa (Foraminifera); Jellyfish larvae; Bryozoa "cyphonautes" larvae; Copepod eggs; Ostracod larvae; Sagitta and their teeth; Appendicularia (*Oikopleura*); Hemicordate larvae; Cephalocordate larvae.

Pacific Mackerel (161 stomachs re-examined). Protozoa (Foraminifera, Radiolaria, Tintinnida); Ctenophores; Bryozoa "cyphonautes" larvae; Ostracod larvae; Crustacean (?) eggs; Crustacean "zoea" larvae; Gastropod larval parts; Chaetognath eggs; *Sagitta* and their teeth; Hemichordate larvae; Appendicularia (*Fritalleria*); Cephalochordate larvae.

Pacific Saury (91 stomachs re-examined). Protozoa (*Radiolaria, Foraminifera, Tintinnida*); Bryozoa "cyphononautes" larvae; Ctenophores; Copepod eggs; *Sagitta* parts and teeth; Hemichordate larvae; Appendicularia (*Oikopleura* and *Fritallaria*).

No new forms were found in the stomach contents of the Pacific hake or the market squid.

In those species in which re-examination yielded additional data, the number of kinds of organisms found has been increased as follows: Jack mackerel, 60 plus 9, or 69; Pacific mackerel, 60 plus 14, or 74; Pacific saury, 19 plus 10, or 29. In each case the ones found in the first examination may be regarded as dominant, since the ones discovered only on re-examination were scarcer and harder to find. It may further be concluded that the diet of all three species is essentially zooplankton, since in the specimens studied and restudied, phytoplankton is close to zero. It is clear also that the organisms reported in the first study are the dominant food in each case, since greater effort and higher magnification was required to find the forms added by restudy.

Robert C. Miller
Anatole S. Loukashkin

CALIFORNIA DEPARTMENT OF FISH AND GAME

July 1, 1975 to June 30, 1976

Sea Survey

Acoustic surveys conducted during the fall and spring indicated the central stock of anchovies to be at its lowest level since Sea Survey biomass estimates were initiated. The fall surveys produced an estimate of 740,000 tons off southern California and an additional 131,000 tons off northern Baja California. During the spring, 767,000 tons were detected off southern California and only 25,000 tons were located off northern Baja California. The fall estimate represents a 50% decline in stock size from the previous season while the spring estimate represents a 66% decrease from the previous year. Age composition data gathered during the year indicated the decline may have been the result of poor larval survival during 1974 and 1975.

Additional evidence of successful jack mackerel spawning during 1974 was gathered during fall and winter cruises. Jack mackerel were taken in 50% of the sets off southern California during the night-light cruise, the highest rate of occurrence in 25 years of this type survey. Additionally, they were captured in large numbers during trawling operations, further indicating the unusual strength of the 1974 year class.

Pacific mackerel were taken during most of the season but not in quantities large enough to indicate a strong year class. Originally it was hoped the 1974 year class would be as strong as the jack mackerel was but it appears that it will not be up to previous expectations.

During the year a joint venture between the Instituto Nacional de Pesca of Mexico, National Marine Fisheries Service, and California Department of Fish and Game was initiated to standardize acoustical survey methods. The final format for reporting data should closely follow the one developed in Sea Survey. Completion of the project should result in a more complete and effective assessment of the anchovy stocks residing in the California Current System.

Market Squid Study

The department, in cooperation with Sea Grant, continued to work on electrophoretic studies to determine genetic variations in market squid. Four cruises were scheduled to collect specimens for protein analysis. Preliminary work on the enzyme phosphoglucomutase (PGM) showed that there are five allozymes present and nine phenotypes represented. Comparing the phenotype distribution against Hardy-Weinberg equilibrium expectations, using the chi-square test, suggested that PGM is homogeneous throughout the range tested with the possible exception of La Jolla squid. This electrophoresis work and that of another laboratory will supplement the morphometric and morphological work conducted by Sea Grant in an endeavor to distinguish among stocks for proper management of the resource.

Pacific Mackerel

The department continued to monitor the Pacific mackerel population in response to legislation passed in 1972. Current regulations allow for incidental catches of less than 18% Pacific mackerel in mixed loads. Additionally, the legislature called for a limited fishery when the spawning biomass exceeds 10,000 tons.

During the summer and fall, 7,153 Pacific mackerel were tagged to determine population size. Subsequently, 97 tags were recovered from the partyboat fishery. Analysis of the data indicated mackerel did not mix with fish from adjacent areas. In light of this, no estimate was made since tags would have to be returned from throughout the range for the estimate to be valid. A localized estimate of 2,000 tons of spawning biomass was arrived at for Santa Monica Bay.

Tagging Pacific mackerel failed to provide a valid population estimate so a second technique independent of marking fish was used. The method called for an estimate of the ratio of Pacific mackerel to jack mackerel in cannery landings. Since the size of jack mackerel population is known, it was then possible to estimate the size of the Pacific mackerel by extrapolation. Using this method, an estimated 5,000 to 11,000 tons of spawning biomass was present. Since the mean was 8,000 tons, no fishery was recommended in 1976.

Stephen J. Crooke

MARINE LIFE RESEARCH GROUP SCRIPPS INSTITUTION OF OCEANOGRAPHY

July 1, 1975, to June 30, 1976

The Marine Life Research Group continued to carry out a wide range of research, related to the California Current and other regions as well. The second half of 1975 saw the completion of the triennial CalCOFI cruises, which are used to monitor the pulse of the physical oceanography and pelagic fish status in the California Current. In addition to measurements normally collected in the pelagic region, many stations much nearer shore were occupied to collect data tying the nearshore and pelagic regions together, and to improve understanding of the sport fishes' relationship to the pelagic fish.

A new ship the NEW HORIZON, primarily for the Marine Life Research program, has been approved by the University and the State of California. It will replace the ALEXANDER AGASSIZ, which was acquired in 1961 from the military reserve fleet and converted by MLR for use primarily in the CalCOFI program. The new research ship should be constructed in time for the CalCOFI cruises that begin in December 1977. Its research capability will be much greater than that of the AGASSIZ, and it will therefore increase the types of research that can be carried out by Marine Life Research.

Continued cooperation with the Instituto Nacional de Pesca in Mexico and student participation from the Escuela Superior de Ciencias Marinas at Ensenada, Baja California, have been an important part of the MLR cruises and of CalCOFI research in the California Current.

The following are brief reviews of the research by various members of MLR.

Last year's study of the seasonal range of sea elevation off northern Baja California has been extended to include the west coast of North America, the Aleutian Islands, and Kamchatka. Reid and Mantyla observed that coastal sea elevations measured at tide gages in the northern North Pacific show a seasonal high in winter (November–February). This high is well out of phase with the midocean response of the sea surface elevation to the heating and cooling cycle, which produces greatest elevations in July–October. It has been found that sea surface elevation near the coast varies seasonally in phase with measurements at tide gages and that high elevations in winter are a consequence of the circulation of the subarctic cyclonic gyre of the North Pacific Ocean—that is, the California Countercurrent, the Alaska Current, and the Kamchatka Current. The flow of the coastal limb of this gyre (along the eastern, northern, and western boundary of the ocean) is intensified in winter, and in geostrophic balance the sea surface slopes upward toward the coast, accounting for the winter rise. Along these coasts the sea surface stands

about 14 to 30 cm higher in winter than in summer, while in midocean the sea surface stands about 6 to 8 cm higher in summer than in winter. Reid and Mantyla propose that sea elevation along the eastern boundary does not slope uniformly downward from the equator toward higher latitudes but has several maxima and minima. These appear to be the consequence of sea surface slopes associated with the quasi-geostrophically balanced system of cyclonic and anticyclonic gyres in high and middle latitudes and zonal flows near the equator.

There has been a continued study of eddies in the California Current by Schwartzlose. This last year a cruise on the AGASSIZ to examine an eddy was successful. An eddy was found at exactly the same location where one was found in 1957. While the eddy reported earlier was cyclonic, the recent cruise found a strong anticyclonic eddy. Measurement of temperature and salinity within the first 100 m did not show the effect of the eddy, but it was shown clearly by movement of parachute drogues near the surface. At 200–400 m temperature and salinity measurements gave evidence of the eddy, and there were some indications of it to a depth of more than 500 m. The eddy persisted at the same position for at least 3 weeks. This is an area where the California Current swings shoreward and divides, part going into the Southern California Bight and part going southward along the Baja California coast. This area also is a region of warmer, more tropical water pushing northward beneath the surface into the California Current.

Patzert has continued his work with the El Niño cruise data. Analysis of data confirms the preliminary evaluation that the El Niño disturbance was not confined to the surface layer, but extended as deep as 300 m. An atlas with various physical, chemical, biological, and meteorological data presentations is now in preparation. Some results of the El Niño Expedition were published in *Science.*

Evaluation of near-bottom current meter data obtained during the expedition has revealed exciting results. While hydrographic observations were indicating El Niño activity off the South American coast, the current meters (located near the equator, 300 km west of the Galápagos Islands) recorded a 25 day period oscillation of about 1000 km wave length and 4 cm/sec amplitude propagation westward at approximately 50 cm/sec. These characteristics agree with theoretical models of a first-mode baroclinic Rossby wave trapped at the equator. A paper describing these results has been accepted by *Science.*

During 1976, plans have been developed to initiate a long term monitoring network in the central Pacific Ocean. This network will be a shuttle between Honolulu and Tahiti utilizing ships, aircraft, moored current meters, drifting buoys, and island stations to monitor the low-frequency (months to years) fluctuations of the equatorial Pacific oceanic circulation in order to understand its dynamics. One of the ideas motivating this effort is the possibility that tropical oceans appear to be areas where ocean-to-atmosphere coupling may play an important role in short term variability of atmospheric climate, particularly in the Pacific Basin.

Hemingway has continued his studies into the functional morphology of feeding in marine predatory gastropods. He also organized and carried out a project of collecting plants and animals of the intertidal zone along the west coast of Baja California, Mexico, an area where our knowledge has been limited. Students and faculty from the Marine Science School in Ensenada, Baja California, particpated in this project.

The systematics and distribution of the deep-sea fish family Searsidae, and the young stages of two of these species, have recently been studied by Matsui. The larvae are large, measuring 9–16 mm in length during the yolk-sac stage. In the two commonest species from the eastern Pacific, the length decreases from 15–16 mm to about 11–13 mm while the yolk-sac is absorbed. The smaller sizes at the yolk-sac absorption stage are generally not too advanced and are emaciated. The larvae are collected over the same depth range as older stages, which is approximately 300–900 m.

In the family Searsidae we recognize 16 genera and 22 species; 3 genera and 4 species are new. These are relatively rare fishes that have been collected most frequently in areas of high productivity. It appears that oxygen content is a significant factor in the distribution of species; this is reflected in the degree of development of gill filaments.

Examination of phytoplankton from the central North Pacific Ocean has continued. Venrick, Beers, and Heinbokel completed a study on the effects of enclosing natural assemblages of microplankton in 250 ml bottles, a procedure universally employed for the determination of "simulated *in situ*" physiological rates such as primary productivity. Very striking changes in the composition of the assemblages occur within periods as short as 6 hours. Within 24 hours most of the taxa decrease in abundance and some microzooplankton components vanish completely. A most important finding of this study is that direct extrapolation of physiological measurements made on contained populations to populations in the field may not be valid.

A series of chlorophyll and productivity measurements were taken on *Indopac I* along an east-west transect across the Pacific. In addition to giving broader scope to intensive measurements made at 28°N, 155° W during the past several years, the data will be used to examine the hypothesis that mesoscale and megascale eddies enhance nutrient transfer into the euphotic zone, thereby stimulating primary production and increasing standing stock of phytoplankton.

Brinton and Knight have continued their studies of aspects of development and population ecology of euphausiid crustaceans ("krill"). These include behavioral means by which such planktonic animals conserve their stocks in a drifting milieu, maintain permanent ranges, breeding grounds, and access to adequate food resources. Regions of study are the diverse, overlapping habitats of the California Current and the Eastern Equatorial Pacific, contiguous to the south. Here, fertile and impoverished zones and O_2-rich and O_2-deficient waters abut, but all harbor characteristic populations. Evidently, species which undergo daily vertical migrations of several hundred meters, daily occupy currents of different speeds and directions, whereas nonmigrating species are vertically positioned at intermediate or greater depths, so as to maintain regional stability. Different life stages appear to live at different depth levels. Such ontogenetic changes in habitat—vertical and regional—are being investigated with respect to development and survivorship for the more accessible euphausiid species.

The study of larval development of the three species of the genus *Euphausia* which comprise the "*E. gibboides* group" is almost complete; illustrations and description of the growth stages of *E. fallax* are being prepared, those of *E. sanzoi* and *E. gibboides* are, respectively, in press and published. These species were studied as a group to investigate the relative importance and usefulness of an array of larval characters while providing a key to their identification in the plankton. The available descriptions of *Euphausia* larvae are for the most part based on overall size and general body plan, features which may separate very different species in one area but which may not be sufficient in waters in which similar congeners or members of a species group are found together. A detailed examination of the morphology of larval appendages and a comparison of body proportions as well as size and form have shown that certain features do vary consistently between species within species groups permitting positive identification of early stages, usually the most difficult to separate. The identification of the larvae of *E. fallax,* which are sampled more frequently than the adults, has expanded the distribution of the species to areas within the Indian Ocean; previously it was known only from Southeast Asian seas.

The study of evolutionary trends in planktonic copepods as expressed by morphology, distribution, and behavior is being continued by Fleminger and Hulsemann. The principal approach is to test character divergence against geographical relationships among congeners in two groups of calanoid copepods, the genus *Labidocera* (family Pontellidae) and the genus *Calanus* (family Calanidae). Among a number of interesting developments during the year was the discovery of an unusually large number of speciation events within a planktonic genus occurring in the western tropical Atlantic and centering in the West Indies. The *wilsoni-mirabilis* lineage in the genus *Labidocera* has apparently radiated most extensively in the southern Caribbean as indicated by finding four new species, each from a different geographical locality within the region. Species of this lineage occupy surface waters protected from extensive offshore advection along tropical coastlines, around islands, and over shallow offshore reefs. This particular planktonic habitat has been too sparsely sampled in the Caribbean to judge the total diversity achieved by the *wilsoni-mirabilis* lineage. However, considering the ranges of the six species now known, two unique features appear to have generated the unusually high number of closely related species for so spatially restricted a region as the Caribbean. The unique features, hydrography, and a parasitic fungus, have been incorporated in a hypothesis to explain the unprecedented high diversity for a zooplanktonic taxon. Several new collecting expeditions have been scheduled to determine the extent of this swarm of species and to test the hypothesis. The results should illuminate processes of speciation and morphological divergence in planktonic crustaceans.

Mating in *Labidocera* was examined microscopically for the first time. Individual observations were made on about forty pairings of *Labidocera jollae* and one pairing of *Labidocera trispinosa,* both inhabiting coastal Californian waters. The observations confirmed speculations on the functioning of sexually modified morphological features in both sexes. Comparison with mating patterns in a related family provides a basis for understanding the adaptive significance of morphological differences distinguishing the two families. Sites of spermatophore attachment on the female abdomen (*Labidocera*) were discovered to be characterized by intense concentrations of integumental glands. Comparisons between sets of species differing within geographical relationships showed a pattern of interspecific variation attesting to the importance of these glands in barriers to interspecific hybridization.

Studies on the taxonomy and distribution of *Calanus* were highlighted by resolving questions about the North Atlantic distribution of *Calanus helgolandicus.* A reproductively active population of *helgolandicus* was found in shelf and slope waters of North America living between Cape Hatteras and the New York Bight. This population provides a source for the previously unexplainable sporadic records of the species across the North Atlantic Drift. Comparison of North Atlantic and North Pacific *Calanus* distributions and interspecific morphological divergences indicates fundamental differences in the distribution of *Calanus* habitats in the two oceans, qualities that reflect differences in

circulation patterns of high fertility waters of the mixed layer between the two oceans.

Information on the marine environment recorded in varved anaerobic sediments off the west coasts of North and South America is being examined under John Isaacs' direction by Andrew Soutar, Stanley Kling, and Peter Crill. In such accumulations where disturbance by burrowing organisms is essentially lacking, a faithful time series of various biological and geochemical variables can be resolved to approximately annual scale. Past work has shown that climatic information expressed in such measurements as temperature and rainfall is reflected by physical characteristics (e.g., variations in sediment thickness) and the flux of biological remains (fish scales, foraminifera, radiolarians, diatoms, and coccoliths). Man's impact on the environment has been imprinted via trace amounts of various chemicals (e.g., mercury, lead, and halogenated hydrocarbons). Such results suggest inquiry into the sedimentary record for clues to understanding the present environment. The cumulative nature of the record aggregates seasonal fluctuations in a way not practically obtainable by conventional shipborne sampling techniques (plankton nets, water samples, etc.). Comparison of cores from the Santa Barbara and Santa Monica Basins, for example, reveals a biological imprint characteristic of each basin. A locally characteristic dominance hierarchy in radiolarian assemblages is consistent over the last hundred years such that at no time does either basin come to resemble the others.

While the importance of high resolution sedimentary records as a sampling technique thus becomes apparent, the limited geographic distribution of natural occurrences (a few isolated areas in the world, primarily in high productivity regions) restricts their regional applicability. Accordingly, devices to simulate a sedimentary record are being developed. A newly designed particle interceptor trap is being built to acquire and preserve large samples of settling material under geochemically clean conditions. Traps are to be moored at various levels in the oceans for periods of several months and retrieved upon timed or acoustic command release. The technique outlined could be calibrated as a device for monitoring the marine environment. Samples from an earlier prototype give results consistent with records obtained from underlying sediments.

A scanning densitometer to measure and record varve thickness from X-rays of sediment cores has been built with control functions assigned to a microcomputer. The computer is also available for other data acquisition and analysis functions. A small portable keyboard, for example, has been set up as a tally counter of virtually unlimited capacity for recording individual observations. The device has proven to be more efficient than mechanical counters, and, in addition, eliminates the time consuming and error introducing step of keypunching manually recorded data.

The development of new instruments as discussed above to collect or process data for various projects continues to be an important part of MLR. Not all development projects are for the MLR research staff, but they usually are devices which will benefit MLR research. The MLR machine shop, under Duffrin, has been working on the sediment traps and improvements in the box corers for use in the varved sediments research.

Brown has developed and has in operation three new devices: the decade sampler, the manta net, and the magnetic release and actuator.

This decade water sampler was designed to measure microstructures. It does so by closing ten 450 ml water samplers simultaneously when activated by a messenger. The unit is 2 m in length and is deployed on a hydrographic wire. Particular attention was paid to having no contamination problems inherent in the design; thus, the sampler works essentially like a big suction gun. It was realized that an additional type of sampling might be possible with such a device, namely the sampling of unconsolidated sediments or nepheloid layers on the bottom of the ocean. The decade sampler was thus designed to operate as part of a free-vehicle system. In the free-vehicle mode it could go to the ocean floor, remain on the mechanical bottom for a number of hours to allow the sediments to come to equilibrium again after being disturbed by the landing of the sampler, take a sample, and return to the surface. In this manner, a closely spaced series of water and/or unconsolidated sediment samples could be taken with a known distance from the bottom. The design is such that additional collectors can be added between each of the others; thus, the spacing and number on the frame is adjustable.

The sampler has already yielded information on the microstructure of the chlorophyll maximum layer, showing it to be made up of layers a few centimeters thick of phytoplankton in the area off southern California.

The surface of the sea has come under increasing study as the importance of this interface with the air has come under closer scrutiny. A surface skimming net was devised to sample this surface layer in a manner not achieved by earlier neuston net designs. The objectives were to sample surface water quantitatively, keeping the scare effects to a minimum and being a surface follower. These requirements were met by the design of the manta net. Bongo nets, which have a 220 cm circumference, are used as the filtering part of the net and are towed by a frame with unique properties. The frame is steered by two paravanes to keep the net away from the ship so that it tows free of any scaring effects of either the ship wake or bow wire. A special wire bridle achieves the necessary steering angle, and two wings support the frame on the surface of the water

like hydroplanes. The towing forces on the frame come from a submerged towing weight and bridle so configured as to keep the mouth of the net always on the water, no matter what the state of the sea or the speed of the ship. The submerged towing bridle also reduces the scare effect on the surface creatures, and the paravanes aid in the catch, as they keep the animals from escaping to the side of the net. This is the same action achieved by manta rays when they are feeding on the surface with their mandible extensions protruding ahead of their mouths, hence the naming of the net. The flow through the net is measured by a flow meter.

Catch results have been very gratifying, and have yielded some surprises in the kinds of small fish and squids that have been captured on the surface, even during daylight tows.

The problem of operating instruments in deep ocean waters is a source of constant concern. The magnetic release system transmits the force of a magnet from inside a pressure vessel to an outside keeper, holding the keeper in place. Upon the closure of a switch inside the vessel, the magnet is made to move and release its grip on the outside keeper. A trip hook attached to the keeper then activates the desired function. Thus, electrical systems are never exposed to the water or pressure since they are contained in the pressure vessel. Only magnetic force is transmitted by steel bolts through the pressure wall. All outside mechanisms are mechanical in nature and are not affected by water or pressure.

The first generation of magnetic releases was designed for use with a variety of free-vehicle systems, such as the pressure fish trap. Development problems revolved mostly around corrosion problems associated with using steel and aluminum in seawater. It was this problem that probably thwarted earlier development and caused some early failures. The corrosion problem was solved, and now the releases offer a whole new system of actuating underwater devices.

The opening/closing midwater trawl now uses this sytem which has eliminated all failures that might result from leaking wires, connectors, and solenoids. The bongo net now has a new magnetic mechanism to open and close the net without use of messengers. As a nonexplosive device, the release is a much less expensive unit to use for many free-vehicle systems since it requires no careful assembly, operation, or check-out system. Even rotary motion has been transmitted through the pressure wall and has been used to govern the movement of a drum on a large sediment trap.

The concept has now opened up a whole new way of activating underwater equipment.

During the past year the Ocean Technology Group under Sessions has been engaged in several programs. An improved digital-recording, free-vehicle current meter has been developed to extend the endurance of missions up to 6 months and overcome the data processing problems attendant to the large increase in capacity of information stored within the instrument during long term deployments. A solid-state flux-gate compass was developed for this instrument to remove the problems related to mechanical compasses common to our present day current meters. This current meter also incorporates hardware to permit placing the instrument in mooring lines of moderate loads without stressing the instrument.

A computer based data reading and editing capability has been developed to permit timely reading and processing of data recorded by current meters and other instruments which use this magnetic recording technique. This system is fully operational and permits the reading of several months of data in less than 15 minutes directly into the computer for automatic processing.

In order to overcome the shortcomings of most ocean current meters for near-surface measurements, this group has developed a new type of current meter utilizing a propeller with excellent characteristics. Much of the electronics are the same as the digital-recording, free-vehicle current meter, and several prototype units have been constructed for use in near surface profiling and mooring applications.

Acoustic recall of free vehicles has been developed and successfully tested. Several systems are now deployed in the equatorial Indian Ocean for durations of 4 months.

A low drag flotation package and mooring system has been developed for current meter measurements in high velocity equatorial regions. These systems are now operational and were installed early this spring on the equator by our group. A continuing program of operation for the next year is planned to keep at least two instruments in place at all times in order to obtain a continuous long term current record from the equator at a depth of 500 m.

A NORPAX program of measuring the thermal structure in the North Pacific Ocean in a north-south direction between Alaska and Hawaii utilizing U.S. Navy Fleet aircraft has been conducted for the past several years. Monthly flights between Adak and Honolulu and the onboard recording of data have been successfully maintained throughout the year by this group.

Instrumentation for the performance monitoring of the Tethered Float Breakwater program was designed and installed in support of the bay scale model during the past years. Data was continuously monitored over an approximate 8 month period and automatically recorded when events of significant magnitude, such as storms, occurred. These data permitted detailed analysis of actual sea performance of a large, scale model array. In addition to the Breakwater monitoring program, a

general low cost wave monitoring network was conceived and used much of the hardware developed for the Breakwater program. Four stations were installed between Oceanside and Imperial Beach with data being automatically recorded twice daily at our central computer site. This information is computer processed and disseminated promptly on a monthly basis to interested agencies. This system is highly automated and designed to demonstrate the feasibility and economics of operating a network which can be expanded to provide very large area coverage.

Joseph L. Reid

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES CENTER LA JOLLA LABORATORY

July 1, 1975, to June 30, 1976.

Fisheries research devoted to the objectives of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) continues as a central coordinating theme in the overall program of the National Marine Fisheries Service (NMFS), Southwest Fisheries Center (SWFC) laboratory in La Jolla, California, as it has for the past three decades. Under Reuben Lasker, Leader of the Coastal Fisheries Resources Division at the La Jolla facility, research emphasis has been placed on the causes of larval fish mortality and its effect on recruitment, areas of study increasingly perceived by fishery biologists as fundamental in solving problems of fishery biology.

The report which follows recounts highlights of work accomplished by the Coastal Fisheries Resources Division and records CalCOFI research activities undertaken at the La Jolla Laboratory.

During the above period a number of fruitful areas in larval fish research were investigated at the La Jolla Laboratory, notably the following: histology of starvation of larvae; oceanographic changes which affect the distribution of larval fish food; the determination and analysis of the kinds of food and feeding by larval northern anchovy, jack mackerel and Pacific sardine; analysis of mortality rates of northern anchovy embryos and larvae from 1951–1969 using CalCOFI data; the development of techniques for assessing the suitability of various water masses as feeding grounds for fish larvae; an investigation into invertebrate and vertebrate predators of fish larvae; simulation modeling of larval anchovy growth, behavior and prey microdistribution; the application of otolith-aging techniques to larval anchovy growth studies; and food chain studies of pesticide uptake by larval anchovies. All of these studies have been aimed toward understanding how pelagic fish larvae interact with their environment; ultimately, the data are intended to help explain the all-important stock and recruitment relationship.

Causes of Anchovy Larval Mortality

This year saw the culmination of several lines of research on larval fish. The work of Reuben Lasker and Paul Smith provided first order estimates of distribution, abundance, growth and survival rates of northern anchovy larvae and showed how this information could be used to analyze the causes of anchovy larval mortality.

By examining seasonal and annual variations in the degree of anchovy spawning against sea surface temperature, vertical temperature gradients, upwelling, the speed of the California Current, the flushing rate of the Los Angeles Bight and secondary production, they showed that the usual habit of the anchovy to spawn heavily in the southern California area in winter alters radically in some years. Results indicated that spawning appears to be a simple function of the biomass of adults and the annual record reflects little more complexity than the rapid increase in anchovy biomass over the past 25 years.

Lasker has now developed supporting evidence for his recent hypothesis that upwelling events and storms in the California Current are detrimental to anchovy larvae by diluting concentrations of their food. He has shown, for example, that the advent of storm systems and turbulent mixing of the upper 100 m during the month of March 1975 diluted the larval anchovy's food organisms to a degree where there was not enough food left to sustain first-feeding larvae in their natural environment from March through April. As a result, he predicted that the 1975 year class of anchovy had to be a very poor one, based on the occurrence of massive upwelling in the Los Angeles Bight during the anchovy spawning season and the poor nutritional content of the dominant larval fish food organism, *Gonyaulax polyedra,* present before upwelling occurred. This view has been borne out by subsequent fishery analysis by the California Department of Fish and Game.

Larval Fish Studies in New York Bight

Under a grant from the Brookhaven National Laboratory of the Energy Research and Development Administration (ERDA), Lasker and Scura began studies of the larvae of winter flounder, *Pseudopleuronectes americanus;* summer flounder, *Paralithchthys dentatus;* and scup, *Stenotomus chrysops,* in the New York Bight with the assistance of Geoffrey Laurence of the NMFS laboratory at Narragansett, Rhode Island, and Kathryn Dorsey of the La Jolla Laboratory. The rationale for this study was Lasker's work in the Los Angeles Bight which had shown that there are areas in the ocean where organisms of the proper size for first-feeding larvae congregate (i.e., in chlorophyll maximum layers). Although conditions and species of fish are quite different in the New York Bight, it was believed that similar techniques could be used to locate suitable larval feeding grounds on the east coast. The research strategy was to search for aggregations of possible food organisms at sea, collect samples of

water from these areas and then introduce laboratory-produced fish larvae into the samples. If the larvae began feeding this would provide valuable clues as to the kinds and concentrations of food organisms necessary to characterize an area as a suitable one for larval fish survival.

Series of tests with first-feeding flounder, scup and anchovy larvae showed that, with certain modifications, each species could be used as a bioassay to determine whether feeding conditions in a body of water are suitable for a particular species of fish larvae. For example, it has been ascertained that anchovy larvae require approximately 280, 50-micron diameter particles a day, whereas flounders and scup are competent feeders on larger particles when they begin to feed and require only 10, 150 micron diameter or even fewer larger particles to satisfy their metabolic requirements.

It was shown that preference for certain kinds of food was evident in all species examined thus far. High levels of spiniferous dinoflagellates, *Ceratium tripos,* were ignored by flounder and scup larvae in the New York Bight during November and June, respectively, whereas nauplii and dinoflagellates (e.g. *Prorocentrum)* were taken by flounder, provided that the nauplii and dinoflagellates were in concentrations higher than 100/liter.

Scup preferred a smaller dinoflagellate, *Dinophysis acuminata,* to the larger *Ceratium* despite the predominance of the latter, while anchovy larvae in the Los Angeles Bight will not eat small diatoms, regardless of their abundance. An unusual finding was that scup larvae selected pine pollen grains, despite the extremely low concentration (0.01–0.04/L) of pollen in New York Bight water during June 1976.

Two instruments have been developed in conjunction with the studies of larval fish food patchiness in the New York and Los Angeles Bights to determine *in situ* concentrations of phytoplankton and microzooplankton (less than 1 mm in smallest dimension). A prototype model of a free-fall particle counter has been developed by John Brown of the La Jolla Laboratory and is scheduled for testing in the spring of 1977. This instrument is intended as a survey instrument for rapid measurement of *in situ* stratification and the distribution of particles by size throughout a 100-meter column. A dedicated computer accumulates numbers of particles per unit volume by 0.2 meter strata and by size of particle. The second instrument, already used successfully in the New York and Los Angeles Bights, was developed by Scura. It is deployed on a ship's hydrowire and provides information on relative particle distribution particle sizes between 50 and 500 μm) with depth using a rate meter. Water is delivered on board to provide specific particle concentrations when this is desired. The actual size and number of particles per unit volume is determined with a model Ta Coulter Counter aboard ship. Species composition is determined later in the laboratory from preserved samples with an inverted microscope.

Microdistribution of Small Planktonic Organisms Used as Food by Fish Larvae

Under the leadership of Lasker and Owen, an interdisciplinary multi-ship cruise was conducted in March 1976 with the NOAA research vessels, DAVID STARR JORDAN and TOWNSEND CROMWELL, to study the microdistribution of small planktonic organisms used as food by fish larvae in California coastal waters. Samples taken during this cruise with a 10-bottle vertical sampler have been analyzed by Owen for fine-scale depth differences in phytoplankton concentration, phaeophytin, detritus and microzooplankton patchiness. Because of the small distance first-feeding anchovy larvae can travel, this fine-scale distribution in their food may be a critical factor in larval survival. Owen found, for example, that adjacent bottles, 0.2 meter apart, can differ in phytoplankton content by as much as two times in the chlorophyll maximum layer. Horizontal patchiness was also investigated by constantly sampling with a plankton pump from two ships simultaneously as the ships approached one another.

Life Studies: Larval Fish

Basic to the objectives of the La Jolla Laboratory's Coastal Fisheries Resources Division is the ability to mature and spawn at will important pelagic marine fishes to provide fish eggs and larvae for laboratory experiments. Five important species have been successfully matured and spawned in the SWFC aquarium—the northern anchovy, Pacific sardine, Pacific mackerel, striped bass and Gulf croaker. During the past year, Roderick Leong of the La Jolla Laboratory, submitted a paper to the Fishery Bulletin describing the maturation of captive Pacific mackerel under different light-temperature conditions, the effectiveness of various hormones for induction of spawning, and a procedure for spawning mackerel on demand throughout the year. All of the experimental work on larvae at the Southwest Fisheries Center now depends on these techniques developed by Leong to provide living material.

Developments in Studies of Physiology of Fish Larvae

To provide the physiological information essential to an understanding of how much food fish larvae require in the sea, Hunter, assisted by Carol Sanchez, completed a study of the incubation time, rate of yolk absorption, onset of first feeding, and the effects of starvation on the survival, growth and food size requirements for Pacific mackerel larvae. Hunter and Sanchez determined that in order to survive and grow, Pacific mackerel larvae must feed on progressively larger prey as they grow, unlike the anchovy which can maintain itself on small particles until it is 6–7 mm in size.

Of particular interest were the findings on the vulnerability of first-feeding Pacific mackerel larvae to starvation. It appears that mackerel larvae must find food between 90 and 108 hours after hatching or between 40 and 58 hours after they absorb their yolk and begin to search for food. Although no larvae survived if fed 130 hours after hatching, they were able to eat one or more rotifers in a 4-hour period. The number of rotifers eaten, however, was about one-third of that ingested by unstarved larvae. Thus, starvation did not completely eliminate feeding behavior, but weakened the larvae to the extent that even at high food densities they were unable to eat a sufficient quantity of food to survive.

Hunter and Sanchez completed laboratory and field studies which demonstrated that >10 mm larval anchovies inflate their swim bladders each night and deflate them in the day. By swallowing air at the surface, the larvae could reduce their energy expenditure at night by floating and not swimming until the next morning.

Hunter also completed a study on the laboratory culture and growth of northern anchovy larvae. He found that growth in the laboratory on a number of cultured foods was equivalent to growth on a wild plankton diet. A significant finding was that *Artemia salina* nauplii could only be used as a food for larvae after the larvae had acquired a loop in their intestines as a precursor to the formation of a stomach. Without this loop, Hunter believes that the larvae do not retain the *Artemia* nauplii long enough to digest them and hence starve to death.

Hunter and Sanchez have also begun a study to determine the incidence of cannibalism and its importance as a source of egg and larval mortality in the anchovy. Examination of the stomach contents of adult anchovy captured in the areas of anchovy spawning indicate that the incidence of adults feeding on their own eggs ranged from 0 to 8% of the fish captured at night in a trawl sample. The number of eggs found in the stomach ranged from a single well-digested fragment of a chorion to over 700 eggs in good condition and obviously recently ingested. No larvae were found in any stomachs examined thus far although this was not surprising since laboratory work has indicated that digestion of the smaller larvae proceeds very rapidly (less than 2 hours) whereas eggs and especially the chorions may persist in stomachs from 6 to 8 hours. Recently ingested eggs could be staged and this work indicated that the fish had fed on the previous night's spawn rather than on those eggs released on the night of capture. This is of interest since ingestion of eggs at the time of spawning is more likely to be a density independent mortality whereas ingestion of the previous night's spawn is more likely to be density dependent mortality.

Otolith Aging Technique Developed for Fish Larvae

Until now it has been impossible to relate larvae taken in plankton nets to any criteria which could indicate what proportion of them are doomed to die. With the availability of an otolith aging technique for fish larvae developed last year at the La Jolla Laboratory, a method is now available to assess whether larvae in the ocean are growing optimally or not. D. Kramer, with the assistance of K. Plummer, recently completed a study of aging of anchovy larvae collected at sea by counts of daily increments on their otoliths. Although the larvae were collected at 15–16°C, the plot of size with age indicates that these 16°C larvae had a growth rate comparable to larvae reared at 14°C in the laboratory, indicating that food was limited for these larvae in the sea.

Histological Study on Effects of Starvation on Anchovy and Jack Mackerel Larvae

From a different point of view, Charles O'Connell has developed histological criteria for identification of starvation in early post yolk-sac larvae of the northern anchovy. This study is of major importance because it will make it possible to identify starving larvae in the sea, and thereby evaluate starvation as a cause of larval mortality. Eleven histological features were each graded on scales of poor to good, depending variously on the texture, shape and fullness of nuclei, cytoplasm, extracellular substance and cellular products and stores. The distribution of grades paralleled trends in survival data from this and other laboratory studies of the anchovy, demonstrating that conditions can be evaluated from histological parameters, which are largely independent of age and length over the range studied.

The order of importance of the histological features was estimated by a stepwise discriminant analysis. All 11 histological features were significant indicators of condition but those that best classified larvae as severely (irreversibly) emaciated, conditionally emaciated, or robust, were pancreas condition, trunk muscle fiber separation, notochord shrinkage, and liver cytoplasm. The discriminant analysis indicated that a larva should be evaluated on the basis of three or four features to insure a high percentage of correct classification to determine whether a larva was starving in nature.

Using a similar discriminant analysis, G. Theilacker has studied jack mackerel larvae and has found, as with the anchovy larvae studied by C. O'Connell, that the pancreas is significantly affected by food deprivation. The appearance of several other tissues in the mackerel larvae also seem to be related to starvation—brain nuclei becomes dark and shrink, muscle fibers separate, liver and gut nuclei are irregular and indistinct, and the kidney cytoplasm shrinks. Of these histological criteria, the changes in the pancreas, brain and muscle tissue seem to be consistent and the easiest to detect in starved larvae. An interesting finding made by Theilacker is that starvation may affect body form. Theilacker was able to relate five externally measured morphometric parameters to the histological features of starvation.

These morphological measurements may be a very sensitive diagnostic method (as well as less time-consuming than histology) for determining whether field-caught specimens of jack mackerel larvae are in a state of starvation.

Observations on Physical Condition of Anchovy Larvae

David Arthur, visiting scientist in the Coastal Division, has been studying the physical condition of all sizes of anchovy larvae using the relationship of body depth to length from CalCOFI samples from the years 1963 and 1965; 1963 was a very good year for survival of anchovy larvae while 1965 was a comparatively poor year. Arthur is attempting to correlate the distribution of larvae in good and poor physical condition with the oceanographic conditions for those years. Arthur has found that 6 mm larvae show differences in physical condition which can be correlated with the good survival years. He has also found striking differences in larval condition between very nearshore and offshore areas in the same year.

In a related study, Arthur has showed that there is a distinct difference in the number of microcopepods from onshore to offshore in the California Current. Twelve times as many nauplii per unit volume, on the average, occur near the shore as in the offshore zone. Highest densities found were 195/liter with an average of about 36/liter at those stations with the highest numbers. While the mass of an individual nauplius increased exponentially with increase in nauplius size, the numbers of nauplii decreased exponentially with size. A naupliar biomass maximum was found to occur with organisms 70 μm in width. Nauplii of this size are ingested at first feeding by sardine, anchovy, and jack mackerel larvae. According to Arthur, most larval fish have developed feeding tactics to utilize this small but important food resource at first feeding.

Mathematical Model Completed of Relationship Among Larval Anchovy Growth, Behavior and Microdistribution

A NOAA Research Associate in the Coastal Division until June 1976, W. Vlymen completed a mathematical model of the relationships among larval anchovy growth, prey microdistribution, and larval behavior, using as a base the extensive collection of anchovy larval data collected on CalCOFI cruises during the past 10 years. This simulation showed that nonlinear growth rates are functions of prey contagion, but that the highest growth rates do not occur at the highest levels of contagion, an unexpected finding.

Analysis of Potential Invertebrate Predators of Fish Larvae

Recognizing that a major cause of larval mortality may be the abundance of predators in the California Current region, A. Alvariño has been analyzing the plankton collections of the monthly CalCOFI cruises for 1954, 1956, and 1958 for Chaetognatha, Siphonophorae, Medusae, Ctenophora, Chondrophorae, and other zooplankters. Each species is identified, the number of individuals per species counted and measured. Data are also obtained on the number of organisms containing food in their digestive tracts. The food organisms are identified as well as their relative abundance in the sample. Alvariño has found that fish larvae, copepods and euphausiids appear in the digestive tracts of planktonic predatory species even though these prey may be absent or scarce in the same plankton collection. Sixty percent of the invertebrate predators found with food in their stomachs were found to have eaten fish larvae. Chaetognaths more frequently contain older larvae rather than yolk sac individuals. This may be because Chaetognaths digest yolk sac larvae very rapidly or that Chaetognaths can capture older fish larvae more successfully.

Mortality and Biomass Estimates for Commercial Pelagic Fishes

For almost 30 years, the Southwest Fisheries Center has participated in the California Cooperative Oceanic Fisheries Investigations with the Scripps Institution of Oceanography and the California Department of Fish and Game in determining the biomass of important commercial pelagic fishes by sampling their eggs and larvae through entire spawning seasons. Analysis of these results has also permitted P. Smith to make mortality estimates for larvae from year-to-year and biomass estimates for specific species, notably the northern anchovy, Pacific sardine, jack mackerel, Pacific mackerel, and hake. In 1976, the information obtained on CalCOFI cruises on the distribution of fish eggs and larvae has been corrected for biases inherent in the sampling and provided in tabular form by Smith for use in corrected biomass estimates.

There is a continuous analysis by Smith and J. Zweifel of the errors involved in using the numbers of larval fish caught by plankton nets for biomass estimates. In this connection, Zweifel has devised a weighted negative binomial model which eliminates most of the difficulties inherent in normalizing and linearizing larval catch data. He has devised a maximum likelihood estimate method for analyzing data collected in samples from contagious natural populations (e.g., eggs and larvae) when the vulnerability to capture is not constant. This discrete model permits the use of all plankton tows, and unlike analyses based on continuous distributions, shows that the number of tows in which no eggs or larvae would be expected is easily predicted from the model parameters. In addition, Zweifel has derived confidence intervals for the negative binomial distribution and showed that precise probability statements are possible for a wide range of sampling situations.

Marine Environment Assessment

Egg and larva surveys are one of the basic tools in fishery science for evaluating the kinds and amounts of fish resources. Since the beginnings of CalCOFI, a group of scientists at the La Jolla Laboratory has devoted its efforts 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. Led by E. Ahlstrom, this group has compiled and curated an extensive reference collection used by fishery scientists from many nations for identification of larval fish. In addition, with the objective of training NMFS personnel and others in identification of fish eggs and larvae, a concentrated course was given by Ahlstrom in the spring of 1976. Twenty-one persons were enrolled in the class on a full-time basis and several additional persons audited the course. Ten of the participants were from foreign countries. During the course, 216 life history series were studied representing 98 fish families. This was the fifth time that this course has been presented by Ahlstrom.

A major accomplishment of the group during the past year was the preparation of a manuscript dealing with pelagic stromateoid fishes of the eastern Pacific: kinds, distribution and life history, by Ahlstrom, John Butler and Barbara Sumida. The paper had a dual purpose: to identify the kinds of pelagic stromateoid fishes present in the eastern Pacific together with their distribution and relative abundance and to describe the early life history stages of most of these.

In treating the life history stages, the authors followed the "dynamic approach", pioneered by Ahlstrom. 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, pigment patterns, fin development, ossification, etc. The pelagic stromateoid fishes described belong to four families: Nomeidae (11 kinds treated in this manuscript); Tetragonuridae (3 kinds); Centrolophidae (4 kinds), and Amarsipidae (monotypic). The young of a number of the pelagic stromateoid fishes are associated with jelly fishes—this applies particularly to the centrolophids, of which the common form in the CalCOFI area is *Icichthys lockingtoni,* the medusa fish. The other common kind in the CalCOFI area is the squaretail, *Tetragonurus cuvieri.* Most of the pelagic stromateoids are typical species that enter the CalCOFI area only off southern Baja California, or offshore in the central water mass. However, a number of the species are common in the eastern Pacific, but especially *Cubiceps pauciradiatus,* which must be an important forage fish for tunas and billfishes.

Work also continued on the CalCOFI Atlas which will deal with the distribution of scorpaenid larvae for the years 1951–1969, the sixth such CalCOFI Atlas to be produced by this group. Rockfish larvae of the genus *Sebastes* are typically the third or fourth most abundant kind of fish larvae taken annually in CalCOFI plankton collections. Species identification is difficult because of the large number of species (over 65) occurring in California waters. Identification of some commercially important species had been accomplished by removing larvae from pregnant females and culturing them in the research aquarium of the Center to a point where they can be matched with larval series from CalCOFI plankton tows.

Seven other genera of scorpaenid fishes occur in the eastern Pacific, and their larvae have been identified using specimens from CalCOFI cruises and such wide-ranging expeditions as EASTROPAC.

The recent interest in rockfish off California illustrates the importance of the research on these species for which G. Moser has been principally responsible. As a result it is now possible to determine which species of rockfish are dominant spawners in nearshore California waters and when they spawn. J. MacGregor, working with California Department of Fish and Game (CF&G) biologists, has begun to examine rockfish samples collected by the CF&G partyboat sampling program. The purpose of this study is to obtain some of the basic data necessary to understand the life histories of the various species and to determine what problems are developing owing to the increasing fishing pressure directed at some of the species found in the CalCOFI region.

A study using Moser's species identifications will be carried out next year by MacGregor who will attempt to estimate spawning biomass of rockfish in the southern California area using larvae caught during past CalCOFI cruises.

Criteria for Management of Pelagic Fish Species

The information supplied by Ahlstrom's unit at the La Jolla Laboratory on the identification of fish eggs and larvae is essential for making biomass estimates of Pacific mackerel, jack mackerel, hake, saury, and other fish resources of the CalCOFI region. This year has seen an increased use of such larval fish information in establishing criteria for the management of pelagic fish species. For example, negotiations by the National Marine Fisheries Service, Northwest Fisheries Center with the Soviets and Poles have been based on information provided by Paul Smith for trends in hake eggs and larvae capture. In an administrative report, Smith pointed out that the hake population had apparently reacted to the fishery conducted on this species over the past 10 years by Soviet, and more recently by Polish trawlers. The primary effect noted was a curtailment in spawning on the southern half of the spawning grounds. Until 1965, half of all hake larvae were found north of Ensenada, Baja California, Mexico. After 1965, this proportion declined to less than 5% of the total larvae found. This phenomenon is

reminiscent of the shrinking of the feeding grounds and spawning areas of the Pacific sardine prior to the rapid decline of the total stock. Important changes in the population of hake have thus been sensed by the spawning surveys, indicating that additional caution should be exercised in the management of the hake fishery.

This information was used for renegotiation of the U.S.-Polish bilateral agreement on fisheries by which the present Polish hake quota was reduced by 39%.

Biomass estimates of northern anchovy derived from egg and larva data are still the prime sources for information used to manage the northern anchovy fishery between Mexico and the United States. This year, the California Department of Fish and Game has relied heavily on the larval time series to indicate fluctuations in the major population.

The most recent plan presented to the Fish and Game Commission of the State of California to increase the commercial fishery on the stock was derived from larval abundance estimates produced at the La Jolla Laboratory. In the past, moratoria on fishing of the Pacific mackerel and Pacific sardine stocks was a direct result of scientific evidence provided to the Fish and Game Commission from egg and larva data as well as from small fish surveys conducted by the California Department of Fish and Game.

Hydroacoustic Surveys in the California Current

The La Jolla Laboratory has had an ongoing program of research into the use of underwater acoustics as a tool in assessing pelagic fish biomass in the California Current. The primary motivation for the rapid survey technique with sonar mapping of fish schools, a technique developed by Smith in 1970, has been the 20-fold changes in the central subpopulation of anchovy in a 16-year period. The rapidity of this change in the virtual absence of a significant fishery has emphasized the need for interim estimates between spawning surveys which are now conducted every 3 years.

Sonar mapping was conducted on a series of cruises aboard the NOAA research vessel JORDAN during the period from July 1975 through May 1976. A variety of techniques for determining numbers of schools, kinds of schools and sizes of fish were evaluated. On a number of occasions drop cameras were used by John Graves, SIO student, to determine the species of fish being observed and, in collaboration with the U.S. Navy, echoes from schools were recorded and analyzed by two signal processing systems aboard the JORDAN. With Van Holliday, Smith also used a bottom bounce technique inside the 100-fathom line to estimate the size distribution of gas bladder-bearing fish by resonant frequency analysis. Calibrations of the acoustic system on the Mexican research vessel, HUMBOLDT, and the California Department of Fish and Game vessel, ALASKA, were made using the facilities of the U.S. Navy's Sensory Accuracy Check Site (SACS) at Long Beach, so that these ships may proceed to make rapid comparable estimates of the schooled fish off the west coast. With Bret Castile, day, night and twilight vertical profiles were made in the California Current using multiple high-frequency volume reverberation. High frequency sonar is being investigated as a tool which may be used for detecting the vertical migration of very small organisms.

A report has been completed by Smith and Graves on photographic, visual, and acoustic observations of northern anchovy aggregations which can be used to estimate the impact of an anchovy school on its immediate environment. A representative concentration of northern anchovy in a school is 15 kg/m^2 live weight, 4.2 kg/m^2 dry weight or 1.68 kg/m^2 carbon. If the daily ration is of the order of 5%, this rate imposes a demand on the environment to provide food containing 84 g carbon per square meter of school per day. Since total primary production is of the order of 1 g/m^2 day in the anchovy habitat, the anchovy school must move so that an area hundreds of times its own is occupied and grazed each day.

In December 1975, the Coastal Fisheries Resources Division was host to a MARMAP (Marine Resources Monitoring, Assessment, and Prediction) Survey 3 (pelagic fish) acoustics workship, planned and organized by A. M. Vrooman, MARMAP Survey 3 Coordinator, Washington, D.C. (and formerly on the staff of the La Jolla Laboratory), and attended by representatives of acoustic fishery research groups from fishery research center in the Northwest, Southeast, and Northeast.

As one result of this meeting, Smith, with the assistance of his colleagues in the Coastal Fisheries Resources Division, California Department of Fish and Game, Instituto Nacional de Pesca of Mexico, and Van Holliday of Tracor, Inc., prepared a plan for MARMAP Survey 3 to institute and coordinate sonar mapping surveys, and to provide timely information on the status of northern anchovy stocks during the period of projected rapid increase in the Mexican fishery.

Retrieval System for CalCOFI Oceanographic Data Files

The tremendous volume of oceanographic and biological information collected during almost three decades of CalCOFI surveys has made it necessary to reorganize the material for more efficient and economic retrieval. During the past year the CalCOFI oceanographic data files of hydrocast data taken from 1950 through 1968 are being reassembled at the La Jolla Laboratory and converted from National Oceanographic Data Center card-image format to a packed binary format by Eber.

The converted files are to be reordered chronologically by cruise to facilitate a time series presentation of selected variables. A software package was developed by Eber to extract values of

observed or computed variables for specific stations, depths, and cruises. The result is intended to be a display of the data in a printed tabular format and in the form of contour plots. The tables and contour plots will include long-term monthly means and standard deviations of selected variables, the number of observations and mean day for each monthly mean, the values of the individual variables and their departure from the long-term means.

It is intended to create a pooled regional file which can provide monthly and quarterly averages of the oceanographic variables in a format compatible with the CalCOFI biological files. The latter include the sized larvae of northern anchovy, Pacific sardine, Pacific mackerel, jack mackerel, and Pacific hake; fish eggs and unsized fish larvae; zooplankton volumes; and zooplankton functional groups such as copepods, euphausiids, etc.

Recreational Fisheries Program

In response to the stated intent of the Mexican government to promote an anchovy fishery and the well-publicized controversy between commercial and sportfishermen in California over the best use of the anchovy resource, a Recreational Fisheries program under the Acting Leadership of G. Stauffer was established within the Coastal Fisheries Resources Division as part of the planned reorganization of the La Jolla Laboratory which officially became a reality with the approval of the Central Office of NMFS in Washington in July 1975. The specific task given Stauffer and his staff was to provide stock assessments, stock monitoring and management information on commercial and recreational fish of the California Current for state bodies to manage fish stocks on an objective basis. The group also collaborates with Mexico in the collection of data on stocks common to the two countries, e.g., Pacific sardine and northern anchovy, and a variety of sportfish.

To this end, Stauffer, often in collaboration with Alec MacCall, California Fish and Game biologist detailed to the La Jolla Laboratory, has organized several workshops on various aspects of anchovy biology, arranged a symposium on the anchovy management challenge at the 1975 CalCOFI Conference, hosted by Reuben Lasker of NMFS, and produced numerous documents and working papers examining assumptions and data requirements for management of an anchovy fishery. One important conclusion is that a cooperative research program between California and Mexico is essential for developing standard formats for data collection and exchange.

Cooperative Fisheries Research with Mexico

Recognizing the problems inherent in the equitable sharing of fisheries resources, particularly the stocks of northern anchovy, CalCOFI scientists in the absence of a U.S.-Mexico bilateral fisheries agreement, have organized an informal collaboration with Mexico's Instituto Nacional de Pesca (INP) to obtain the best scientific information available for managing fish stocks through cooperative research. With the creation of an INP/CalCOFI Committee to chart policy, a Stock Assessment Committee to provide technical guidance and the formation of subcommittees on catch-per-unit of effort, eggs and larvae, acoustic surveys, aging and sampling to carry out various aspects of the agreed-upon program, scientists of the two countries have achieved a commendable level of joint effort during the past year.

Meetings of the various working panels were held at intervals. The Stock Assessment Committee which recommends courses of action for stock assessment and conservation of anchovy to their respective institutions, met in La Jolla in December 1975. Some important recommendations made to the INP/CalCOFI Committee were: increased activity in acoustics, aging and sampling of anchovies, a definition of catch-per-unit of effort, and an intensive examination of existing logbooks. In addition, a data management system for anchovy stock assessment was recommended with initial action to be taken by a new subcommittee which was established on data management systems.

The Egg and Larva Subcommittee of INP/CalCOFI met in early February 1976 at La Jolla to discuss cooperation between Mexico and the U.S. in stock assessment with egg and larva surveys. Recommendations were that a bi-national larval fish sorting center be considered in anticipation of the 1978 CalCOFI year, utilizing the resources currently available in both countries; that steps be taken to improve the training of technicians to improve standardization of hydrographic data and, recognizing the need for oceanographic expertise in analyzing fisheries problems, that oceanographers be assigned specifically to the FAO/INP/CalCOFI biology groups.

As a result of this growing cooperation in fisheries research through the mechanisms of INP/CalCOFI, Mexican scientists and fisheries students now routinely participate in CalCOFI biological, oceanographic and acoustic survey cruises sharing the data; training in the identification of fish eggs and larvae of the California Current has been provided to Mexican fishery biologists; there has been an increased exchange of scientific papers and information sharing between individual scientists and, at the level of the working scientist, reinforcement of the belief that the formulation of rational pelagic fishery policies requires that they work together to serve their mutual interests.

Izadore Barrett