

## AGENCY REPORTS

### CALIFORNIA ACADEMY OF SCIENCES

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

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

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

### CALIFORNIA DEPARTMENT OF FISH AND GAME PELAGIC FISH INVESTIGATIONS

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

Historically our efforts have been species oriented; i.e. separate sections were responsible for conducting all phases of work in Pacific sardine, Pacific mackerel,

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

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

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

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

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

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

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

## HOPKINS MARINE STATION

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

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

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

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

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

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

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

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

be compared with studies in progress on *Engraulis mordax*.—*Malvern Gilmartin*.

## SCRIPPS INSTITUTION OF OCEANOGRAPHY MARINE LIFE RESEARCH PROGRAM

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

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

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

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

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

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

### *Nutrition in the Sea*

Nitrogen is often the limiting nutrient for phytoplankton growth in the sea. Most of the transformations of nitrogenous compounds in the sea are effected by micro-organisms. In laboratory experiments it has been demonstrated that both nitrifying bacteria (which oxidize NH<sub>3</sub> to NO<sub>2</sub><sup>-</sup> or NO<sub>2</sub><sup>-</sup> to NO<sub>3</sub><sup>-</sup>) and nitrate-reducing bacteria and algae (which reduce NO<sub>3</sub><sup>-</sup> to NO<sub>2</sub><sup>-</sup> and other products such as N<sub>2</sub>, N<sub>2</sub>O, etc.) contribute nitrite to the secondary nitrite maximum found in the deeper, oxygen-poor, waters off the coast of Peru. The nitrite in the primary nitrite maximum arises mainly from the activities of nitrifying bacteria, and, in cases where standing stock is high, from excretion by various phytoplankton.

Photography of deep benthic fish populations has continued. During the year a movie camera obtained several series of ten-second strips taken at regular intervals over a period of several hours in depths ranging from 600 to nearly 4000 meters. Large numbers of sable fish, grenadier fish, and hag fish were photographed. Continued use of the still camera and bait is improving our knowledge of deep benthic

fishes. Their use in conjunction with fish traps and other instruments will improve species identification and knowledge of population densities, and may possibly uncover populations of commercial extent.

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

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

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

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

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

Investigation of the Santa Barbara Basin in continuing to add to our knowledge of: distribution and abundance in past times of those species of plankton encountered in the sediments; sedimentation rates; history of the fishes of the California Current; and man's effects on the nearshore ocean. During this last year the water below sill depth in the Santa Barbara Basin overturned. This occurred some time between a January, 1970, cruise and a May, 1970, cruise. In January the oxygen content very near the basin bot-

tom was 0.1 to 0.05 milliliters per liter. During the May cruise the oxygen level was up to 0.4 milliliters per liter; in June it was 0.23 milliliters per liter and in July 0.05 milliliters per liter. The overturn of the waters may have occurred very rapidly during the strong north winds in April and early May. The June and July cruise data show that the basin was quickly returning to its normal condition of very low oxygen content below the sill depth.

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

#### NATIONAL MARINE FISHERIES SERVICE FISHERY-OCEANOGRAPHY CENTER

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

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

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

#### *Development of Hydroacoustic Techniques*

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

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

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

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

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

In connection with the research on fish biomass, sonar target strengths of fish schools, both wild and

captive, were measured during a cooperative cruise with the Westinghouse diving vehicle, DEEPSTAR 2000. Critical measures of school compactness were made and supplemented by photographs. Thus far, it is estimated that the usual wild fish school weighs about 0.03 metric tons per m<sup>2</sup> cross-sectional area.

### Hake

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

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

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

Personnel in the Population Dynamics Group provided plankton equipment, assistance and advice on sampling techniques, and the scanning and sorting of samples to scientists on the Soviet research vessel, OGON, during her egg and larva surveys of hake off California and Baja California in February-March 1970. Results of scanning of 143 plankton samples by Fisheries Service biologists for hake eggs and larvae indicated that the distribution of hake spawning had shifted northward relative to 1969 and was accompanied by a 1.3° sea surface temperature shift in the

5° square which includes San Francisco. These data were presented in a report prepared for the U.S.-Soviet fishery meetings in Moscow in September 1970.

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

### Anchovy

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

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

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

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

### Wetfish Operations Pool

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

### Local Fisheries Development

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

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

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

### San Pedro Wetfish Fishery

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

In this connection, "Development of the San Pedro Wetfish Fishery—A Systems Approach" was the sub-

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

### Larval Fish Ecology

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

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

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

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

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

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

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

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

#### ***Behavior of Pelagic Fishes***

A series of extensive experiments with jack mackerel and to a lesser degree with Pacific mackerel,

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

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

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