AGENCY REPORTS

CALIFORNIA ACADEMY OF SCIENCES

The investigations during 1970–71 have been directed primarily toward study of the food habits of the squid (*Loligo opalescens*) and the Pacific hake (*Merluccius productus*). This work has been carried on by Anatole S. Loukashkin. At the meeting of the Marine Research Committee on October 22, 1970, Mr. Loukashkin asked and received approval of the Committee to also further pursue his previous studies of the food and feeding habits of Pacific mackerel and jack mackerel in order to round out his earlier investigations and clarify certain points that lack of material and insufficient opportunity for field observations had left in doubt. In particular he wishes to obtain more data on food of different age groups, and to observe feeding patterns and feeding behavior at sea, as was done in his study of the northern anchovy.

The investigation of squid has thus far proceeded as follows. Forty-six male specimens were collected for us by Mr. James Hardwick at Pfeiffer Point in Southern California on November 13, 1970, using line and jig. Of these, 42 stomachs were filled with food, mostly crustaceans; a few contained remains and bones of small fish. 120 squids picked up from commercial landings at Monterey Bay on December 10, 1970, (103 males and 17 females) contained no food in their stomachs. 21 specimens (3 males and 18 females) were received from Mr. S. Kato, Fishery Oceanography Center at La Jolla, collected near Catalina Island on January 21, 1971, using an electric lamp and a fish pump. Five stomachs contained some unidentified crustacean remains and some indeterminate fleshy and jelly-like remains. The rest were empty. This suggests a periodic non-feeding time, related to breeding activities or other factors.

Of Pacific Hake, Ken Mais of the California Department of Fish and Game collected 110 specimens ranging in size from 130 mm. to 255 mm. (total length) during a cruise of the M/V ALASKA in the Channel Islands area. Only nine stomachs were empty. The remaining 101 contained food in various quantities, ranging from "very poor" to "well filled" (four were "gorged"). The only food found was euphausiid crustaceans—100 per cent. It cannot yet be said with certainty whether the hake feeds selectively on these, or whether they happened to be the dominant food of suitable size that was available.

Of jack mackerel, 32 specimens ranging in size from 105 to 355 mm. were picked up by Jim Hardwick from commercial landings in Monterey Bay on January 26, 1971. Three stomachs were filled to extreme capacity ("gorged"), containing one or two intact small squids. The rest contained small quantities of fleshy and jelly-like substances, probably remains of fish. 193 specimens were collected in April and May by Ken Mais in a cruise of the M/V ALASKA in the Channel Islands area. Of these, 23 stomachs contained no food. The remaining 168 stomachs contained food, ranging in amounts from "very poor" to "capacity" (four were "gorged"). The food consisted of euphausiids (44.2 per cent), copepods (22.4 per cent), crustacean remains (6.7 per cent), fish remains (3.6 per cent), polychaete worms (1.8 per cent), mysid remains (0.7 per cent), salps (0.6 percent), and indeterminate fleshy remains (20 per cent).

This confirms our previous report, in which we considered jack mackerel to have a dual mode of feeding relative to the food available—particulate feeding on euphasiids or fish, filter feeding on copepods or other small crustaceans.

Robert C. Miller

CALIFORNIA DEPARTMENT OF FISH AND GAME PELAGIC FISH INVESTIGATIONS

Sea Survey

Sea survey cruises this year were more varied in methodology and purpose than those of the past 4 years. Nine cruises, totaling 163 vessel days at sea, were conducted aboard the research vessel ALASKA. Routine acoustic-midwater trawl surveys were made during fall, winter, and spring off southern California. Waters off Baja California were similarly surveyed by two cruises in May and June.

Most work on anchovies this year centered on behavior and commercial availability studies. Results have provided some insight into causes of poor or successful fishing and resultant catch fluctuations. Extreme behavioral patterns of anchovies observed this year indicate anchovy reduction fishery landings can fluctuate rather drastically due to availability to purse-seining gear. The summer months have been periods of poor availability as determined by past surveys, aircraft surveillance, and information gained from a single purse seine vessel fishing out-of-season by special permit. At this time of year, schools are highly scattered over the deep water basins of southern California. The only commercial concentrations were found in shallow inshore waters in the Santa Barbara area which are closed to anchovy purse seine fishing. Large compact schools began to form south of San Pedro by the end of August. In early September, these schools had moved into San Pedro Channel and were highly available to the reduction fishery when the season opened September 15. An acoustical survey in September and October found anchovies highly concentrated within 20 miles of shore between Newport Beach and Point Dume. These fish stayed densely schooled in this area through January, during which time the reduction fleet landed a record catch.

Surface temperatures during late winter of 1970 and spring of 1971 were among the lowest on record

in the temperate eastern Pacific and may have been responsible for poor anchovy availability and failure of the spring fishery in southern California. Acoustic surveys during this time found anchovies plentiful but highly scattered in noncommercial schools. These surveys indicated spring commercial concentrations formed much later than usual and after the reduction season had closed. A survey in February, during which a 1 month fishing closure was in effect, detected a mass exodus offshore and scattering of anchovies toward the south and southeast. Anchovies at this time were distributed over a wide area in numerous small surface schools which is a behavioral pattern typical of spawning. An April survey found the population had moved somewhat inshore and northwest, but was still highly dispersed in small schools. Near the conclusion of this cruise, there were indications of large commercial school formation. This was substantiated by sudden improvement of commercial catches that continued for the final 2 weeks of the reduction season. Aircraft surveillance and reports from commercial fishermen indicate availability was good the latter half of May and most of June.

Acoustic surveys of southern and central Baja California waters were made during May and June. These surveys completed temporal coverage of Baja California waters. They found far better anchovy availability than did surveys during other seasons. Both surveys indicated good but limited commercial concentrations of anchovies along the narrow coastal shelf of this region. Schools ranging from 5 to 150 tons were detected and sampled. Age-length data from these fish further substantiated the existence of a separate subpopulation residing in southern and central Baja California.

Studies made on echo sounder and sonar survey methods indicated both equipment systems underestimate the number of anchovy schools. Echo sounder estimates are lower due to the tendency for surface schools to flare from the vessel's path, thereby avoiding detection. Sonar fails to detect small schools at intermediate and long ranges. When the two equipment systems were compared, the echo sounder detected 4 to 6 times as many schools per unit of area as did sonar.

A survey of offshore waters between central California and northern Baja California was made in August to locate and sample large old adult jack mackerel reportedly residing in this area. None was detected or caught. Apparently this population of older fish is located more northward during summer. During fall months in southern California, small jack mackerel from the previous spring spawning were quite vulnerable to our midwater trawl. The September-October cruise took juvenile jack mackerel in 43% of the trawl tows. This was the best catch made for several years and was an indication of a strong 1970 year class.

Acoustic surveys in southern California during the spring of 1971 detected extensive concentrations of juvenile hake ranging from 158 to 187 mm standard length. Schools consisted of small discontinuous groups of fish forming a coarse scattering layer 125 to 145 fathoms from the surface over deep water basins between San Pedro and Port Hueneme. Some layers extended at least 5 miles. This is the first substantial quantity of hake found by our sea surveys, and can be attributed to our recently acquired improved echo sounding system.

A night-light, blanket-net, survey in Baja California and southern California was conducted in September 1970 to assess the incoming year class strength of Pacific mackerel and Pacific sardine. Pacific mackerel of the 1970 year class were taken at 6% of the stations occupied with all but one sample being taken in Sebastian Vizcaino Bay, Baja California. These results indicate another poor year class when compared with similar surveys over the past 20 years.

One postlarval fish was the only sardine taken during the night light survey and none were caught in the 200 midwater trawl tows made in California and Mexican waters during the year. The sardine population apparently is too small to detect by present survey methods.

A special saury survey was conducted in November 1970 to study their distribution and abundance in central and southern California waters. Very few schools were located. The only commercial concentration consisted of a 10 ton school of fish ranging from 182-240 mm fork length. This school was found close to shore in Monterey Bay. Smaller, but more numerous schools of smaller fish were located and sampled in Santa Cruz Basin in southern California. Offshore search was unsuccessful and presented severe operating problems due to prevalent weather conditions. Small quantities consisting of 1 to 50 very small juveniles were frequently attracted by night light stations on other cruises.

Large concentrations of Panama lightfish, *Vinciguerria lucetia*, were located and sampled offshore from southern Baja California. Schools extended over a 10 mile area and were found at 35 to 40 fathoms from the surface during daylight hours. Some schools were nearly 40 fathoms thick and very likely contained over 100 tons of fish. Midwater trawl catches in this area consisted of 97% Panama lightfish and the remainder postlarval northern anchovies. This was the most offshore (165 miles) major concentration of fishes yet discovered by sea surveys. The Panama lightfish appears to be a major potential resource in the subtropic region of Baja California pending development of efficient capture gear and commercial use.

Pelagic red crabs appear to be the largest macroconstituent of the marine biomass in central and southern Baja California. They represent a large latent resource and may have the greatest potential of any unutilized species in the California Current System. The two spring surveys of 1971 indicate spring is favorable for harvesting pelagic red crabs by midwater trawl. Approximately 1,200 pounds of live crabs were delivered to National Marine Fisheries Service for studies of utilization in human and animal consumption. Preliminary reports on both uses have been optimistic.

A new scientific echo sounder was installed aboard M/V ALASKA in early 1971. This equipment has greatly improved our capabilities to detect deep dwelling midwater and bottomfishes. The recent discovery of large hake concentrations would have been impossible without this new equipment.

Data reports covering sea surveys during 1968, 1969, and 1970 were published in California Cooperative Oceanic Fisheries Investigations Data Report series. Edited reports of cruises completed through June 1971 have been compiled, and will be combined into a single report for publication at year's end.

Sea Survey Data Analysis

During the fiscal year, considerable time was spent on developing a plan for a systems analysis of the Pelagic Fish Program. The first phase consisted of determining program objectives, describing the present system, and compiling an inventory and index of relevant historical data. This study is designed to improve the effectiveness of our research efforts.

Analysis of all data pertaining to the jack mackerel resource was continued. Jack mackerel otoliths collected during the 1968–69 and 1969–70 seasons were read. A computer program to determine age composition of catch for these seasons is being developed.

—K. F. Mais

HOPKINS MARINE STATION

The Hopkins Marine Station of Stanford University at Pacific Grove, California, has conducted a continuous hydrobiological survey of Monterey Bay and adjacent waters since 1951. Under the program, the Station monitors the marine environment, and is involved in studies of the pelagic food chains and their relation to the biological oceanography of Monterey Bay.

Collection of basic oceanographic data in Monterey during approximately bi-weekly cruises to six stations continues along with recording of daily shore temperatures at Pacific Grove and Santa Cruz. Both shore and cruise data are compiled and distributed to interested agencies and individuals in the form of an Annual Data Report.

During 1970–71, the study of entry and transfer of DDT residues in pelagic marine food chains was concluded. Under this portion of the program, continuous samples of seawater and organic particulate material collected along linear transects in the California Current system were analyzed for DDT residues, and it was found that DDT residue concentrations in whole seawater, as determined by continuous-flow liquid-liquid extraction, ranged from 2.3×10^{-12} g/ml off Oregon and Washington, to 5.6×10^{-12} g/ml off Southern California. Geographical patterns in these concentration values were considered in relation to mechanisms of land-sea DDT residue transfer. DDT residue concentrations in particulate material, collected by continuous-flow centrifugation and filtration of the centrifugal pellet onto GFC glass fiber filters, ranged from 1.2 to 5.7×10^{-6} g/g carbon (with one exception). These values were related to the density of the standing crop, but DDT residues in this particulate fraction accounted for less than 10% of the DDT residues in the whole seawater samples. However, residues which are fixed to particles of less than 1–2 μ in diameter could have accounted for the balance of the DDT residues in the whole water samples. Certain experimental results implicate adsorption as the uptake mechanism for algal cells; these experiments also support the idea that 1–2 μ diameter particles carry most of the DDT residues in whole seawater.

Euphausia pacifica Hansen, an important constituent of the zooplankton in the California Current, was studied. Results indicated that this organism can acquire sufficient DDT residues from its food to account for amounts found in its tissues, and assimilation efficiencies for DDT residues in ingested food were found to be similar to published figures for assimilation of carbon from food. Interestingly, the direct uptake of ^{14}C-DDT from water was partially reversible by returning animals to unlabelled flowing seawater; ^{14}C-DDT present in animals after two weeks' exposure to flowing seawater was apparently retained in proportion to the fat percentage of the individual animals. Various effects of dietary change, moulting, and surface to volume ratios on observed natural levels were also evaluated.

In addition to the phytoplankton and zooplankton studies, the DDT residue content of different size classes of *Engraulis mordax* Girard, an important planktotrophic fish of the California Current system, was also analyzed. These were found to range from 0.2 to 2.8 parts per million, wet weight. Highest concentrations were found in fish of 17 to 22 grams wet weight, which correspond to the third year class. Mature male fish had higher DDT residue concentrations than younger sexually maturing fish, possibly due to loss of DDT residues in reproductive materials or other mechanisms related to the annual oil cycle. Fish of less than 13 grams wet weight had a constant amount of DDT residues per unit of fat; they also had much lower wet weight DDT residue concentrations than any of the larger fish. A model of DDT residue assimilation from food and DDT residue loss via transport in the reproductive materials was developed and used to integrate these findings.

—Malvern Gilmartin

MARINE LIFE RESEARCH GROUP SCRIPPS INSTITUTION OF OCEANOGRAPHY

For many years the Marine Life Research program at Scripps concentrated on the ecology of the California Current system. In recent years the program has been broadened to include other topics that affect the resources of the California Current of interest to the people of California. The following are short reports on a few of the studies of Marine Life Research Group. Other reports were given in last year's Annual Report.

Tetsuo Matsui and Richard Rosenblatt have recently begun a study of the little known life history of sablefish and grenadier off Southern and Baja California. In the deep waters off Baja California

and Southern California, sablefish (*Anoplopoma fimbria*) are usually found between 200 and 800 fm. To the northward, off Oregon, Washington and Alaska where they are fished commercially, sablefish are found nearer the surface. Off California, there is almost no fishery for sablefish because they inhabit only the greater depths.

Species of grenadier are found at depths within the sablefish range and at greater depths (to at least 3200 fm). The species (*Coryphaenoides acrolepis*) off Southern California are found between 500 and 1300 fathoms. This species is a wide-ranging fish also found off Japan.

The compelling need to study the life history of the sablefish and grenadier off Southern California is that no eggs, larvae or small fish have been found. These two fish constitute a very large portion of the fish population at these bottom depths.

One of the very interesting findings so far in this study is that most of the males and females are separated geographically. Sablefish and grenadier taken at selected stations since February 1971 have been mostly females; for grenadier the ratio has been roughly 5:1. The males have been much smaller than females. From a station in April, 1970, off Guadalupe Island, all 12 grenadier taken were males as large as most females, and one was nearly as large as the largest female caught to date. Of four stations where males dominated, only one had a female. The distances between male dominated and female dominated areas appeared to be related to topography, the female fish being taken on the bottom of the San Clemente trough and the males higher up on the slopes. The few grenadiers taken in trawls show a more equitable sex ratio. Mention of this segregation by sex in these two species is not found in the literature. This research is continuing to determine more about the sex ratio at various locations and to look for the eggs, larvae and young fish.

Estimates of total primary production in the Ocean may have to be revised upward according to the research of John McGowan, Elizabeth Venrick and Arnold Mantyla. Most of the past work on total primary productivity has been based on data that were taken above 25 meters and over half of the measurements were made only from sea surface data. Most estimates of total production in the water column have been strongly dependent upon some assumed depth of zero productivity. This is traditionally taken to be the depth at which the light intensity has been reduced to 1% of the incident radiation. From this recent research it appears that the deep chlorophyll maximum occurs below the depth of penetration of 1% of the incident surface radiation most of the year in the central gyres of both the North and South Pacific. This may represent a major portion of the standing crop of plant material and thus account for a substantial portion of the primary productivity. The rate of production throughout the water column is variable on rather small spatial and temporal scales, but appears to be considerably greater than the maximum estimate of 100 mg $C/m^2/day$ estimated by Koblentz-Mishke and others. From the present data it is expected that a similar chlorophyll maximum may be well developed in other large, persistent temperate gyres, such as the south Atlantic and Indian Ocean. If found, the estimates of world ocean primary productivity will need to be revised upward.

Joseph L. Reid has continued a study of the abyssal circulation of the world ocean. Work at sea during this period included 42 days aboard the *Thomas Washington* in the Antarctic Ocean south of New Zealand. The immediate purpose of the expedition was to make long series of measurements (15–26 days) of the velocity near the bottom of the ocean (about 3000 meters in the area studied) and in particular to confirm an estimate of flow toward the west near the coast of Antarctica. The larger purpose was a continuation of the studies of Antarctic circulation carried out earlier in the Drake Passage; these studies are part of the general study of the exchange of water between the Atlantic, Indian, and Pacific oceans through the Antarctic Circumpolar Current.

Westward flow was found in the deep waters close to Antarctica; the very cold and salty water from the shallow Ross Sea was observed to be moving westward across the Macquarie-Balleny Rise. In addition to the detail near Antarctica, the results have been combined with earlier results to provide a map of the surface currents of the Antarctic Ocean (geostrophic flow at the sea surface relative to about 1000 meters depth) in the Pacific sector south of 40° S. This clearly reveals the nature of the westward flow that exists south of the main eastward flowing Antarctic Circumpolar Current.

In another study the contribution of the Atlantic Ocean (Norwegian Sea and Weddell Sea) to the bottom waters of the North Pacific has been shown. The very saline waters of the North Atlantic are traced into the Antarctic and then eastward with the Antarctic Circumpolar Current (where they are cooled and freshened) into the South Pacific and northward into the North Pacific.

The first phase of the halophyte program, under the direction of John D. Isaacs with the assistance of Walter Schmitt and Peta Mudie, has been nearly completed. It has been clearly demonstrated that some plants can be grown in sea water. Table beets were grown to maturity in sea water after they were started in fresh water for the first two months. Other plants being grown in various concentrations of sea water are Swiss chard, broccoli, bell pepper, cherry tomato, celery, marguerite, calendula, stock, statice and sea pink. As expected, some are doing better than others. These plants are being grown in sand or hydroponic solutions. The specific objectives of the first phase of the programs are: 1. Examine and evaluate accepted concepts regarding factors controlling plant growth under saline conditions, 2. Demonstrate growth in sea water of economically important plants, 3. Evaluate, under controlled conditions, related work on sea water irrigation, 4. Examine the opportunities for exploiting the genetic salt tolerance of halophytes through hybridization or grafting with related economic taxa, and 5. Elucidate research opportunities for improving salt resistance of plants.

Professor Isaacs points out that the greatest potential of the experiments with salt water may be the eventual hybridization of true salt tolerant plants, or halophytes.

There are many other projects in Marine Life Research that cannot be elucidated in this short review. Those that will be reported in the next annual report are: vertical migration, a tactic to maximize net yield of primary production to the zooplankton; enhancement of natural marine productivity by artificial upwelling; and an open ocean wave powered electrical generator. —*John Isaacs*

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES CENTER

CalCOFI Report—FY—1971

As described in the previous report, the formation of the National Oceanic and Atmospheric Administration (NOAA) in the U.S. Department of Commerce on October 3, 1971, consolidated many of the ocean and atmospheric-oriented activities of the federal government. The Bureau of Commercial Fisheries, one of six agencies transferred into NOAA, was re-named the National Marine Fisheries Service (NMFS).

Nine months after the formation of NOAA, a major reorganization was announced by Dr. Robert White, Administrator of NOAA, which greatly affected the organization of fishery laboratories in NMFS. Among other changes this plan placed laboratories with common interests under single scientific and technical direction. Four major national offshore fishery centers were established among which is the Southwest Fisheries Center (SWFC) with headquarters in La Jolla. The SWFC includes the former Hawaii Area Fishery Research Center, now renamed the Honolulu Laboratory and the Fishery-Oceanography Center, now the La Jolla Laboratory.

During all of FY–1971, however, the La Jolla Laboratory continued to be organized into four multidisciplinary research groups involved in problems associated with the coastal pelagic fisheries of the California Current and with the tuna fisheries of the warmer parts of the Atlantic and Pacific Oceans. Although all of these research groups, with the exception of the Fishery-Oceanography Group which is concerned with research into the ecology and biology of tuna populations and into the processes of their ocean environment, contain some elements of CalCOFI-coordinated research, the Population Dynamics Group has the main responsibility for CalCOFI research at the La Jolla Laboratory.

Acoustic Surveys

An important part of the work of this Group, under Dr. Paul E. Smith concerns the identification and assessment of unexploited resources by fish egg and larval surveys and the development of the methodology of such surveys. During the past 2 years acousticians in this Group have been perfecting techniques for the rapid counting and measuring of pelagic fish schools using scientific fishfinding sonars on the NMFS research vessel, DAVID STARR JORDAN. These have included the development of a first approximation to the number of fish schools in the 200,000 square-mile study area in the California Current, estimation of the horizontal dimensions of fish schools, derivation of a conversion from fish school size to fish school weight and development of a technique for predicting the variability of effective range as affected by internal waves, vertical migration of fish schools, variation of target strength of schooling fish and depth of the towed sonar transducer.

The first of two approaches to estimating the size of clupeoid fish within schools was tried on JORDAN in early January 1971. Small explosions and electrical discharges were triggered near concentrations of fish. Analyses of the sound spectrum of the discharge and the sound spectrum of the echo from the fish aggregation were compared to identify frequencies where the resonance of the fish gas bladder had increased the echo level.

On a subsequent JORDAN cruise in mid-May, Van Holliday, a UCSD graduate student in applied physics, demonstrated that acoustic resonant frequency analysis of fish swim bladders is a practical technique with potentially important applications in monitoring the growth and survival of juvenile fish with air bladders. An example of how this technique may be applied can be illustrated for the Pacific hake. From theoretical considerations and growth information, a hake at a depth of 64 m, would change in resonant frequency from more than 9 kHz (kilocycles per second) to 0.9 kHz in the first year of life. In the second year the fish would further grow and the resonant frequency would lower to 0.5 kIIz; by the third year to 0.4 kHz.

Data on resonance peaks and accompanying fish samples have also been collected for the northern anchovy, jack mackerel, and rockfish. Resonance peaks have also been measured near saury and hake schools. Non-resonant return data have been collected for targets which are believed to be either red crab or squid. Resonant frequencies are generally lower than 2,000 cycles per second for commercial fish. Higher resonant frequencies originate in bubbles containing invertebrates, in small midwater fishes, and in the young of commercial fish. The resonant frequency will be important in distinguishing anchovies from other schooling fish in that resonances below ca. 1 kHz would not be expected from this species.

Because the costs of monitoring sound velocity profile changes in time and space were considered prohibitive, the La Jolla Laboratory began a cooperative program with the Fleet Numerical Weather Central and J. H. Johnson, Director of the NMFS Environmental and Fishery Forecasting Center, Monterey, to study a statistical approach to mapping sound velocity climatology by region and season, and to develop a shipboard strategy for predicting vertical profiles of sound velocity in order to determine optimum transducer depth at the time and to analyze the fish school target data collected under these sonar conditions.

To develop the probability model, serial expendable bathythermograms obtained during the original sonar-

mapping cruise in the fall of 1968 were used. Effective ranges were estimated from propagation loss estimates derived from ray-tracing models developed for anti-submarine warfare problems. Since a ship-mounted sonar was used, the sound source depth was at a constant depth of 4 m: targets were placed at 4 m, 10 m, 20 m, and 50 m for this model. Depths below 50 m were not evaluated because echo sounders begin to be more effective than sonars below that depth in the California Current region. This model of probability of target detection is an important first step toward compaction-corrected biomass estimates of individual schools and the technique will be applied to the historical sound velocity profiles to make decisions on the best time of year to conduct sonar-mapping surveys in the eastern temperate and tropical Pacific.

In summary, the acoustic survey program has realized most of its original objectives. Biologists in the Population Dynamics Group now have the capability of using sonar mapping for counting and estimating the biomass of schools of pelagic fish from a moving ship proceeding at full speed—a useful supplement to the traditional egg and larval survey methods for fishery resource assessment. Work is now proceeding to distinguish northern anchovy schools from all other pelagic schooling fish. Commercial purse seiners, under charter, will be used to confirm target species identification.

In connection with the hydroacoustic work, two cooperative cruises were made with JORDAN and the research vessels SEARCHTIDE and DEEPSTAR 2000 of the Westinghouse Ocean Research Laboratory in local waters within the Channel Islands and in the area of the San Diego Trough. The objective of this work was to observe fish schools visually and record them photographically while they were being insonified with the Simrad sonar on the JORDAN. Direct observations were made of layers of animals in the ocean and of fish schools. Changes in the size and abundance of the layering organisms were noted and new data obtained on the spacing of fish within fish schools.

MARMAP TECHNIQUES

In preparation for the nationally-coordinated Marine Resource Monitoring, Assessment and Prediction Program (MARMAP) scheduled to begin in 1972, a cruise was made on JORDAN in late January and early February 1971, to test and compare various types of collecting gear. Four types of collecting gear were used for this study: the standard CalCOFI double net, rigged with a 1 m 505 micron mesh and a ½-m, 333 micron mesh, for oblique tows from 200 m depth to the surface; the bongo net, using two 505 micron mesh nets, for horizontal tows of 10 minutes duration at depths of 9 m, 3 m, and at the surface; the SHAT net (Soutar-Hemingway Animal Trap) with a ½-m mouth opening and 333 micron mesh, for vertical tows from 100-m depth to the surface; and the MARMAP double bongo net, rigged with two 60 cm mouth openings and two 20 cm mouth openings, to make oblique tows at various depths and speeds.

The objectives of the cruise were: to determine the effect of tow speed on retention of hake and anchovy eggs and larvae and on avoidance of nets by fish larvae; to determine the effect of the internal wave structure on concentration of anchovy eggs in the upper mixed layer; to estimate the dispersal rate of anchovy and hake eggs; to determine the fine structure of plankton distribution in the upper 9 m of the sea; and to study the effect of sample size on variability in numbers of anchovy eggs and larvae.

A special objective of this study was to determine the sampling characteristics of the Woods Hole modification of the SIO bongo in the presence of high concentrations of newly-spawned anchovy and hake larvae in the Los Angeles Bight. For some time biologists have noted apparent anomalies in the ratios of numbers of planktonic to numbers of motile animals in catches by conventional sampling gear. Other apparently anomalous ratios have been observed between numbers of a given motile species in daylight and night samples. In view of the possibility that motile organisms may evade the sampler because they are warned by seeing or receiving other signals from the preceding tow cable or bridle, biologists have been experimenting with designs that are free of these features. In previous tests the bridle-free bongo at 3 and 6 knots has caught more large fish than bridled ring nets at low speeds. In the present tests, at high speeds small fish larvae were extruded and large larvae damaged. The day/night apparent bias was still present.

The objectives of the MARMAP program also require a net capable of collecting small organisms which are able to escape the regular plankton nets. Three types of medium-sized midwater trawls were selected: the 5′ x 5′ Blackburn trawl, the 6′ Isaacs-Kidd trawl, and the Graham, Boothbay larval herring trawl, modified to suit requirements.

Anchovy Subpopulations

In a recent paper, "Biomass of the subpopulations of northern anchovy *Engraulis mordax* Girard," by A. Vrooman and P. Smith, the distribution and abundance of anchovy larvae were used to estimate the spawning biomass of the central subpopulation and those portions of the southern and northern subpopulations which spawn within the regular CalCOFI survey area.

The mean total biomass of anchovies for the 5-year period 1962 through 1966 in the whole CalCOFI area was 6.1 million tons. The Central subpopulation made up 77.3% of that total or 4.7 million tons. The winter range of the Central subpopulation is from Point Conception to about Cedros Island. The Southern subpopulation, south of Cedros, with 1.1 million tons, accounted for 18.5% of the total. The Northern subpopulation ranges from about Point Conception north to at least as far as Newport Oregon. That portion of it which was within the CalCOFI survey area contributed only 0.26 million tons or 4.2% of the 5-year mean.

Subpopulation studies completed have shown the existence of a previously postulated subpopulation of

anchovies which has a southern limit in the summer approximately between San Francisco and Monterey. The gene in the serum transferrin protein of the blood is the fourth allele found in this anchovy genetic scheme and is never found south of Monterey, California. Previously, anchovy subpopulations from southern Baja California and the Los Angeles Bight have been defined. It now appears that there are three subpopulations of anchovies occurring along the west coast from the tip of Baja California to Vancouver, B.C.

In a recent paper, Dr. W. Lenarz studied length-frequencies of several species of larval fish taken during the CalCOFI program with standard 505 mesh nets. One of his conclusions was that northern anchovy larvae were undersampled relative to Pacific sardine larvae. This is a significant conclusion, for estimates of the standing stock of anchovies are based on the ratio of anchovy larvae to sardine larvae. Dr. Lenarz concluded that a major cause of undersampling of anchovy larvae is that small anchovy larvae are retained at a lower rate by the mesh of the plankton net used by the CalCOFI program than are small sardine larvae.

Hake Spawning—1970

In 1970, a single Soviet vessel, OGON conducted the hake spawning survey from Cape San Lucas to San Francisco. All the resulting plankton samples were turned over by the Soviets to be scanned by the sorting Group at the La Jolla Laboratory; the halves of each sample were sent to the Vladivostok Laboratory of TINRO.

Preliminary results obtained from samples indicate that hake spawning in 1970 shifted northward. The sea surface temperatures in the area of hake spawning in 1970 were about 1.5° C higher than in 1969. There were also indications that spawning was reduced in the important on-shore areas. There are no apparent quantitative differences between the hake spawning seasons of 1969 and 1970. Areal coverage varied by less than 2% and variation in number of larvae per unit area was normal.

The position of the spawning was markedly different, however, from 1969. Deficiencies of 3 to 50% in coverage in all the inshore areas were noted. These were mostly compensated offshore, especially in the northern part of the survey area. A cursory look at the size frequency of hake larvae shows them to be normal for the years of comparison available.

SESKAR, the third Soviet vessel operated by the Far Eastern Seas Fisheries Research Institute to work in the CalCOFI area under the terms of the bilateral fisheries agreement between the U.S. and U.S.S.R. arrived in July 1970, conducted an acoustic and trawl survey of the hake and rockfish populations off the Pacific Coast between 32° and 44° N. Data from these surveys were slated to be received from the Soviets at a scientific meeting of U.S. and U.S.S.R. fishery specialists held in Moscow in December 1971. As part of the background material for the meeting, Dr. Paul Smith, completed a report, "Spawning biomass of Pacific hake, 1970," based on the cooperative U.S. and Soviet hake egg and spawning surveys earlier in that year. Dr. Smith concluded that the spawning biomass of hake in 1970 was between 2 and 3 million metric tons and was essentially unchanged from 1969.

Sardine Biology

Drs. Smith and Lenarz have re-examined the CalCOFI ichthyoplankton data with particular attention to the status of the northern subpopulation of sardines. Indications are that the present northern population of sardines may now be smaller than 5,000 tons and that the anchovy population, in the period before the sharp decline in the sardine population may have been much larger than thought previously. The CalCOFI data do not appear to support the species-replacement concept, nor the thesis that removal of anchovies will materially hasten the recovery of sardines.

Dr. Lenarz has developed a stochastic model which uses the population parameters developed by Dr. Garth Murphy for the years 1932–1949. Both the Murphy population model and the Lenarz model indicate that periods of several decades are necessary for recovery of non-fished sardine stocks from the postulated levels. Dr. Lenarz thus has developed a table of probability of attaining a given spawning biomass of sardines in 10 years and in 25 years, given some combination of yield and assumed biomass.

In a cooperative study with the California Department of Fish and Game, fishery biologists in the Population Dynamics Group have been systematically sampling San Diego Bay for sardine eggs and larvae. This work was begun in response to the State's need for information on the extent of sardine spawning in San Diego Bay and the possibility of closing the Bay and adjacent areas to sardine bait fishing. State biologists have been conducting similar work at Horseshoe Kelp Point, outside Long Beach, with the resulting samples sent to the Center for sorting. Both groups are finding sardine eggs and larvae at all three stations in each area. The most abundant fish eggs found in San Diego Bay, however, are those of an anchovy whose eggs are much shorter and wider than those of the northern anchovy and which are assumed to be *Anchoa delicatissima.*

Handbook of Fish Populations

Knowledge of the fish populations of California waters is stored in over 1,000 scientific articles. To provide access to this information, work began on compiling a handbook of California fish populations which will include a bibliography, summary of catch records and fecundity, growth, and mortality rates of each population. Working both with published and unpublished data, the population parameters for each species are being compiled in a standardized form that will permit information retrieval with the aid of a computer.

Research in the *Behavior-Physiology* Group during the past year has concentrated on understanding the processes of mortality which determine the survival or lack of survival of larval fish. This problem is par-

ticularly important in the California Current area since there is a considerable body of scientific opinion that the important factors which determined the collapse of the great California sardine fisheries of the 1940's were first, a series of extremely poor year-classes of sardines and subsequently, a series of extremely strong year-classes of the competing northern anchovy.

Larval Fish Ecology

Progress has been made by behaviorists and physiologists in this Group in measuring the factors which cause variable mortality in fish larvae and lead to variable year classes of fish. Working with the northern anchovy, a successful technique was developed for the routine induction of spawning in the laboratory in order to obtain supplies of viable eggs and young larvae for experimentation, and also to develop experimental techniques and standard diets for rearing these young larvae through their first weeks of life. Based upon these techniques the studies have now resulted in a quantified description of the development and nature of larval feeding behavior and mechanisms, and of their energy budget during their first few weeks of life.

Details of this work included efforts to find and maintain adequate food sources for larger anchovy larvae to replace the nutritionally inadequate *Artemia,* and the development of successful mass rearing techniques in the laboratory of the rotifer, *Brachionus plicatilis,* as food. Progress was made also in large-scale laboratory production of the copepod, *Eurytemora affinis*, known to be an important food for clupeids. A variety of cultured phytoplankton organisms was tested to ascertain the best one, or several in combination, to serve as a food to stimulate growth and reproduction of the copepod. A manuscript was published describing the mass culture of *Brachionus* as food for larval anchovies between 6 and 20 days of life. The growth rate of anchovy larvae on a diet of *Brachionus* was significantly greater than the maximum rate obtained with a diet of wild plankton and it appears that *Brachionus* is a valuable source of food energy and nutrients to larval anchovies. As a result of the success with *Brachionus,* several mariculture organizations, government laboratories, and universities have requested and been supplied with *Brachionus* cultures from this laboratory.

A parallel line of research within this Group has been concerned with the mechanisms of predation of larval anchovies by crustacean zooplankton and the Group should soon approach a situation in which it will be able to separate the two major forms of mortality of these extremely small larval fish—starvation due to inability to secure sufficient food for growth and maintenance, and predation by other members of the plankton community. Similar studies are now beginning on Pacific sardine larvae, a competitor of the northern anchovy for living space within the ecosystem in the California Current.

Based on the efficiency with which larval anchovies catch their food, the amount of water searched and the metabolic requirements, the density of food particles required by a larva has been ascertained.

These data, probably unmatched for any other species of marine fish, have enabled biologists in this Group to draw conclusions concerning the possibilities of survival of larval anchovies in various situations in the ocean.

Pollution in Marine Ecosystem

There is clear evidence that the pelagic ecosystem has been seriously contaminated by pesticides as shown by the disastrous die-off of fish-eating sea birds in California and the recent difficulties in marketing DDT-contaminated commercial species of fish in the California region. In a new project this year, physiologists began studies of man's chemical invasion of the waters off California and initially directed their attention to a single series of questions: namely, what are the routes and rates of transfer of DDT and other pesticides into the offshore ocean pelagic ecosystem and what is the effect of the observed contamination upon the pelagic fish resources off California?

Since the early 1950's, plankton samples have been routinely and systematically collected by CalCOFI at stations in the California Current. The first problem considered was whether it was possible to use this unique plankton bank to trace the historical origin of DDT contamination of the ecosystem; results have now demonstrated that this approach is completely feasible. Two target species, both small myctophid fishes, were chosen and sorted from selected samples taken from all the major sections of the California Current and extending back 20 years in time. These samples, together with special samples taken over the past year with plankton nets over the same grid of stations, were subjected to precise analyses in order to trace the routes of transfer of hydrocarbon pesticides through the planktonic ecosystem which forms the food of the commercial fish species which have been found to be contaminated. A second line of investigations is proceeding concurrently with these, on the effect of the observed contamination levels in certain fish species upon the survival rates of their pelagic eggs and larvae since it appears that a considerable quantity of the body load of pesticides is transferred during the reproductive cycle.

The Operations Research Group at the Center studies the California fisheries from both the economic and technological viewpoints and suggests ways in which they may be placed on a more rational basis through development of new and more efficient forms of fishing gear and methods and utilization of latent fishery resources.

Local Fisheries Development

Work has continued on systems analysis of, and technical assistance to the southern California fisheries, and in particular, the smaller inshore boats which are technologically out-of-date and economically depressed. In collaboration with the Marine Research Committee of California, scientists in this Group successfully modernized a single San Pedro

wetfish purse seiner by replacing its conventional net handling gear with a hydraulic seine-drum, similar to those used in the salmon fisheries of the Pacific Northwest, together with a number of other modern devices. The result of this has been to reduce the number of crew members aboard the vessel markedly and to bring the test vessel, SUNSET, to a position as a front-runner in the wetfish fleet. Since the primary obstacle to the development of the inshore wetfish fisheries has been economic, the demonstrated increase in profitability of this boat has stimulated interest by other boats in the fleet.

In other developments, a study of the operating economics of the San Pedro wetfish fleet, has been completed in cooperation with the NMFS Branch of Economics. Efforts by this Group have also resulted in an improved shrimp trawl, and encouragement of fisheries for such underused resources of the California Current as red crab, sea urchins, and sable fish.

—*Izadore Barrett*