AGENCY REPORTS

CALIFORNIA ACADEMY OF SCIENCES

Collections made by Eric Knaggs of the California State Fisheries Laboratory, Terminal Island, from commercial catches in southern California during the period January–July, 1969, and collections made from the commercial catch in Monterey Bay on June 3 and July 15, through the courtesy of Joseph L. Olivieri, President of the Santa Cruz Canning Company, Moss Landing, California, supplemented by a few specimens taken incidentally during the study of food habits of the northern anchovy in 1965–66, provided a total of 516 stomachs of jack mackerel and 166 stomachs of Pacific mackerel. These have all been examined by Anatole S. Loukashkin, who noted the general character of the stomach contents and sorted them out for more detailed identification.

Most of the stomachs were found partially filled with food. Empty stomachs occurred infrequently. Some of the stomachs were filled to capacity with mackerel scales, presumably ingested after the fish were netted. This was true of both species.

Both species, as far as the material at hand indicates, are primarily carnivorous, feeding on animal plankton, smaller fishes, etc. They are both filter feeders and particulate feeders, depending on the size of the food in their immediate environment.

Among planktonic elements in the stomach contents examined, crustaceans in larval and adult stages occupy a dominant position. This category includes euphausiids, some other shrimp-like crustaceans, larger copepods, and larval crabs. Fish larvae and young fish of several different kinds were found, including juvenile flatfish and rockfish. Among other animals found in the stomachs of both species were small squids, small octopi, salps, and polychaetes. Thus far no phytoplanktonic organisms have been found.

The food of jack mackerel and Pacific mackerel appears to be closely similar, except in the size of the organisms ingested.—*R. C. Miller*

CALIFORNIA DEPARTMENT OF FISH AND GAME PELAGIC FISH INVESTIGATIONS

Sea Survey

Nine cruises, totaling 177 days at sea, were conducted during the year. Northern and central California waters were surveyed in August 1968. Southern California was covered by 7 cruises, 2 of which were of short duration, and Baja California was surveyed in January 1969. All areas except Baja California have now been adequately surveyed on a seasonal basis. Spring and summer surveys have yet to be accomplished in this region.

The cruises' objectives were modified from the broad general surveys of previous years and more emphasis was placed on locating commercial concentrations of fish and discovering areas of prime habitat. Schooling habits and behavior also were more intensively studied.

An intensive survey for commercial quantities of Pacific hake was made in northern California. Extensive echo sounding in areas considered prime hake habitat failed to locate concentrations such as occur off Oregon and Washington. Although surveys to date indicate this region contains the lowest pelagic fish populations, adequate seasonal coverage has not been achieved due to the extreme weather conditions which prevail during most of each year.

The results of the central California cruise (August 1968) corresponded with those of previous surveys which found a relatively small anchovy population consisting of large adult fish. This population was distributed close to shore and was usually confined to rather localized areas. Rockfishes were the second most abundant species. This central California region now has been broadly surveyed during nearly every month of the year. A change from broad general surveys to an intense detailed search for commercial concentrations of anchovies and rockfishes will commence through a series of cruises in the fall of 1969.

A broad anchovy survey of southern California, made during the spawning season in May and June of 1969, found the anchovy population widely distributed in various sized surface schools. School estimates, from echo sounding transects, totaled 543,121. This is 21 percent less than estimated from a similar survey the previous year. School sizes were highly variable, ranging from several hundred pounds to over 100 tons; the majority being small and located well offshore. All commercial size schools were found within 20 miles of shore. Purse seiners fishing on these concentrations during daylight hours made excellent catches.

A series of cruises in the fall of 1968 were designed to locate anchovy concentrations and make studies of schooling behavior and habitat preference. During these surveys we observed anchovies densely schooled in relatively small localized areas characterized by near-shore steep bottom gradients (drop-offs) and submarine canyons. During the day dense schools were located 60 to 120 fathoms below the surface over bottom depths of 70 to 175 fathoms. At night these fish came to the surface and dispersed until shortly before dawn when they re-schooled at the surface. These schools then descended to the daytime depth with the first light of dawn. This behavior limits commercial fishing to the short period of time just before dawn when the fish are schooled near the surface. We located a sizeable proportion of these fall concentrations within three miles of the coast, an area closed to commercial fishing of anchovies for reduction.

During our fall cruises we expended some effort on jack mackerel scouting. Some of the unfished offshore

banks were searched by echo sounder and sonar but with negative results. However, additional experience was gained in visual observation and acoustic detection of known jack mackerel concentrations. Our results indicate that this species concentrates in a rather restricted habitat and is difficult to detect both visually and acoustically. For example, jack mackerel are much more difficult to survey than anchovies.

A one day cruise was conducted to assess the effect of an oil well leak on the pelagic species of Santa Barbara Channel. No ill effects could be determined. A second short cruise was conducted to study methods of assessing anchovy school sizes from echo sounder and sonar records. A commercial purse seiner was chartered to catch schools monitored and recorded by our acoustic equipment; the catches and corresponding echograms were then compared. This work substantiated the difficulty of determining school sizes solely from acoustic records, except on a gross relative scale. School density and compaction largely determine the amount of fish and the existing electronic equipment cannot accurately measure these factors.

Central and southern Baja California were surveyed by a cruise in January 1969. A most significant finding was our discovery of a large concentration of Panama lightfish (*Vinciguerria lucetia*). These fishes were in loose discontinuous midwater schools covering an estimated area of 32 square miles. They were found where bottom depths varied from 100 to 300 fathoms.

The anchovy population of this Baja region was highly dispersed with virtually no surface schools observed. During the day, loose, layer-type schools were found near the bottom at depths of 40 to 80 fathoms. At night these fish rose to the surface and dispersed. Midwater trawling on the surface produced good catches; however, not one school suitable for purse seining was observed or detected.

Further evidence that a subpopulation of anchovies exists in this region was collected. Nearly all fish were in a spawning condition, yet none exceeded 110 mm SL which is the minimum size of sexual maturity for California anchovies.

This region has been surveyed in all but the spring and summer months. We propose to expand more effort in these seasons to assess adequately this area's pelagic fish populations.

Our evaluation of sonar indicates it is extremely effective for detecting fishes schooled near the surface over deep water. Those fishes schooled close to the bottom or over rocky areas are detected much less effectively. Another factor limiting this gear's effectiveness is the variability of the thermal structure in the water column. This refracts the sound beam, resulting in reduced range and the confusion of boat wakes with fish schools. School sizes can be more accurately assessed; however, and the effect of fish flaring away from the vessel's path is eliminated. Further, the large horizontal range greatly increases our search area, producing more comprehensive transect surveys. This gear permits us to maintain contact with a given target for long periods of time, providing an excellent means of studying school behavior and movement.

The prospect of using sonar in purse seining operations appears fair, particularly under certain conditions. Our experience to date indicates this equipment would be most effective for anchovy fishing.

Sea Survey Data Analysis

During this report period (July 1, 1968–June 30, 1969) the first computer program using our newly instituted magnetic tape storage system was completed. The program output gives a summary of 16 years of sea surface temperature readings and the occurrence of seven species of fish and two invertebrates.

The data are summarized by year, in each of six geographical areas, and show the general distribution and occurrence in relation to surface temperature, of all Pacific sardine, northern anchovy, Pacific mackerel, jack mackerel, Pacific saury, round herring, thread herring, squid, and red crab taken by dynamite or blanket net from 1950 through 1965.

Preliminary examination of the summaries has shown some interesting north-south distributional patterns, but the raw output of temperature vs. species occurrence needs further analysis.—*Charles H. Turner.*

HOPKINS MARINE STATION

DDT residues have entered all compartments of the world ecosystem due to their mobility, environmental stability, and affinity for biological materials (Risebrough *et al.*, 1968; Risebrough, 1969). Due to estuarine and airborne transport of DDT residues into the ocean and their relatively irreversible fixation in marine organisms, one would expect an eventual net transport of these materials to the ocean and their accumulation in oceanic food chains (Wurster, 1969). Under certain conditions, organochlorine compounds such as the DDT type compounds tend to become increasingly concentrated in successive tropic levels in aquatic food chains (*e.g.*, Langford, 1949; Hoffman and Surber, 1949; Rudd, 1966; Hickey *et al.*, 1966; Woodwell *et al.*, 1967). If this "tropic magnification" effect quantitatively reflects tropic relationships, it has potential usefulness for the study of the energetic requirements of pelagic organisms. The approach is based on the following assumptions:

(1) DDT residues accumulate in phytoplankton and detritus in proportion to their energy content as food.

(2) Zooplankton which graze on this material retain the associated DDT residues.

(3) Plankton-feeding fish (or other pelagic animals) retain the DDT residues from assimilated food (or they retain a constant, measurable proportion of the residues in the food).

The amount of DDT residues in an anchovy therefore may be directly related to its cumulative caloric assimilation during the period of the year that it feeds on phytoplankton, and indirectly during the balance of the year. Two initial conditions must be

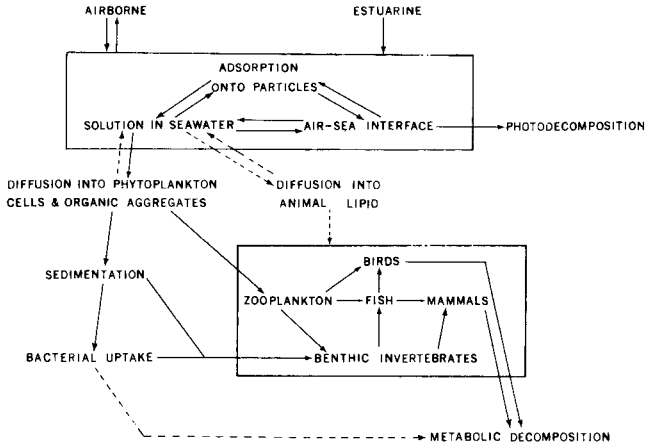

FIGURE 1. A schematic depiction of the various processes likely to control the fate and distribution of DDT residues entering the ocean. Residence time of the compounds in the upper box, the physical equilibrium system, is probably very short; eventually residues are taken up into organisms and cycle in the food chain, indicated by the lower box. See text for details.

met. First, DDT residues in the phytoplankton and other finely divided organic material must be quantified in order to interpret residue concentration data from the consumer organism. Second, it must be determined if the residue levels are constant enough to produce coherent increments of residues found in the consumer, such that they would be interpretable in terms of cumulative food assimilation. This report summarizes studies dealing with these two conditions.

Uptake of ^{14}C-DDT by Phytoplankton

The numerous processes involved in the transfer of DDT residues into the marine environment will affect the temporal and spatial distribution of DDT residues found in the phytoplankton and detritus which forms the food base for pelagic animals. Figure 1 shows some of these processes and the potential routes of residues once they reach the ocean. While environmental input of DDT residues into air and fluvial currents is probably seasonal and erratic, some damping of the pulses must occur. Once in surface waters, DDT will tend to accumulate at the air-sea interface, adsorb to particles, or be taken up by the particulate organic material—principally the phytoplankton, detritus, and microzooplankton. Direct uptake by larger organisms is relatively unimportant compared to assimilation via food (Macek and Korn, 1970). Phytoplankton accumulate residues by rapid absorption from the surrounding medium (Sodergren, 1967) but it is not clear what physical state the DDT is in when it is taken up. Some of it is probably in solution, but the term "solution" may be misleading. The study of aqueous mixtures of DDT suggests that it exists as a collection of aggregations of molecules in suspension; the maximum solubility of DDT in water is in fact operationally defined as that concentration in a supernatant after an arbitrary amount of ultracentrifugation (Biggar *et al.*, 1967). Concepts which assume normal solubility properties cannot be applied without modification to DDT in aqueous systems. Thus the idea of a partition coefficient, which has been suggested as a means for consideration of the biological concentration of DDT residues (Freed, 1970), cannot be used without qualification. Other conditions, such as the area of adsorptive interface in the system and the physical state of the DDT when it enters the system will affect the uptake of DDT by phytoplankton as well as the "dissolved" concentration in the water. However, it is difficult to account for such effects in experimental situations. Our experiments with ^{14}C-DDT uptake were designed to either minimize them or keep them constant. These experiments are described in detail elsewhere (Cox, 1970), but the results are presented here in Table I.

The concentration factors for the species of phytoplankton tested exceeds the estimate of Keil and Priester (1969) for *Cylindrotheca closterium* when correction is made to make our figures comparable to theirs. This discrepancy probably reflects the fact that they used high concentrations. Actual partition coefficients (ratios using the same concentration base) were calculated using known carbon to volume percentages for the algal clones used in these experiments; they are 3×10^4 for *S. carterae* and *T. fluviatilus*, and 8×10^4 for *A. carterae*. These values are equivalent to wet weight concentration factors.

Using a mean value of 2×10^5 for a carbon-based partition coefficient, and a local estimate of the

TABLE 1

^{14}C-DDT Uptake by Three Species of Marine Phytoplankton

Species	Total* pg^{14}C-DDT	Uptake* pg^{14}C-DDT	Cell C g	Equil. ppt	ppb/C in algae	Relative Part. Coefficient
Syracosphaera carterae	274 34(2)	143 31(2)	301	2.0	475	2.3×10^5
Syracosphaera carterae	274 34(2)	112 16(2)	151	2.6	741	2.9×10^5
Thalassiosira fluv.	362 20(2)	238 32(2)	730	2.4	326	1.4×10^5
Thalassiosira fluv.	362 20(2)	194 15(2)	365	3.3	532	1.6×10^5
Amphidinium carteri	323 22(2)	273 6(2)	1226	1.0	223	2.2×10^5
Amphidinium carteri	128(1)	68(1)	961	0.5	70	1.4×10^5
Amphidinium carteri	192(1)	92(1)	961	0.8	96	1.2×10^5

* Mean followed with standard deviation of the estimate; number of values shown in parentheses. The symbol pg denotes picograms, or 10^{-12} grams.
Column 1 shows the estimate of total activity in terms of ^{14}C-DDT added to the system. Column 2 shows the amount recovered from the cells after equilibration with the medium. The equilibrium concentration in parts per trillion is calculated from the difference between columns 1 and 2. Algal concentrations are expressed in terms of weight of ^{14}C-DDT per unit weight of wet combustion carbon in the algal cells. The relative partition coefficient is a ratio of columns 4 and 5.

concentration of DDT residues in whole seawater of 15 ppt (Odemar *et al,* 1967), we obtain an expected value of 30 ppm (concentration based on carbon content) of DDT residues in the phytoplankton. This value is encompassed by the confidence interval (95%) of values obtained by gas chromatographic analyses of phytoplankton samples from the same approximate time and location as the water concentration sample.

Analyses of Phytoplankton Samples

Samples for DDT analysis consisted of current net haul samples from CalCOFI station 3 in Monterey Bay (samples kept frozen until use) and formalin preserved samples taken at the same station from 1955 until the present. The samples were passed through fine mesh zooplankton netting (0.33 mm) to exclude the larger zooplankters prior to the analyses for carbon content and DDT residue content. Carbon was determined on replicates of each sample by the wet combustion method of Strickland and Parsons (1968). Some error is to be expected when carbon determinations are done on formalinized material, but the error involved is negligible in these studies when the range of variation of the DDT estimates is considered. Preliminary studies have indicated that there is no interference of formalin with the DDT determinations, but these results await further study and confirmation.

Two methods were used for the DDT determinations on the frozen and preserved samples. Originally, samples were filtered onto combusted GFC filter pads, ground in a glass and teflon homogenizer with successive rinses of high purity n-hexane, and passed through an acid-Celite column (Stanley and Le Favoure, 1965). The column eluate was collected in a Kuderna-Danish concentrator and concentrated for gas chromatographic injection. Subsequent experiments showed that the percent extraction efficiency of this method was poor (50%). Later analyses used different cleanup and concentration procedures resulting in better than 95% extraction and recovery efficiency. Hexane extracts in this procedure were chromatographed on silica gel microcolumns (Kadoum, 1968) and the eluates were concentrated at 37°C under a stream of nitrogen. All glassware for both procedures was combusted at 350°C overnight or run through an exhaustive rinsing procedure with redistilled and high purity solvents. Glassware was used when the cleaning procedures provided essentially a zero background of interfering peaks on the gas chromatograph.

The extracts, after cleanup and concentration were injected into a Beckman GC-4 gas chromatograph equipped with two columns and two electron capture detectors. Each sample was chromatographed on two columns of different composition; we used 5% DC-200, 5% QF-1, 5% mixed bed QF-1 and DC-200; and 6% SE-30 with 3% QF-1, all on DCMS Chromsorb W. Operating parameters were those suggested by the U.S. Food and Drug Administration.

Results of the determinations of DDT residues per unit of carbon are shown in Figure 2. Figure 2 shows

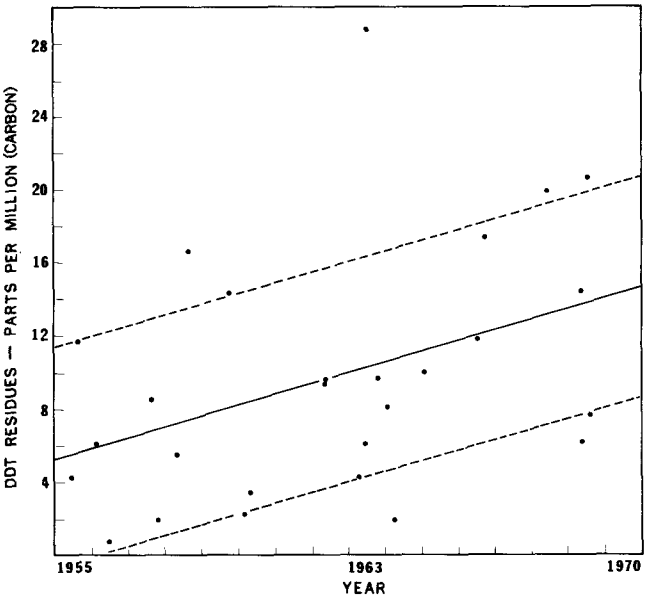

FIGURE 2. DDT residues (sum of p, p'-DDT, p, p'-DDE, and p, p'-DDD) concentrations in marine phytoplankton samples from CalCOFI station 3 in Monterey Bay. The solid line shows the least squares regression line; the dashed lines are a standard error of the estimate away from the regression line.

the results obtained by the original method. Results produced by the improved procedure show the same trend. This data will be reported in detail elsewhere when more analyses are completed. The trend toward higher residues in later samples could be produced either by loss of analyzable residues due to sample storage or by an actual increase in the residues to be found in phytoplankton from later years. Two lines of evidence indicate that the trend seen in Figure 2 is caused principally by the actual increase in environmental levels of DDT residues: first, the relative proportion of the three principal constituents of DDT found in all samples (p,p'-DDT, p,p'-DDD, p,p'-DDE) is quite constant and second, when ^{14}C-DDT is heated in sealed ampoules with the sample material, these compounds are produced as the principal breakdown components and their proportion changes with the degree of decomposition of the parent compound. The evidence is not conclusive on this basis, however, and the matter merits further study.

Sources of Variability

The variability of points in Figure 2, if they reflect actual levels of DDT residue concentrations in the phytoplankton, could have various sources. Short term variation in the amount of DDT entering the study area is undoubtedly a source. Another source is the change in size of the phytoplankton standing crop. Since our carbon measurments are based on a standard aliquot from a standard vertical net tow sample, they are an index of the standing crop size. When these carbon values are plotted against the DDT residue concentrations there appears to be an inverse relationship. This might be expected on the basis of a concentration-dependent or partition mechanism for

uptake of residues. This was previously observed by Wurster (1968) who noted that the phtosynthetic depression he observed for phytoplankton (which is presumably dependent upon internal concentrations of DDT) diminished when larger amounts of cells were present in the test cultures, independently of the nominal concentration of DDT in the medium.

Conclusion

DDT residues found in marine phytoplankton samples from Monterey Bay vary considerably relative to the carbon content of the analyzed samples. Residue concentrations increase significantly in samples taken over the last 15 years. Two important sources of variation in the estimates of the DDT residue concentrations are standing crop size at the time of sample collection and short term variations in environmental levels of DDT residues in the collection area.

The prospects for using DDT as an energy tracer depend upon how the variability of phytoplankton DDT concentrations affects the DDT-based estimate of how much phytoplankton carbon has contributed to the growth of the consumer. If certain assumptions can be made concerning the relative contribution of grazing upon standing crops of phytoplantkon of diferent size, perhaps the study could be continued to analyses of consumer organisms. Preliminary estimates of carbon assimilation of anchovies based on available analyses of their DDT residue concentration cannot be made since age data are not available for the fish used in those analyses.

LITERATURE CITED

Biggar, J. W., G. R. Dutt, and R. L. Riggs. 1967. Predicting and measuring the solubility of p,p'-DDT in water. *Bull. Environ. Cont. Toxicol.* 2:90–100.

Cox, J. L. 1970. Low ambient level uptake of ^{14}C-DDT by three species of marine phytoplankton. *Bull. Environ. Cont. Toxicol.* 5 (3): 218–221.

Freed, V. H. 1970. Global distribution of pesticides. *In: Symposium on the Biological Impact of Pesticides in the Environment.* Oregon State University Press, Corvallis. P. 1–10.

Hickey, J. J., J. A. Keith, and F. B. Coon. 1966. An exploration of the pesticides in a Lake Michigan ecosystem. J. Appl. Ecol. *3* (suppl.): 141–154.

Hoffman, C. H., and E. W. Surber, 1949. Effects of feeding sprayed insects to freshwater fish. *U.S. Fish. Wildlife Serv. Spec. Sci. Rep. Fish.* No. 4, 9 pp.

Kadoum, A. M. 1968. Application of the rapid micromethod of sample cleanup for gas chromatographic analysis of common organic pesticides in ground water, soil, plant, and animal extracts. *Bull. Environ. Cont. Toxicol.* 3: 65–70.

Keil, J. E., and L. E. Priester, 1969. DDT uptake and metabolism by a marine diatom. *Bull. Environ. Cont. Toxicol.* 4: 169–173.

Langford, R. R. 1949. The effect of DDT on freshwater fishes. *Dept. Lands Forests Bull.* 2: 19–38.

Macek, K. J., and S. Korn. 1970. Significance of the food chain in DDT accumulation by fish. *J. Fish Res. Bd. Canada* (In Press).

Risebrough, R. W. 1969. Chlorinated hydrocarbons in marine ecosystems. Ch. I, p. 5–23. *In: Chemical Fallout: First Rochester Conference on Toxicity,* (M. W. Miller and G. G. Berg, eds.) Thomas, Springfield. 531 p.

Risebrough, R. W., P. Reiche, D. B. Peakall, S. G. Herman, and M. N. Kirven. 1968. Polychlorinated biphenyls in the global ecosystem. *Nature* 220:1098–1102.

Rudd, R. L. 1964. *Pesticides and the Living Landscape.* University of Wisconsin Press, Madison and London. 320 p.

Sodergren, A. 1967. Uptake and accumulation of C14-DDT by *Chlorella* sp. (Chlorophyceae). *Oikos 19:* 126–138.

Stanley, R. L., and H. T. LeFavoure. 1965. Rapid digestion and cleanup of animal tissues for pesticide analysis. *J. Assoc. Office. Agr. Chemists 48:* 666–667.

Strickland, J. D. H., and T. R. Parsons. 1968. A practical handbook of seawater analysis. *Fish. Res. Bd. Canada Bull. 167,* 311 p.

Woodwell, G. M., C. F. Wurster, Jr., and P. A. Isaacson. 1967. DDT residues in an east coast estuary: a case of biological concentration of a persistent insecticide. *Science* 156: 821–824.

Wurster, C. F., Jr. 1969. Comments section, p. 20. *In: Chemical Fallout: First Rochester Conference on Toxicity,* (M. W. Miller and G. G. Berg, eds.) Thomas, Springfield. 531 p.

——, 1968. DDT reduces photosynthesis by marine phytoplankton. *Science* 159: 1474–1475.

—*James L. Cox.*

SCRIPPS INSTITUTION OF OCEANOGRAPHY MARINE LIFE RESEARCH PROGRAM

The Marine Life Research Group at Scripps has advanced on many fronts during the last year toward increasing our understanding of the California Current. These advances have been toward both broadening the program and intensifying the attack on specific problems. Only a few of the advances can be briefly presented below. Added funding for the programs has been obtained from a variety of sources including the National Science Foundation, the Atomic Energy Commission, and the Office of Naval Research.

The Marine Life Research Program has approached the following problems:

A. The continued monitoring of the California Current System with 1969 being the year set for intensified coverage.

B. The behavior of the northern types of zooplankton as they encounter the less hospitable subtropical conditions of the southern portions of the current.

C. The nature and causes of the large-scale changes in the oceanography and biology of the eastern North Pacific.

D. The history of changes in the conditions, general biology, and fish stocks of the California Current as indicated in special sediments found in the California Basins.

E. The nature of the populations of larger organisms on the deepsea floor.

F. The characterization and quantification of the zooplankton component in California waters into "functional" groups and a study of the various changes in these groups that occur in the California Current.

G. The behavior of important zooplankton populations.

During 1969, on nearly a monthly basis, patterned cruises from San Francisco to southern Baja California were carried out with the National Marine Fisheries Service. Hydrographic, chemical, and biological material were collected. Twelve special 24-hour stations

on lines 70, 90, and 120 were carried out, on four of these cruises, to explore the vertical distribution of zooplankton. These special stations used Brown-McGowan opening and closing nets to collect plankton at various depths to 500 m, twice a day, near midnight and near noon. Nutrient, productivity, chemical, and temperature measures were obtained.

At the same time as our near monthly sampling of the California Current, we maintained deep-moored instrument stations in the North Pacific at 41° N, 148° W; 43° N, 158° W; and 42° N, 164° W. These instrument stations were anchored in September, 1968, and are continuing to gather continuous water temperature and meteorological data. The data from the moored stations plus historical North Pacific water temperature and meteorological data are leading toward an improved understanding of the fluctuation of the California Current, and provide improved ocean weather, and fishery forecasting along the coast. Records of meteorological and oceanographic data continuing for months at a time are beginning to make it possible to understand some of the factors affecting the temperature structure of the surface layer of the ocean. It is hoped that in the near future one or more buoys will also be anchored in the California Current. Data gathered would be substantially help to augment our knowledge of the spectrum of variability in the CalCOFI regime and to enhance the value of the long series of records that have been collected from CalCOFI cruises.

The varved anaerobic sediments in the Santa Barbara Basin are continuing to be analyzed to establish the past changes and to understand the natural fluctuations of the California Current. It should be possible to establish the nature and magnitude of the effect that man is producing on the environment of the California Current since these detailed and virtually continuous varved sediments preserve many of the plant and animal remains on a year-to-year basis from prehistoric times into the present. A positive correlation between rainfall, tree growth, and sedimentation rate supports the sediment chronology and begins to open up an important climatic and marine biological record. The distribution of pelagic fish scales in the surface sediments closely parallels the recent history of these fish as found from the fishing records and CalCOFI data. This lends credence to the studies of fish population fluctuations over the last two thousand years, which have previously been reported.

Some experimental sable fishing (*Anoplopoma fimbria*) was carried out near San Diego, the Los Coronados Islands, and San Clemente Island. This is an important fish off the Pacific Northwest and Alaska, but has been fished rarely off Southern California, because of their much deeper occurrence. The free vehicle technique using traps and set lines with hooks were dropped to depths between 250 and 500 fathoms. Yields of fish per hook ranged between 0.1 and 0.75 on 30 hook lines, while the traps yields were between 1.7 and 8 fish per trap. The potential ultimate size and areal extent of this fishery off Southern California has not been established, but the population can be estimated from present data as exceeding hundreds of thousands of tons. Additional research is expected on this during the next year.

The Biomass Analysis Laboratory has just published its first Atlas of the biomass in the California Current. This covers biomass in the spring and fall for several important years. This Atlas shows large changes in the various functional groups of zooplankton between the colder years and warmer years in the CalCOFI area. The laboratory is presently working on the winter and summer periods for the same years.

The presence of salps in bloom conditions in the California Current may have a critical effect on other members of the plankton communities. Some feeding experiments have shown that the highest filtering rates were exhibited by actively-growing young solitary salps. Chains of *Salpa fusiformis* may increase by 1–2 cm/hr in unenriched sea water, suggesting that these organisms are well adapted for immediate use of suitable food conditions. Considering the high densities achieved by salps at various times in the California Current it appears that salps may remove half of the available microplankton food in bloom areas in less than 24 hours! Of the 24 known species of salps, 21 occur in the California Current.—*John D. Isaacs.*

NATIONAL MARINE FISHERIES SERVICE FISHERY-OCEANOGRAPHY CENTER

The commitment of the National Marine Fisheries Service to investigation of the abundant pelagic marine fish resources of the California Current area has continued, mainly within the framework of the California Cooperative Oceanic Fisheries Investigations, for more than 20 years. This work is conducted by the Fishery-Oceanography Center, La Jolla, which is the Federal laboratory responsible for fishery research in the Service's Pacific Southwest Region.

Research is oriented towards specific fisheries, but organized within the laboratory into four groups—Fishery-Oceanography, Population Dynamics, Behavior-Physiology, and Operations Research. With the exception of the Fishery-Oceanography Group, whose activities are concerned primarily with tuna ecology and tuna oceanography, all of the others are involved in various aspects of research on the industrial species of the California Current—anchovy, hake, saury, jack mackerel, Pacific mackerel, sardine, etc. The report which follows is concerned only with those research activities directly related to the interests of CalCOFI and is not intended as a comprehensive account of the research of the entire laboratory.

Most of CalCOFI-coordinated research at the Fishery-Oceanography Center is carried out by the *Population Dynamics Group*, which seeks to estimate the stock size and availability of latent resources and to demonstrate the effects of the fishery on recruitment, mortality and stock size of exploited fish populations. During this fiscal year, Dr. Paul Smith and biologists in this group participated in a full-scale cooperative oceanographic and biological survey of the California Current, the first such survey since 1966. For the

first time, the surveys became international with the addition to the survey fleet of the research vessel, PROFESSOR DERYUGIN, from the Soviet laboratory TINRO in Vladivostok. For the second consecutive year, MILLER FREEMAN, research vessel of the Service's Biological Laboratory in Seattle, joined DAVID STARR JORDAN, research vessel of the Fishery-Oceanography Center and ALEXANDER AGASSIZ from Scripps Institution of Oceanography. The four-ship research operation was able, for the first time, to survey the whole of the spawning range of Pacific hake off the coast of southern California and Baja California. Preliminary analysis of the numbers and distribution of hake eggs and larvae taken with standard plankton nets indicate that about 3 million tons of adult hake were present in the 1969 spawning concentrations.

In an effort to develop hydroacoustic techniques for stock assessment, a series of three cruises was made on JORDAN by Dr. Smith and biologists in his group from August to November 1968, to investigate the use of sonar to map densities of targets over the transects of the CalCOFI grid. Now almost completed, an analysis of acoustic targets revealed that scattered targets are present over the entire range of the California Current with the heaviest concentrations occurring in the Los Angeles Bight during the January survey. A sonar survey taken in May and June 1969, from San Francisco to Cape San Lazaro, Baja California, indicated that about a million targets, probably individual schools of fish, inhabit the upper mixed layer of the sea during daylight hours. A new survey system has been designed, consisting of a towed body with transducers of three different frequencies for mapping fish schools in the upper 50 meters. This array is intended to provide target characteristics which can be used to distinguish schooled anchovy from other schooled fish and to estimate the size of individual fish within schools.

During the massive Santa Barbara oil spill in February 1969, Service biologists conducted a cruise on JORDAN into the area to assess effects of the oil on fish larvae and plankton. Samples taken from directly under the oil indicated that fish larvae were present in the usual numbers and kinds representative of the area at that time of year and it was concluded that the oil spill at that point had no major discernible effect on the planktonic biota.

New information on the aging of Pacific sardines is available from studies conducted on a large group of fish hatched at the Fishery-Oceanography Center in May 1968, and maintained in large aquaria. It has been found that growth in captivity compares favorably with growth estimates obtained from wild fish. The cooperative collection with California State agencies of data on the age structure of the anchovy populations from samples taken from the commercial catch has continued. A study of techniques for aging anchovies has resulted in a shift in approach which saves 50% in man-hours over the previous method.

Information obtained from a Service contract with the California Academy of Sciences and by agreement with Mexican fisheries agencies indicated that the anchovy landings from the Baja California fishery in 1968, are nearly the same as in 1967, while Pacific mackerel and jack mackerel landings remained low.

Research has also continued on elucidating the subpopulation structure of the anchovy. Indications from genotype analysis are that all anchovies south of Point Conception, in the southern California area, and at least as far south as Ensenada, Mexico, are drawn from a single homogeneous population.

The *Operations Research Group* is working to develop efficient tactical search tools for fishing vessels to understand how the biological characteristics of various species of commercial fish affect their reaction to fishing gear. In cooperation with the NMFS Branch of Economics, a study of the operating economics of the San Pedro wetfish fleet has been completed by this group. This study has shown that unless changes can be made in crew size, catch rate, and lay share percentage, the entry of new construction into the wetfish fleet will remain unprofitable.

One of the primary ways in which this group is working to solve some of the problems of the wetfish fleet is to reduce the manpower requirements for catching anchovy for reduction. During the past year a 10-inch Marco hydraulic fish pump has been placed aboard a wetfish boat to help eliminate mechanical brailing. Work has also been started to devise alternative seining techniques which will not require a power skiff, hence 1 or 2 less men.

In early July 1969, the MRC, acting on a subcommittee report, recommended the formation of a Wetfish Operation Pool to be made up of MRC, NMFS, California Department of Fish and Game, the Fisherman's Cooperative Association and labor to combine their resources and undertake a program of applied gear research. The MRC has now contracted with the Operations Research Group for a cooperative experiment to study methods of mechanizing the wetfish seining operation and negotiations have begun with the owners for the use of one wetfish boat to explore some of the methods suggested.

Sea surveys of the California Current have consistently indicated under-used fishery resources. During the past year biologists in the Operations Research Group have been investigating such potential fishery resources as shrimp, swordfish, basking sharks, and saury, the latter in cooperation with the Service's Exploratory Fishing Gear Research Base, Seattle. Saury, in particular, seems to offer some promise as an additional species for inclusion in the wetfish catch. With the Exploratory Fishing and Gear Research Base in Pascagoula, Mississippi, the Group has also been studying bioluminescence as an aid in night scouting for wetfish.

The experimental longline fishery for swordfish was started by this Group by inviting fishermen on a demonstration/experimental trip aboard the research vessel, DAVID STARR JORDAN, and by furnishing gear and assistance to the boats. This year the first commercial west coast longline trip was completed with 2.5 tons of swordfish caught. Although the catch was not spectacular, the hook rate of 0.8 fish/100 hooks

set was encouraging, and a second vessel has since entered the fishery.

Scientists in the *Behavior-Physiology Group* are concerned with the behavior of larval, juvenile and adult fish and with the trophodynamics of the food chain of which the important commercial species of fish and invertebrates are a part. Principal emphasis of the Behavior-Physiology Group during the past year has been on the biology of larval fishes, particularly anchovy reared in the laboratory. Recent experiments have shown, for example, that at 22° C anchovy larvae can survive without food for 3 days after hatching or 1.5 days after absorption of the yolk. Best survival for anchovy larvae occurred when the density of food organisms was at a concentration of between 4 and 8 copepod nauplii per ml. The implication of these results is that the period of time which can elapse before the larvae must feed in order to survive after exhausting their yolk supply may be longer than expected and less critical in terms of survival.

A technique has been established for photographing fish larvae and their food which will make it possible to determine the feeding efficiency, the perceptive field for feeding, and to describe the feeding behavior of larvae of different sizes. Larval anchovies, 7–10 mm, were filmed with a high-speed camera and it was possible at higher photographic magnifications to resolve both the larvae and their food which ranged in size from 100–300 microns. These data will be used to determine plankton densities required for survival of larvae.

A study has been concluded which describes differential feeding of the anchovy on two sizes of crustaceans as a function of food density and indicates the density ratios at which the feeding attack will be directed exclusively at one of the organisms. After a satisfactory procedure had been established for culturing a unicellular algal flagellate, *Platymonas,* in the laboratory, feeding trials with the northern anchovy were made. The data indicate that large schools of anchovies respond immediately to *Platymonas* by increasing their swimming speed and filtering.

As part of a study of the mechanism and physiology of swimming in oceanic pelagic fish, a machine has been constructed and calibrated which will measure the swimming speeds of fish, 5–30 cm in length. Using a jack mackerel as the experimental animal, it was found that the frequency of tail-beat is not linearly related to fish length as has been previously supposed, but that the relation is logarithmic. It further appears that the relationship is essentially similar in all groups of teleosts tested—from goldfish to jack mackerel.

A series of experiments on the effect of temperature on hatching time, development, yolk utilization and growth of hake, jack mackerel, anchovy, and a number of other coastal pelagic marine species was completed. The data indicate that the rate of hatching and other related developmental processes triples over the 10° range (16–26° C) for the species studied. This information is vital for predicting biomass estimates from field egg and larval collections.

A study was begun on the effects of various physical conditions on the gonads of anchovies, beginning with different light and temperature regimes. From data accumulated thus far, it appears that ovary development is highly variable even under constant conditions and that eggs can develop to the yolked stage in a relatively short time.

An organism, the unarmored dinoflagellate, *Gymnodinium splendens,* has been found that is culturable in the laboratory, yet acceptable and nutritious to first-feeding fish larvae. During a series of experiments with this organism, anchovy larvae fed *Gymnodinium* survived 3 weeks beyond the mortality of starved larvae acting as controls.—*Alan R. Longhurst.*