

AGENCY REPORTS

CALIFORNIA ACADEMY OF SCIENCES

Brief summary on food habits of Northern Anchovy (Engraulis mordax)

Three basic collections of anchovy stomachs were made in Central and Northern Baja California, Southern California, and Central California, and three supplementary small ones were made in Northern Baja California (two) and in Southern California (one). These six collections were made between May, 1965, and February, 1968, totaling 926 stomachs. The collections were chiefly made, and all were examined, by Anatole Loukashkin.

Out of 926 stomachs examined, 86 were empty, in 173 food items were evenly distributed, and in 667 dominance of one type of food over the others was clearly evident.

Stomach contents varied from "very poor" to "full capacity." A majority of stomachs fell into categories "poor" and "very poor."

The best-filled stomachs were found in fishes caught during the day, or in fishes caught at night attracted by an electric light under which they were feeding on plankton swarming within the illuminated zone. Less-filled stomachs and most of the empty ones were found in fishes caught in midwater trawl net hauls during night fishing.

In May and June collections of 1965 (Monterey Bay and Northern Baja California), phytoplankton (diatoms) dominated, up to 34.57 percent and 83.33 percent respectively. In some stomachs diatoms were the only food item found, and quite often 99 percent of the diatoms belonged to a single form (*Chaetoceros*, for instance). In other stomachs, phytoplankton and zooplankton were present in equal volumes. In a greater number of cases, only a few specimens of diatoms were found. Dinoflagellates were found in meager quantities.

From actual observations in the field and in the Steinhart Aquarium, and from the examination of the stomach contents, it is evident that the anchovy is both a filter-feeder and a particulate feeder, depending on the size of the available food organisms. The anchovy is an omnivorous animal feeding on whatever suitable food material is available.—*R. C. Miller*

CALIFORNIA DEPARTMENT OF FISH AND GAME PELAGIC FISH INVESTIGATIONS

The Department's research under CalCOFI is concerned chiefly with studies of the pelagic wet fisheries and with studies of the fishery resources of the California Current System based on echo-sounder surveys. These studies are directed toward assessing the distribution, abundance, and age structure of the northern anchovy, Pacific sardine, jack mackerel, Pacific

mackerel and other important fish populations. This information is basic to developing an understanding of fish population dynamics relative to their proper utilization.

The Pelagic Fish Investigations include four research projects; (i) Anchovy, (ii) Mackerel-Sardine, (iii) Sea Survey, and (iv) Sea Survey Data Analysis.

Anchovy

Routine activities such as fishery sampling and monitoring aimed at determining the age composition of landings, catch-per-unit-effort of the fleet, and areas of fishing were continued. Techniques and sampling procedures have been reported in volumes XI and XII of this report series.

Very few data relative to developing an understanding of the dynamics of the anchovy population were gained during the fiscal year. This can be attributed to the poor fishery, only 852 tons landed in southern California, caused chiefly by the low price of fish meal and oil.

The live-bait project initiated a three-month program of intensive sampling in June 1968. The objective was to obtain background data for the design of a statistically evaluable live-bait sampling scheme. Preliminary analysis indicate that the past level of sampling must be doubled or tripled to obtain numerical age composition estimates, of the dominant year class, with 90% probability and $\pm 15%$ standard error.

During the year ending June 30, 1968, 205,657 anchovies were tagged but only 136 recovered. Total anchovies tagged and recovered since March 14, 1966 were 320,743 and 609 respectively. Tag recoveries were low because of the lack of a fishery in southern California. Recoveries demonstrated nothing new but did corroborate previous findings: That fish from as far away as Sausalito (San Francisco Bay) and San Diego contribute to the Monterey Bay fishery; Monterey fish contribute to the southern California fishery; and southern California fish contribute to the Baja California, Mexico fishery.

Mackerel-Sardine

Two programs, designed to monitor the condition of the fishery, continued through the fiscal year. The first involved estimation of the age compositions of the landings. Due to the sardine moratorium which commenced June 7, 1967, it was difficult to obtain sufficient samples to describe the catch adequately. We intensified work at the markets and sampled all sardine catches that were mixed with mackerel and landed at the canneries.

The new jack mackerel sampling plan installed in May 1967 has worked well and has allowed smoother

collection of the necessary data on a sound statistical basis.

Pacific mackerel landings are at an all time low and, as with the sardine, we are forced to sample all landings available. We made a major adjustment in our procedure in that now fewer fish are taken per sample and all are aged and weighed.

The fleet monitoring program continued routinely and seems to be fulfilling its objective of monitoring fishing effort on a sound, systematic basis. Through log-interviews we obtained detailed fishing information on approximately 90% of the southern California vessel landings of mackerel, sardines, and bonito.

Analysis of the backlog of jack mackerel age-length data from 1947-67 continued when time permitted. A paper on the jack mackerel resource was presented to the 1967 CalCOFI conference.

A paper on the current status of the Pacific mackerel fishery and the condition of the resource was presented to the Marine Research Committee. This discussion incorporated some of the preliminary population work by Patrick Tomlinson of the Department's Biostatistical section and highlighted the present depressed state of the resource.

Reports on the age composition of the landings were completed for the 1965-1966 sardine season and the 1964-65 through 1966-67 seasons for Pacific mackerel.

Sea Survey

During the past year 10 sea survey cruises averaging 20 days each were conducted in the California Current System. Nine were routine and one was experimental.

Northern California was surveyed once in the summer of 1967, and central and southern California three times each by cruises during fall, winter and spring. An additional experimental cruise to test trawl gear and a new sonar was made in southern California. Baja California, Mexico was surveyed during late fall and early spring.

After two years of work, all regions have been surveyed during every season except summer. The principal pelagic species, as determined by echo sounding and midwater trawling, are in order of abundance: northern anchovies (*Engraulis mordax*), lanternfishes (family Myctophidae) and deep sea smelts (family Bathylagidae), juvenile rockfishes (*Sebastes* spp.), Pacific hake (*Merluccius productus*), jack mackerel, (*Trachurus symmetricus*), and Pacific sardine (*Sardinops caeruleus*). Pacific herring (*Clupea pallasii*) and whitebait smelt (*Allosmerus elongatus*) were locally abundant at times in northern and central California. Anchovies completely dominated as the most abundant species in terms of biomass. The bathypelagic lanternfishes and deep sea smelts very likely constitute a fairly large biomass but their dispersed schooling habits would make it difficult to utilize them directly. Rockfishes, although not a true pelagic species, constitute a large resource. The remaining species occurred in relatively minor amounts due either to ineffectiveness of the surveys or actual low species density.

A new fish finding sonar was installed aboard the R/V ALASKA during the last week of June, 1968. Preliminary trials indicate this equipment will be of great value, both as a survey tool and as an aid in fishing operations. Thus far it has been very effective in locating and tracking anchovy schools and may be of potential value in determining school sizes.

This instrument can also be used as an echo sounder. Comparisons made with our regular echo sounder indicate the sonar has much better fish detecting sensitivity. This capability should enhance the detection of scattered fishes such as lanternfish and hake.

A net reel for improving midwater trawl operations was delivered in late June and was later installed aboard the ALASKA.

A new method of coding permits direct coded data entry during collection at sea. This method eliminates tedious shoreside work and reduces chances for error. All 1968 data have been collected in this manner.

Sea Survey Data Analysis

During the 1967-68 fiscal year several computer programs were written and utilized to extract data from past Sea Survey cruises.

The sardine length-age composition computer program was completed and data obtained on Sea Surveys for twelve years (1950 through 1961) were analyzed. After examination of the data it does not appear that the dynamite and blanket net surveys gave us any quantitative measure of the Pacific sardine populations, or any new insight into their biology. However, general trends of abundance by year and by area were apparent.

The sardine length-age program was modified to compile similar data on the northern anchovy. At best the data were spotty and inconsistent. Modifications of anchovy sampling techniques under the new midwater trawl surveys are expected to give us new insight as to migration patterns and population parameters of this species.

The transfer of over 50,000 cards to tape was completed. Sea Survey data from 1950 to 1966 is now on tape and in usable form. The cost and time involved in making these tapes made it of vital importance to have duplicates in case of loss or damage. Therefore, duplicate tapes were copied using a Univac 1107 tape "soft ware" program.

Besides the obvious assets of tapes over cards as a storage facility, tapes will allow us to analyze many years of data concurrently instead of one year at a time which the card system necessitated. Conversely, easy cruise by cruise analysis and even the ability to pick out any particular cruise is made available to us by an end-of-file routine. This routine requires a minimum of computer programming instructions.

With the completion of the card-to-tape program work was resumed on the computer program which will relate Sea Survey catches of economically important fish and invertebrates to environmental conditions.—*J. L. Barter.*

HOPKINS MARINE STATION

The Hopkins Marine Station of Stanford University at Pacific Grove, California, conducts studies on the environment and organisms of the coastal waters off central California. Under the program, the marine station monitors the marine environment and phytoplankton of Monterey Bay, and is starting a study of the food chain of the anchovy and its relation to the biological oceanography of Monterey Bay.

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

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

In addition daily shore temperatures are recorded at Pacific Grove and Santa Cruz.

Both shore and cruise data are compiled and distributed to interested agencies and individuals in the form of quarterly and annual reports.—*M. Gil-martin.*

SCRIPPS INSTITUTION OF OCEANOGRAPHY MARINE LIFE RESEARCH PROGRAM

The Marine Life Research Program is the administrative unit of the Scripps Institution of Oceanography which carries out the portion of the California Cooperative Fisheries Investigations that has been assigned to the University of California. The program is broadly involved in investigations of the ecology of the California Current System—with its currents, temperatures, chemistry, climate, and populations of organisms, and with the fluctuations of these parameters.

As was pointed out in the preceding CalCOFI Report (Vol. XII), the scope of the Marine Life Research Program has, over the years, become considerably augmented and expanded by research grants from a number of agencies. This has allowed us to extend the program's inquiries both in depth and width into the conditions and processes of the North Pacific. This has been possible because of the fundamental and perception broadness with which the cooperative investigations were imbued by its prescient originators, two decades ago.

The basic report of the Marine Life Research Program is contained in the publications of its investiga-

tors. This resume briefly points out some of the present conditions of the eastern North Pacific and some of the scientific developments.

Recent Oceanographic Conditions in the Pacific

The northeast Pacific Ocean was generally warmer than normal by 2° F from July, 1967 to June, 1968. A colder than normal area in the Gulf of Alaska from September, 1967 through February, 1968 became approximately normal from March through June, 1968. A cold area off the west coasts of the United States and northern Baja California developed in April, 1968 but it had become much smaller by July, 1968.

North Pacific Study

A program to study the large-scale oceanographic and meteorological conditions in the North Pacific, reported in Volume XII, is progressing smoothly.

An array of unmanned instrument platforms is being prepared to collect data from the central North Pacific. Data is now being collected off Monterey by such stations. Extensive records from two moored stations in the tropical eastern North Pacific are being analyzed. Such information in conjunction with an extensive historical study in progress should provide a greater understanding of the ocean conditions and weather of the California coast.

Zooplankton

This extremely important component of the living populations of the sea continues to be studied intensively. Plankton collections at sea have always been a major part of the CalCOFI Surveys. There is now in the archives at Scripps the greatest and most complete plankton collection of any area in the world. Only a miniscule fraction of the value of such a collection can be realized unless careful scholarly analysis is continuously conducted. Analysis of this collection and publication of results has thus always been a major portion of the Marine Life Research Program. All of the major groups of zooplankton are under continuous study.

Results of these studies have shed more and more light on the processes in the California Current. For example, a study of the community structure and distribution of zooplankton sampled during a spring cruise that covered a large part of the California Current has shown: (1) very little pattern of community distribution, (2) no relationship to physical stability. This lends support to an earlier conclusion based on purely biogeographic data, namely that the primary factor influencing the numerical species relationships in most of the California Current is advection, not trophic relationships. That is, the principal factor that determines the composition of the important zooplankton populations in the California Current is the current system rather than the level of phytoplankton, the chemistry or other conditions. This is a most important confirmation of earlier indications.

The discoveries of the scientists working with the zooplankton urge that the coming surveys in 1969 include a considerable number of stratified net tows.

For example, some of the important species of zooplankton seemingly disappear from the California Current in certain regions. Actually these species descend in those regions out of the range of the conventional plankton nets. This and other sorts of changes in vertical distribution require the vertically stratified sampling that is to be an important part of the 1969 cruises.

Considerable advances have been made in artificially rearing some of the larvae of the planktonic organisms. This, of course, finally allows these larval organisms to be identified positively. This and other research throws important light on the rate of growth and reproduction of the zooplankton. The growth rates of plankton appear to be much more rapid than they were previously thought to be. That unexpectedly rapid growth may be the rule rather than the exception is also indicated by studies of the rate of production of the sediments, which is discussed later.

Biomass Analysis

Although the exact species identification of the creatures in the plankton is essential for a complete understanding of the planktonic populations, such identification of all species in all samples is an extremely lengthy task. Insofar as concerns the plankton as food for higher organisms, such as fish, the exact *species* spectrum of plankton present is undoubtedly not as important as are the abundances of important *types* of plankton. For example, the proportion of crustacea, worms, jellies, etc. in the plankton is more important to a fish such as the sardine or anchovy than is the exact species composition.

Thus, several years ago, techniques for biomass analysis were developed in the Marine Life Research Program. This work of the Biomass Analysis Laboratory has developed very satisfactorily. The plankton are separated into about twenty "functional" groups and their total biomass is measured.

The first major results of this work are now in advanced stages of publication. They show that profound changes in the functional groups of zooplankton have occurred in critical years.

Varved Sediments

The analysis of the varved (layered) sediments from the Santa Barbara Basin and elsewhere (previously reported) continues, and continues to show increasing details of the history of oceanic conditions and of fish populations along the eastern North Pacific. About eight periods of abundance of sardine scales have now been identified during the last two thousand years. These periods on the average occurred about every two hundred and fifty years and their average duration was of the order of seventy to one hundred and twenty years. The populations of hake and anchovies apparently remained relatively large throughout the entire period, although also fluctuating.

Attempts to separate and study the relative populations of Pacific and jack mackerel were unsuccessful, because of the rarity of Pacific mackerel scales.

The indicated *minimum* total populations of anchovies and hake are close to but somewhat below the present estimates from larval and other data.

Sedimentation

This new entree into the productivity of the California Current involves the collection of the debris from the surface waters that is falling to the bottom. Development of an autonomous collector to carry out this difficult task has been successful. The results indicate that the maximum generation time of the planktonic organisms studied was much briefer than supposed. This supports the findings reported above from studies of the zooplankton populations.

Deep Currents

Autonomous current recorders, developed by the Marine Life Research Program, now permit the long term measurement of the bottom water flow over large areas. Since the major part of the productivity of the North Pacific is the ultimate result of this deep flow, the measurement of the total flow into the North Pacific is of substantial importance. Exploratory attempts at measuring the flow have been encouraging and a major effort is now being undertaken.

Deep Creatures

The photographs of large populations of fish and crabs have been published previously. Analysis of the large number of photographs now available indicate that the populations are much larger than previously thought and that they must, in a large part, be dependent upon windfalls of large particles of food, such as the carcasses of whales, large sharks, or large fish, and possibly upon quantities of smaller fish debris resulting from predator attacks on large near-surface schools of prey.

General

In consonance with the CalCOFI Program, in general, the Marine Life Research Program is continuing its task of fundamental elucidation of the potential of the eastern North Pacific for man's use.

Although the major constraints to this use by the State of California appear now to be institutional rather than strictly scientific, technical, or economic, the continued expansion of knowledge of these important resources cannot fail to be of ultimate benefit in a future enlightened period.—*John D. Isaacs.*

U. S. BUREAU OF COMMERCIAL FISHERIES FISHERY-OCEANOGRAPHY CENTER

This fiscal year is the first in which the Fishery-Oceanography Center has been operated as a unit, following the amalgamation of the former Tuna Resources and California Current Resources Laboratories. Research at the Center, which is the Federal laboratory responsible for fishery research in the BCF's Pacific Southwest region, is intended to supplement that of the State agencies, with which it collaborates, mainly within the framework of the California Cooperative Oceanic Fisheries Investigations.

In addition to conducting research on problems which are relevant to specific fisheries and designed to improve their status, the Center is also charged with advancing basic fisheries science. The work of the Center is carried out under four research programs, each of which confines its activities to a single discipline of fisheries science.

One of the main accomplishments of the past year in the *Fishery-Oceanography* Program has been completion of the field surveys for EASTROPAC, a multi-agency, international series of expeditions designed to investigate seasonal changes over a large part of the eastern tropical Pacific. Under Bureau leadership, EASTROPAC was a major oceanographic effort, comparable with the largest oceanographic expeditions in numbers of stations and observations. With the completion of work at sea, the EASTROPAC staff has turned to the task of processing a vast amount of data. To expedite the job, computer programs were written for data processing and for the generation of vertical sections and horizontal plots of physical, chemical, and biological properties to be presented in a comprehensive published atlas.

Aided by an increased use of automatic data processing and communication techniques, the environmental monitoring and fishery forecasting project continued its services to fishermen through publication of fishing information, weather summaries, and radio broadcasts. Towards the end of the year, the project staff prepared for an albacore oceanography cruise designed to measure the distribution and availability of albacore in offshore waters.

In the *Behavior-Physiology* Program, a long-term study of the energy budget of the Pacific sardine has been completed. Measurements have shown that growth accounts for about a fifth of the assimilated energy of the average sardine during its first year of life, declining in succeeding years to as little as 1 percent. Respiration is the dominant energy-consuming process throughout the sardine's life. With the historical decline of the sardine biomass, a major part of the calories formerly needed for its respiration became available to other predators, e.g., the anchovy; the amount of energy made available to anchovies by the demise of sardines is about 30×10^{12} kilocalories per year in the California Current.

This program has also completed its studies on the mechanism of feeding in the northern anchovy, on the development of automatic data processing techniques for the quantitative analysis of fish schools from pho-

tographs and on the perfection of an effective, if empirical, rearing technique for pelagic fish larvae in the experimental aquarium at the Center.

Among the accomplishments of the *Population Dynamics* Program this year has been the demonstration that there are at least two genetically distinct subpopulations of the northern anchovy off the coast of California and Baja California. Samples from these two areas differ significantly in the frequency of three genes which control six recognizable transferrin types. The location of the division between the two subpopulations has not been established and the existence of a third, far northern stock, postulated by earlier investigators, has not yet been confirmed.

During the past year all of the biological and many of the physical data, including those taken on monthly CalCOFI cruises from 1951-60, have been coded for automatic data processing. This work furnishes an excellent data base for analyses of spawning seasons for each species, and of yearly anomalies from the long-term average and will be used in the design of the extensive CalCOFI cruises planned for calendar year 1969.

Because Mexico and the United States have a common fishery for sardines, anchovies, jack mackerel and Pacific mackerel from the California Current, arrangements were made this year to bring the Mexican Federal Laboratory into the fish sampling and ageing program carried out cooperatively by BCF and the State for more than 25 years.

Designed and built by scientists in the *Operations Research* Program this spring, the hybrid tuna purse seine combines the fast-sinking qualities of the North Atlantic purse-seine with the strength, deep fishing, and ease of handling of the American tuna seine. Data from field trials indicate that the new net sinks approximately 70% deeper and at a faster rate than conventional 7-strip tuna seines while maintaining its initial diameter well into pursing. If the net performs as well as expected under actual fishing conditions, American tuna fishermen could save more than \$1 million annually in operating costs.

Other work in this program has been concerned with reactivating a basking shark fishery for extraction of squalene from liver oil, evaluation of the Continuous-Transmission-Frequency-Modulated sonar as a tactical fishing tool, and the beginning of a study to investigate the economic base of the California industrial fishery, presently in a depressed state.—A. R. Longhurst.