

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME
MARINE RESEARCH COMMITTEE

CALIFORNIA
COOPERATIVE
OCEANIC
FISHERIES
INVESTIGATIONS

Progress Report

1 July 1953 to 31 March 1955

Cooperating Agencies:
CALIFORNIA ACADEMY OF SCIENCES
CALIFORNIA DEPARTMENT OF FISH AND GAME
STANFORD UNIVERSITY, HOPKINS MARINE STATION
U. S. FISH AND WILDLIFE SERVICE, SOUTH PACIFIC FISHERY INVESTIGATIONS
UNIVERSITY OF CALIFORNIA, SCRIPPS INSTITUTION OF OCEANOGRAPHY

LETTER OF TRANSMITTAL

POST OFFICE BOX 807
LOS ALTOS, CALIFORNIA

HONORABLE GOODWIN J. KNIGHT
Governor of the State of California
Sacramento, California

DEAR SIR: We respectfully submit a report on the progress of the California Cooperative Oceanic Fisheries Investigations for the period 1 July 1953 through 31 March 1955.

The report is divided into three main sections. In the first we briefly review sardine research since the beginning of the program. In the second, we depart from the format of the first three reports of this series to present a formal scientific paper. This is *Population Dynamics of the Pacific Sardine*. The authors are Frances N. Clark, Director of the State Fisheries Laboratory, Marine Fisheries Branch, California Department of Fish and Game, and John C. Marr, Chief, South Pacific Fishery Investigations, U. S. Fish and Wildlife Service, and Director, Marine Life Research Program of the University of California's Scripps Institution of Oceanography.

The publication of this paper under the auspices of the Committee does not necessarily mean that the members of the Marine Research Committee subscribe to all of the conclusions reached in the paper; other conclusions are possible; as the paper itself discloses, the authors disagree on some aspects of the sardine problem. The paper does represent the best effort of two of the chief research workers in the field to construct a general theory that will explain many aspects of the sardine problem. The third major section of the report lists all publications that have arisen from the work under the California Cooperative Oceanic Fisheries Investigations.

Respectfully,

J. G. BURNETTE, Chairman
Marine Research Committee
D. T. SAXBY, Vice Chairman
RICHARD S. CROKER, Secretary
J. R. BIVEN
SETH GORDON
ROBERT C. MILLER
JOHN V. MORRIS
WM. J. SILVA
GILBERT C. VAN CAMP

ABSTRACT

In 1954, Nature conducted an oceanographic-fisheries experiment far beyond the scope of man.

Sardines spawned off southern California earlier and over wider distances than at any time since the start of the expanded sardine investigations in 1949.

Ocean temperatures off southern California were consistently warmer than in previous years.

The fishing season saw some sardines taken as far north as Avila.

In southern California, sixteen times the previous season's catch was taken.

The sardines came from off Mexico.

Whether they will return to California next year is beyond our present ability to forecast, but in this spring of 1955 they are spawning again in the southern California-northern Baja California center.

When the scientific data for 1954 are completely reviewed, we should be several strides nearer to being able to forecast where the sardines are, how many there are, and if they can be caught.

The important thing to remember is that the year 1954 was the one the scientists have been waiting for, a better year to contrast with the five bad ones previously studied.

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PART I: THE MARINE RESEARCH COMMITTEE, 1947-55

It seems unlikely that any marine fishery in California will face a situation more baffling than did the sardine industry in 1947-48. For several years the succulent little Pacific sardines had formed the basis of one of the nation's great fisheries. Approximately half a million tons were being taken annually; in some seasons the catch went well above that figure. Monterey's Cannery Row was known all over the world; less noted but equally thriving sardine ports were San Francisco and Los Angeles Harbor, with San Diego playing a minor role.

After dropping somewhat in the early 1940's, in 1947-48 the catch plummeted to a low of a little over 100,000 tons. Several scientific agencies had investigated the fish to the best of their means. But it was clear that there was not enough factual information on hand fully to explain the disaster or to predict the future of the fishery. Particularly needed was information on sardine behavior and distribution, to find out the influence of oceanic conditions on the sardine.

It was under these circumstances that the Marine Research Committee was formed by legislative action. The membership consisted of five men from the sardine industry, one public representative, and three ex-officio members—one from the Fish and Game Commission, two from the Department of Fish and Game.

A special tax was put on sardine landings and was later expanded to cover anchovies, jack mackerel, Pacific mackerel, herring, and squid. All but a fraction of these funds has been spent by the Marine Research Committee to foster research on oceanic fishes.

Bad as it was, the 1947-48 season was by no means the lowest ebb of sardine fishing in California. Much worse was to come. In the 1953-54 season only about 3,500 tons of sardines were landed in California, virtually all from southern California waters.

By that time, the scientists had worked for almost five years on intensified sardine investigations. They believed that they knew the answers to some aspects of the problem. But they had been working in an era when oceanic conditions seemed uniformly hostile to sardines. They had a great deal of detailed information on very bad years. What they sorely needed was comparable information on good years.

The scientists were working under the California Cooperative Oceanic Fisheries Investigations, as the expanded sardine studies have come to be known. The program was modeled upon investigations carried on continuously since 1919 by the California Department of Fish and Game and augmented after 1937 by the U. S. Fish and Wildlife Service. The plans for the joint oceanographic-fisheries research cruises were based on investigations undertaken between 1929 and 1932 and again between 1937 and 1940 by the Depart-

ment of Fish and Game and expanded in 1939 through 1941 by the cooperative efforts of Scripps Institution of Oceanography and the Fish and Wildlife Service. Scripps, Fish and Wildlife Service, California Fish and Game, and California Academy of Sciences planned the present broad program of investigations in 1947 and Hopkins Marine Station joined in the work in 1951. Their money has come from various sources.

To date more than four million dollars has gone into this program from state, federal, and industry sources. Of the total, the Marine Research Committee has directed the spending of \$772,960 in the fiscal years 1948-49 to 1954-55.

Of this sum, the Scripps Institution has received 29.6 per cent. Since 1949, as a rule, two university vessels have put to sea each month. These ships have sailed over 300,000 miles covering oceanic waters in a region that extends from the Oregon border to the tip of Baja California and 200 to 300 miles at sea. As a result, a large proportion (in 1954-55, an estimated 65 per cent) of the money Scripps has received through the University for marine life research has been spent on the collection of data at sea and its processing. Only the lesser share has been available for the important work of analysis of the data and conducting special studies. With the Marine Research Committee grants, the Institution has been able to undertake studies of the food of the sardines, of some oceanic plants, of the genetics of sardines. In addition, it has supplied editorial and illustrative services for the publications of the Marine Research Committee.

The South Pacific Fishery Investigations of the U. S. Fish and Wildlife Service has been given \$378,509, or 49.0 per cent, of the sum. The Fish and Wildlife Service has used the money to expand its studies of the eggs and larvae of sardines and to continue its joint studies with the Department of Fish and Game of the commercial catch, and to participate, with its vessel *Black Douglas*, in the routine oceanic surveys.

The California Department of Fish and Game has received 7.8 per cent of the total. This was used in part to purchase equipment, in part for salaries in connection with the Department's sardine studies. Through its regular budget the Department has conducted young fish and adult fish surveys, has kept records of the catch and age and sizes of sardines, mackerels and anchovies as well as all other commercial species, has participated in the very important scale reading program, and has collected material at sea for the use of the other agencies.

It has supplied one or more ships as needed, regularly the *Yellowfin*, occasionally the *N. B. Scofield*. At least one vessel has been at sea during approximately ten months out of each year.

The California Academy of Sciences has received 7.5 per cent of the total. This agency has conducted studies of live sardines in the Steinhart Aquarium, investigating schooling behavior, feeding behavior, differences in behavior at different controlled temperatures, and behavior in an electrical field. (This last opens up at least the possibility of a new method of selective fishing, since sardines swim toward the positive electrode, and the largest fish are most easily affected.)

Stanford University's Hopkins Marine Station at Pacific Grove joined the program in the 1951-52 fiscal year. It has received 2.7 per cent of the total, using the money to conduct oceanographic studies in and near Monterey Bay, which will be of great value, particularly at such time as sardines return to that area.

The Committee has spent 3.4 per cent of the total on general operating expenses and the printing of its reports.

The Committee has been able to direct the expenditure of 97.5 per cent of the total returns from the special tax; 2.5 per cent was required to be paid into the Fish and Game Preservation Fund. This money, because of a quirk in the law which has just been changed, has not been available for any purpose whatever.

In reviewing the course of the investigations, it would be difficult to separate the results that have been obtained with "Marine Research Committee money" from those with "University money," "Fish and Game money," or "Federal money." But many results have been obtained; they appear in the form of reports and of papers in the scientific journals. By 1 January 1955, almost 150 such papers dealing with the sardine program had appeared. (These are listed later in this report.)

In April, 1947, the staffs of the California Department of Fish and Game, the U. S. Fish and Wildlife Service, and the Scripps Institution of Oceanography conferred and recommended a program of research that eventually was adopted as the expanded sardine program. It is interesting to compare this plan with the achievements of the program:

1947	1955
BIOLOGICAL RESEARCH	
I. Recruitment.	
a. Measurement of amount of spawning.	One major spawning area off southern California was known as early as 1930; a second off Baja California has been delineated. In 1954, approximately 325,000 billion sardine eggs were spawned in contrast to 440,000 in 1953, 145,000 in 1952, and 610,000 in 1951. Amounts of eggs of other species are also measured.
b. Measurement of the abundance of larvae.	This has been done annually.
c. Measurement of the relative abundance of year-class before it enters the fishery.	This has been done every year since 1950, for the several species, and has enabled comparisons with previous surveys made in 1938, 1939, and 1940.
d. Measurements of the sizes of year-classes in the commercial fishery.	This work, which has been done every year since 1932, and which has provided the basis of much of the research on the sardine, has continued.
e. Studies of the spawning stock on the spawning grounds.	These have been conducted whenever possible.
II. Availability of the stock to the fishermen.	
a. Analysis of the commercial catch.	This work, begun in 1919, is also of a continuing nature, and has been done.
b. Exploratory work on and off the fishing grounds during the fishing season.	This has been done.
c. Exploratory food studies.	This has been done insofar as it concerns sardines. There has been some work on other species.
III. Investigation of rapid methods of plankton collection and analysis.	
	This work was done in the early years of the program. It provided tools and techniques that are becoming standard in the field.
IV. Physiological studies of behavior, feeding, and nutrition.	
	These studies are continuing.
V. Dynamics of the sardine population and fisheries.	
	This is being done. A paper that represents an attempt to construct a general theory of sardine populations comprises the major part of this report.
PHYSICAL AND CHEMICAL OCEANOGRAPHY	
	Approximately 6,000 "oceanographic stations" have been occupied. The information gained from these cruises should make the California waters the best understood in the world and will be basic to any future studies of the eastern Pacific and its resources.

In addition to these tasks accomplished, valuable new information has been gained on species that are now little exploited or not at all, such as hake and sauries, which have been found to be present in large numbers.

The Committee has thus been instrumental in the progress of a program that has enormously expanded our knowledge of the California waters. A dramatic instance of the potentialities of such information occurred last fall:

The biggest news in sardine research in 1954 occurred outside the laboratory. Nature obligingly conducted an oceanographic-fisheries experiment far beyond the scope of man.

Between two and five billion sardines came north from Mexican waters to provide California with the best catches since 1951-52.

The fish started coming northward in the spring. Egg-and-larva surveys showed widespread spawning quite early in the year.

Water temperatures showed a marked increase in the early spring.

Together, these factors indicate that wide spawning off southern California may depend largely on the right temperature at the right time of year. And if the sardines come to southern California to spawn, they may remain there (or return) to be caught.

This theory has been advanced several times, but it has never been possible to nail it down before. For five long years (1949-53) ocean temperatures off the coast varied so little from year to year that oceanographers would have had to concede that if fish were responding to these slight differences they were more acute than our most sensitive measuring instruments.

Then early in 1954, ocean conditions changed.

The first evidence of the change came from charts of surface temperatures. These are plotted up after each cruise. They showed a consistent warming off southern California in the spring months.

Now it is known that warming extended throughout a layer of water at least 300 feet deep.

Second evidence of changing conditions came as plankton collections were sorted. Sardine eggs and larvae turned up from regions where none had been found in the past two years.

In July, fishermen reported schools of adult sardines around the Channel Islands and large schools were seen from the air near Hueneme. The opening of the southern California season, on 1 October, found the fish available in numbers not seen since

1951-52. More than 60,000 tons were caught. That was many times the previous season's catch.

These sardines were not members of a large, new year-class. Age composition studies showed that the 1952 and 1951 year-classes contributed about a third each. Of the remainder, the 1948 year-class produced one-third. These 1948 fish were surprisingly small. They were the "little, old" fish that usually appear in only insignificant numbers off southern California. They are fish that were spawned and spent their first years off Baja California.

The return of the sardines did not take the scientists by surprise. It had been pointed out in the last progress report that "the success or failure of the fishery in the immediate future will be largely determined by the number of sardines that may move from the Baja California waters into our fishing grounds."

The next question is, will the sardines return next season? And if so, in what quantities?

The first cruises of 1955 have shown the water is as warm as it was in 1954. By taking spot samples, it has been learned that in March and April there was extensive spawning off southern California. The fish surveys will tell where the sardines are. With this evidence, the scientists should be able by summer to predict whether enough sardines will be available to give the State a substantial fishery in the coming season. It is already known that the incoming year-class, that of 1953, is not a very good one. That is shown by the egg-and-larva counts and by the young-fish surveys. The 1952 year-class stands out as the best spawned in these five lean years, being one and one-half times the size of any of the others. But this and the other year-classes present in the fishery may appear in sufficient numbers to insure a profitable catch.

Research lags events. It is still not known exactly whether other aspects of the ocean changed as strikingly as did temperature in 1954, or if the food supply of the sardines changed. Scientists are working on these problems.

Without research, the revival of the industry in southern California would have been almost impossible to explain. Now it seems possible that the data will be on hand to explain several aspects of fluctuations in sardine populations and perhaps other fish populations. The information may eventually lead to accurate prediction of how many fish there are, where they are, and if they can be caught.

