PART I

REVIEW OF ACTIVITIES

January 1, 1958-June 30, 1959

GENERAL

Though the essentials of the research objectives and programs were little changed during the period, there was an important change in the directional organization of the California Cooperative Oceanic Fisheries Investigations. In June 1957 a Special Technical Committee was appointed by the Marine Research Committee to examine the CalCOFI research program and organization. As a result of their report the Marine Research Committee moved as follows on December 19, 1957:

Now, therefore, be it resolved, That the Marine Research Committee accept the report of the Special Technical Committee and act as follows:

1. The Technical Advisory Committee, having fulfilled its purpose, is hereby dissolved.
2. CCOFI leadership, direction, responsibility and authority will be vested in a four man committee (to be known as the CCOFI Committee), comprised of a representative from each of the following: California Department of Fish and Game, Marine Research Committee, Scripps Institution of Oceanography, and the U. S. Bureau of Commercial Fisheries. The members of this committee will serve in equal status, with the Marine Research Committee representative acting as chairman. The members of the CCOFI Committee shall serve at the pleasure of the Marine Research Committee and the heads of their respective parent organizations.
3. The Marine Research Committee representative will be employed by the Marine Research Committee as a full-time scientific member of the CCOFI Committee. The individual selected shall be a broad and practical senior scientist acceptable to the other members of the committee. It is intended that his functions include, (a) to act as an integrative force in the CCOFI COMMITTEE, (b) to advise the Marine Research Committee on research progress, staffing, budget and other matters, (c) to represent the Marine Research Committee on the CCOFI Committee in the expression of policy, interest, and in the allocation of funds. In the discharge of these functions he shall receive the full support of the Marine Research Committee. In order to fulfill these functions he must frequently visit all cooperating organizations including the California Academy of Sciences and the Hopkins Marine Station, in order to become completely familiar with all aspects of the research work under way.
4. The representatives of the other three organizations will be appointed by their respective heads. They shall be the full-time working heads of the program in each parent organization. They should have authority within their own organizations to carry out commitments made to the CCOFI Committee.
5. The CCOFI Committee shall meet at least once a month. The Chairman shall be responsible for preparing agenda and calling regular meetings of the Committee. Any CCOFI Committee member or the Chairman of the Marine Research Committee may call additional meetings by notice to the Chairman of the CCOFI Committee. The Chairman shall prepare and distribute minutes to the members of the CCOFI Committee, the Marine Research Committee, and the co-operating organizations.
6. Some matters will of necessity have to be referred to the Marine Research Committee and the parent organization heads. These include, (a) questions that cannot be satisfactorily resolved within the Committee because of disagreement or lack of authority, and (b) policy matters on which the Committee needs guidance. However, differences of interpretation of scientific matters probably indicate insufficient understanding and should be resolved by obtaining additional understanding through outside advice or additional research. Decisions reached on matters within the authority of the Committee should be acted on without further referral.

The motion was not fully implemented until January 1959. In the interim the newly formed committee functioned with the chairman of the Marine Research Committee serving as their representative. Beginning in February, 1959, the CalCOFI Committee has held regular monthly meetings as well as a number of special conferences. About half of their deliberations have involved solving current administrative problems, the balance being devoted to program review.

One recommendation stemming from the committee involves this report. In the past the report has been construed as and treated as a progress report. With the maturation of the program the concept of a progress report has outlived its usefulness, and, in fact, recent progress reports have contained original scientific papers. With this report formal recognition is given to an accomplished fact, in that the word "progress" is dropped and a serial numbering system adopted. The contents of this and future reports will

be Part I, consisting of very brief progress reports, and Part II, containing original signed scientific contributions. These will be contributions arising from the research programs, and in general will consist of large monographic papers, or series of interrelated papers such as the symposium contained herein.

AGENCY ACTIVITIES

California Academy of Sciences

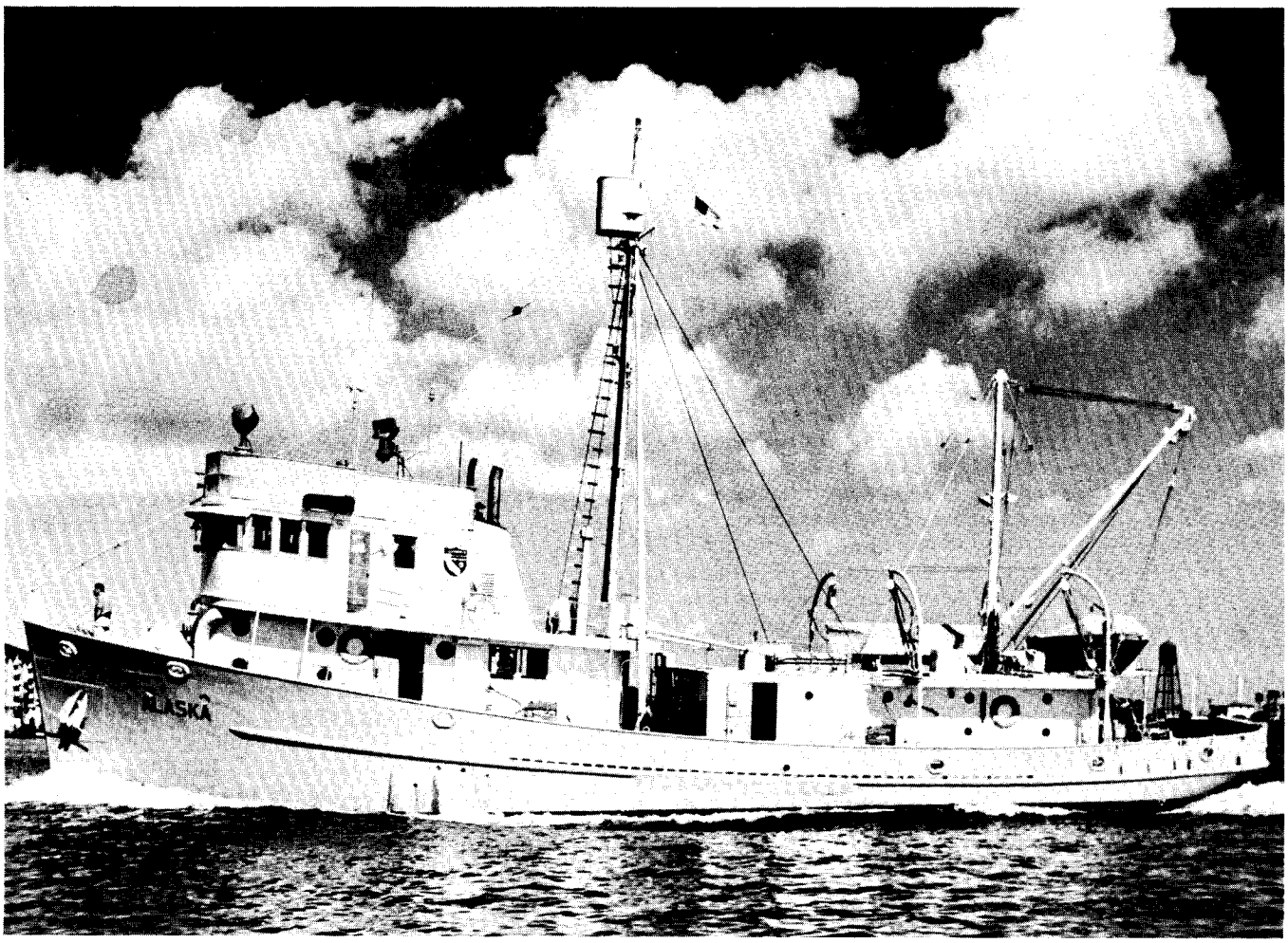
Studies on the behavior and reactions to stimuli of sardines and ecologically related species were continued, utilizing one investigator and assistance as needed. These studies are directed towards developing the intimate knowledge of the sardine needed to understand its reactions in nature as an individual and as an aggregational entity. A conceivable product of such investigations is reduction of the costs of harvesting the resource.

California Department of Fish and Game

The department conducted its portion of the investigations through its organizational unit called the Pelagic Fisheries Investigations. In addition to collecting the basic catch statistics on sardines, anchovies, jack mackerel, Pacific mackerel, and squid, the department undertook several important investigations. These include: (1) measurements of the relative abundance of year classes based on field surveys on the high seas; (2) measurements of the sizes of the year-classes in the commercial fishery in cooperation with the U.S. Bureau of Commercial Fisheries; (3) systematic field sampling for morphometric and genetic studies; and (4) sampling of the commercial catch, live bait catch, and airplane surveys of the population. In the laboratory emphasis has been laid on the production of reports and analyses predicated directly by the nature of the field work itemized above, as well as specialized studies such as the re-distribution of fishes during the past two warm years, and the population dynamics of the Pacific sardine. The staff of the Pelagic Fisheries Investigations has been strengthened, and an unfortunate, but unavoidable lag in analysis and reporting will soon be closed.

Hopkins Marine Station, Stanford University

Hopkins Marine Station continued to monitor the physical, chemical, and biological environment of Monterey Bay, formerly the largest and most colorful center of the sardine industry. An approximately



weekly schedule is maintained. In addition personnel from the station collect shore data from points to the south of Monterey Bay. The formal program is essentially one of monitoring the bay, but the collected data and samples have been and are utilized extensively by investigators in and out of the formal CalCOFI array.

Division of Marine Resources—Scripps Institution of Oceanography, University of California

Scripps Institution has since the inception of the CalCOFI program been the major participant. Its portion of the program can be roughly separated into oceanographic survey and monitoring, and fundamental studies relating to the basic problems of utilizing the living resources of the ocean. The first portion of the program is in part a service function in that Scripps endeavors to measure the ocean climate as background for other studies, principally biological. In addition, these oceanographic data are fundamental and of great interest in their own right, and are the basis of descriptive and analytical studies of the California Current system. The ship time involved in the oceanographic studies is also used to collect the field data needed by other projects such as the egg and larva studies of the Bureau of Commercial Fisheries.

The second phase of the Scripps research involves a number of basic programs some of which draw extensively on the materials and data collected during the field work and others that are independent of the field work. In general these studies are concerned with aspects of the biology of marine organisms, and the ecology of the sea not generally included in the traditional fishery program. Examples are the zoo-geography of chaetognaths, salps, and euphausiids, studies of micro-nutrients in the sea, the genetics of *Tigriopus,* and climatological studies of the eastern North Pacific.

A secondary but nonetheless very important program at Scripps is the development of better tools for looking at the ocean. Work of this nature is haphazardly supported throughout the world, despite the fact that many, if not all of our conventional methods are either exceedingly expensive, or very inadequate. A striking example of this work is the development of free vehicles, by which instruments or devices can be placed at any depth in the sea and recovered later, without a vessel standing by during the operational period. One of these free vehicles is a simple fish trap. One of the results of using this trap was the discovery that sablefish could be caught in 746 fathoms off La Jolla. Sablefish had not been previously reported from over 400 fathoms, and fishing for sablefish off southern California has generally been conducted between 100 and 300 fathoms. Deep moored instrument stations are another development bearing important implications to marine research. The recording skiffs have been moored in 2,800 fathoms.

The Scripps program has been strengthened by clearly associating the CalCOFI research with the Division of Marine Resources, to stimulate studies into the interrelationships of the various disciplines, fisheries, and oceanography. In dealing with these subjects the scientist must synthesize diverse facts into models, either conceptual or formal that resemble nature as a functional whole, in addition to the strict disciplinary approaches that tend to isolate certain phenomena or classes of phenomena for study. It is for this synthesis that many of the research problems, including the CalCOFI program, have been assembled in the Division of Marine Resources.

U. S. Bureau of Commercial Fisheries (BCF)

Investigations conducted by the BCF center around the sub-population problems, egg and larva surveys, sampling of the commercial catch of sardines in Baja California, composition of the catch, early survival of sardines, availability, population dynamics, and physiology of the sardine. In general the Bureau conducts the kinds of studies normally considered a part of a fisheries investigation, and their work complements that of the California Department of Fish and Game. Many of their studies are jointly conceived and executed with the latter agency.

The BCF continued to operate the motor vessel Black Douglas, which together with the equivalent of two vessels from Scripps and one from the Department of Fish and Game made a total of about four research vessels on the CalCOFI program. Among the highlights of the BCF activities during the year was finding the first indications of genetic diversity in the Pacific sardine, initiation of badly needed physiological studies on the sardine, and development of a practical way to examine the detailed distribution of the plankton organisms comprising sardine food.

REVIEW OF THE PARTIAL RESURGENCE OF THE SARDINE FISHERY

During the 1958-59 Season

The most exciting event in the past several years of the sardine fishery was the catch of 102,000 tons made during the 1958-59 season. The catch created considerable interest because it was the largest since 1951, and because for the first time since 1951 sardines were taken in appreciable quantities off central California, that is captured and landed in the vicinity of Monterey and San Francisco. The table below gives the landings in recent years in thousands of tons.

Season	*Thousands of tons*	*Season*	*Thousands of tons*
1949-50	339	1954-55	68
1950-51	353	1955-56	74
1951-52	129	1956-57	34
1952-53	6	1957-58	22
1953-54	4	1958-59	102

The full story behind this event cannot be related now because the resurgence must be subjected to the tests of time and to further scientific analysis. Nevertheless, there is enough information on hand to permit a somewhat detailed description of the 1958 fishery, and to suggest some of the factors responsible for the increase in the catch.

THE FISHERY

The fishing season officially opened on August 1, in central California and September 1, in southern California. The fishing fleet totaled 150 vessels, 30 from Monterey and 120 from the San Pedro area. Fishing was delayed until August 18, in the central California or Monterey area because of price negotiations but for the first time in many years began promptly on the opening of the season in the southern California or San Pedro area.

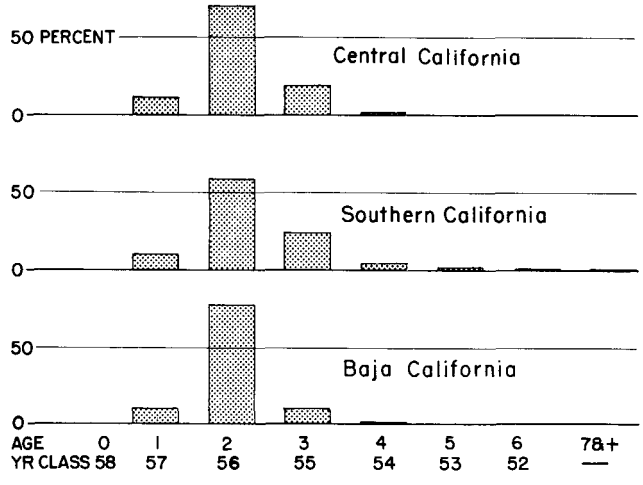
During the initial part of the season the ex-vessel price of sardines was $60 a ton. In late September and early October there was a two weeks stoppage of fishing because of price negotiations. Commencing October 5 a reduced price of $50 a ton was agreed upon, with a 40,000 ton minimum set for the balance of the season. This minimum was allocated among the several canneries. In addition, a 40 ton nightly boat limit was imposed on the fleet. Quotas were reached by some canners in mid-November when they stopped taking fish for a time, then resumed under lower limits toward the last of the season.

As might be expected, the complicated situation described above was the result of a relatively poor market for canned sardines related to the recent decade of scarcity of sardines, which had reduced the domestic usage and demand, and because the highly competitive South African and Japanese fisheries had expanded to fill the voids created by the recent California shortage. (In recent years including 1958 canning has been the only primary use of the sardine catch.)

The restricted fishery, then, failed to realize the potential catch. What the catch might have been is speculative. Fish continued in fair abundance through the end of the fishing season (Dec. 31), so it is not unreasonable to suppose that an unfettered fishery might have taken an additional 25,000 to 50,000 tons. Despite the overall oversupply of sardines, the distribution of the fish along the coast resulted in something less than an adequate supply off Monterey and San Francisco where canners had to rely on trucked fish from Morro Bay for about half of their raw material.

COMPOSITION OF THE CATCH

During the season approximately 25,000 tons were delivered to Monterey and San Francisco canneries and 78,000 tons were processed in Southern California. The Mexican fishery in Baja California landed 7,800 tons during the California season, and 11,600 during the earlier part of 1958. As indicated in the figure below, the catch was dominated by the 1956 year class taken as two year olds. These two-year-old fish were smaller than the usual two-year-old fish of recent years. For instance the mean size of two year



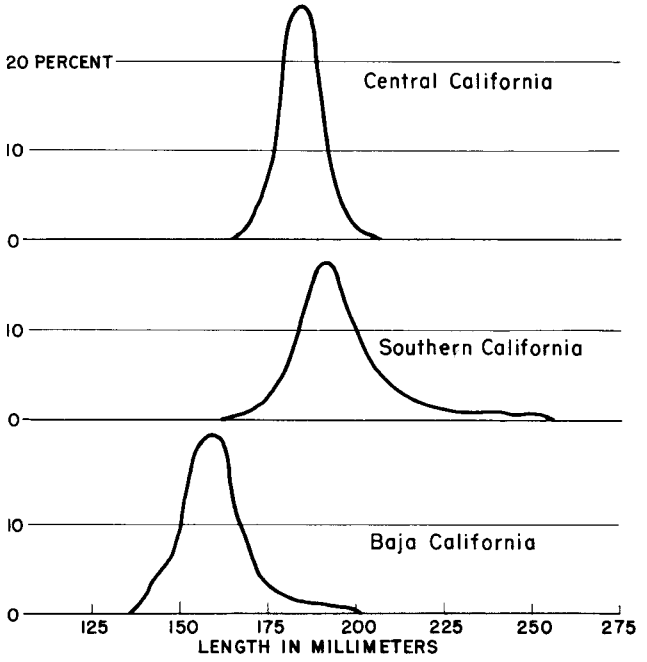
Age Composition of the Commercial Sardine Catch in Three Main Fishing Areas

olds at San Pedro during 1958 was 191 mm (7.6 inches), which is 12 mm (.5 inches) smaller than the previous recent minimum (1954-55), but is not much smaller (3 mm, or .1 inches) than the 1939 year class as two year olds, an outstanding year class.

AVERAGE SIZE OF TWO-YEAR-OLD SARDINES AT SAN PEDRO

Season	*Average size*	*Season*	*Average size*
1950-51	205 mm	1955-56	206 mm
1951-52	205 mm	1956-57	224 mm
1952-53	222 mm	1957-58	204 mm
1953-54	213 mm	1958-59	191 mm
1954-55	203 mm		

The Baja California fish were even smaller, in fact they were so much smaller that it suggests that the fishery was not utilizing the same stocks of fish as the Southern California fishery. The average size of their two-year-old fish during comparable portions of the fishing season was only 162 mm (6½ inches), that is 1.1 inches smaller than the San Pedro fish. The two year olds landed at Monterey were also smaller than the San Pedro fish, indicating somewhat more population heterogeneity than usual.



Length Composition of the Commercial Sardine Catch in Three Major Fishing Areas

The composition of the 1958 catch was also unique in that it was the first year since 1950 that two-year-old fish have dominated the catch. During the intervening years three year olds were generally the most abundant year class in the fishery. At the risk of oversimplification this could have been the result of one of three alternatives or combinations thereof (1) There had been very heavy mortality, natural and/or fishing on the 1955 year class. (2) The 1956 year class is outstandingly large, and (3) there was a northward shift of the population which might place a relatively larger portion of the 1956 year class in the area of the California fishery. There is considerable evidence against the first alternative, and little for it, so it need not be considered further in this brief discussion. A review of some of the events preceding and external to the fishery sheds some light on the validity of the remaining two suggestions.

HISTORY OF THE 1956 YEAR CLASS

The 1956 year class had an inauspicious start. The number of eggs (256×10^{12}) was modest, being only about 1.6 times the numbers of eggs spawned in 1955. As in 1955, the majority of the eggs were deposited off Baja California with only light spawning in the Southern California spawning center. The total spawning area was, however, only 0.7 as large as that of 1955. Oceanographic conditions during the spawning period in 1956 were even colder than the previous several "cold" years that produced mostly small year classes. However, the first indications of the shift to the "warm" ocean conditions of 1957-58 can be detected in the final months of 1956.

Tracing this year class onward, tabulation of the numbers of large larvae in the plankton samples suggest that survival to this stage was almost twice as high as in any of the previous four years. This, in itself, suggests a somewhat larger, but certainly not an outstanding year class. Actual surveys of the fish population that are conducted annually furnished estimates at ages "6 months" and one year but neither of these indicies suggested that the 1956 year class was anything but typical of recent years. Thus, if one sets aside the evidence provided by the fishery there is nothing in the record to suggest that the 1956 year class is unusual with respect to size, so it is logical to examine the other possible causes of the upsurge in the fishery.

The decline in the sardine fishery involved an absolute reduction of the population. The size of this reduced population is known with considerable certainty. The size of the pre-decline population is not known with similar exactitude, but it was probably not more than 10 times larger than the reduced population. Even this is not enough to account for the reduced catch which fell to less than 1/100 of its former amount. Hence, superimposed upon the effect of the reduced population in producing the dramatic decline of the sardine catch is a further significant factor, reduced availability, as a result of the population being located to the south, essentially placing it out of reach of the California fishery.

Over the last decade these events have been concurrent with the onset and persistence of uniformly cold water in the California Current, the result of vigorous upwelling and stronger southward flow. This could have had an effect on population size, and almost certainly had an effect on the distribution of the sardine, that is the cold water and increased flow could affect both population numbers and distribution.

Conversely, the partial resurgence of the fishery in the 1958 season need not have involved an upsurge in the population, but could easily result from a northward shift of the population in response to a warming of the oceanic climate associated with a reduction in currents. This appears to be precisely what happened, and probably accounts for most of the change.

It was mentioned earlier that near the end of 1956 there were weak indications of the warming of the ocean climate. This trend, instead of reversing itself as was usual during the past 8 years, strengthened through 1957, and persisted through 1958 and 1959. As indicated, the most dramatic and perhaps important change was a rise in the temperature of the seas off California of about two to four degrees Fahrenheit. This is a remarkable change in an area with a seasonal variation of only ten or twelve degrees Fahrenheit. Associated with this, "southern" plankton appeared

far to the north and close to the coast. Judging from their biology, at least some of these organisms were actually transported into northern areas, thus providing evidence of changes in the water flow along the coast. The associated appearance of "southern" sportsfishes, such as the yellowtail, in large numbers is probably the "warm years" change noted by and appreciated by the most people.

The sardine population also responded to the change, and spawning in 1957 was farther north than the previous year. However, the estimated number of eggs deposited was less than during earlier years so there are no grounds for supposing a significantly larger population. The 1957 catch was not impressive, however, for a variety of reasons. In 1958 oceanic conditions were, if anything, warmer than 1957, sardine spawning was again northerly oriented, and the fish remained north through the fishing season. Thus, the most significant and best documented event underlying the 1958 catch was the persistent northward shift of the sardine population.

In summary the moderately successful 1958 season may be attributed first of all to a fishery that began much earlier in the year than 1957 thus reducing the effect on the fishery of the usual pattern of the sardines migration to the south in winter; second, to the presence of a year class (1956) probably larger than the several preceding classes, but certainly no larger than "moderate sized"; and third, and most important, to continued high availability through the fishing season. Future catches and surveys should serve to substantiate or revise this tentative appraisal of the best year in the recent history of the sardine fishery.

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