HISTORICAL REVIEW OF THE OCEANOGRAPHIC APPROACH TO FISHERY RESEARCH

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ABSTRACT

For the last 70 years either one or both of the major clupeoid stocks off the Californias (the Pacific sardine and the northern anchovy) have been the subjects of almost continual study. This attention was stimulated by the need for information to manage the local harvest of these fishes and by the realization that the successful management of clupeoid stocks was a goal with worldwide implications.

During the 1920s, 1930s, and 1940s the California Department of Fish and Game (CDFG) conducted field studies in cooperation with the Scripps Institution of Oceanography (SIO), the California Academy of Sciences (CAS), and the U.S. Bureau of Commercial Fisheries (USBCF, now known as the National Marine Fisheries Service—NMFS). In the late 1940s, when the future of the sardine fishery became problematic, the industry funded a more intensified program of research. Endowed with an infusion of money and political support, agency scientists laid out an ambitious plan of attack.

Their plan became known as the oceanographic approach to fishery research (today we might call it an ecosystem approach) and was made synonymous with the CalCOFI program. Monthly cruises were conducted to collect plankton and water samples from a grid of stations; laboratory studies were undertaken to describe developmental stages of the young and behavior of the adults; the fishery was sampled to determine adult demography and vital rates; and new instruments and techniques were developed to enhance data collection and analyses. A more detailed understanding of the physical dynamics of the California Current and of the population dynamics of the sardine began to emerge, and the central question of the "sardine problem" came into clearer focus: What was the relative influence of exploitation versus the environment on the productivity of the sardine population?

In spite of this new understanding, the abundance of sardines declined steadily, while that of anchovies increased. The original focus of the CalCOFI program tended to diffuse, and major program reviews were conducted in 1957, 1961, and 1966. As the objectives changed, so did the field-sampling protocols.

When the state charter for the CalCOFI program ended in 1979, CDFG, SIO, and NMFS entered into an agreement to continue the field surveys, albeit on a smaller scale; to continue sponsoring annual conferences; and to continue publishing the *CalCOFI Reports* and Atlas series. The extensive time series of ichthyoplankton data, together with complementary measurements of the physical environment, constitute a major portion of the CalCOFI legacy. On-line computer display and extraction of these data is now available to the research community interested in the pelagic ecology of the California Current.

RESUMEN

Durante los últimos 70 años, ya sea uno o ambos stocks principales de clupeidos presentes frente a California (la sardina del Pacífico y la anchoveta del Norte) han sido estudiados en forma continua. Este interés fue estimulado por la necesidad de obtener información para el manejo de la producción local de estos peces y por el reconocimiento que el manejo exitoso de los stocks de clupeidos es un objetivo con implicaciones mundiales.

Durante las décadas de 1920, 1930, y 1940, California Department of Fish and Game (CDFG) llevó a cabo estudios de terreno en cooperación con Scripps Institution of Oceanography (SIO), California Academy of Sciences (CAS), y U.S. Bureau of Commercial Fisheries (USBCF, ahora conocido como National Marine Fisheries Service—NMFS). A fines de la década de 1940, cuando el futuro de la pesquería de la sardina se tornó problemático, la industria respaldó económicamente un programa de investigación más intenso. Ayudados por una infusión de dinero y apoyo político, los científicos de estas agencias prepararon un ambicioso plan de ataque.

Este plan se hizo conocido como el enfoque oceanográfico en investigación pesquera (hoy en día probablemente denominado enfoque de ecosistema) y fue hecho sinónimo del programa CalCOFI. Se efectuaron cruceros mensuales para colectar plancton y muestras de aguas en una red de estaciones; estudios de laboratorio fueron com-

pletados con el fin de descubrir los estadíos de desarrollo de los juveniles y el comportamiento de los adultos; la pesquería fue muestreada para determinar la demografía y las tasas vitales de los adultos; nuevos instrumentos y technologías fueron desarrollados para mejorar tanto la colección de datos como el análisis delos mismos. Un entendimiento más preciso de la dinámica poblacional de la sardina comenzó a emerger, y la pregunta central del "problema de la sardina" se definió: "Cuál es la influencia relativa del hombre en comparación con la del ambiente sobre la producción de la población de la sardina?"

A pesar de este nuevo entendimiento, la abundancia de las sardinas disminuyó continuamente, mientras que la de las anchovetas aumentó. El objetivo original del programa CalCOFI se volvió difuso y, como consecuencia, importantes reevaluaciones del programa ocurrieron en 1957, 1961, y 1966. A medida que cambiaban los objetivos, cambiaron los programas de muestreo en terreno. Cuando el apoyo del estado para el programa de CalCOFI terminó en 1979, CDFG, SIO, y NMFS acordaron continuar los programas de muestreo, aunque a menor escala, al igual que el apoyo a las conferencias anuales, y a la publicación de las serie de Reports y Atlas de CalCOFI. La extensa serie de tiempo de datos ictioplanctónicos, junto con las mediciones complementarias de parámetros físicos constituyen una parte importante del legado de CalCOFI. Estos datos están ahora disponibles a través de computadoras para el uso por la comunidad de investigadores interesados en la ecología pelágica de la Corriente de California.

INTRODUCTION

Welcome to the symposium of the 1987 CalCOFI Conference. We're here today to discuss the heart of CalCOFI: the 37-year time series of data collections—its extent, utility, and, ultimately, its value. The California Current has been referred to as the most intensively studied piece of ocean in the world. This reputation is enjoyed for two reasons: one, because the large number of marine institutions located along the coast of North America have each conducted many and varied field research programs; and two, because of the CalCOFI program.

The CalCOFI program was initiated to determine what happened to the sardines—the population declined rather precipitously in the 1930s and 1940s—and to determine the relative influences of exploitation and the environment on that decline. I will describe what was sampled, how often, over how large an area, and for what reason; that is, the extent of the CalCOFI data. Other speakers will describe the data's usefulness in depicting physical and biological processes.

In addition, we hope to encourage discussion on how the sampling design may be improved to address current research questions. Consideration should be given to new tools, new techniques, the geographic coverage, and how frequently we should make observations. We also wish to encourage discussion of a more fundamental question: Do we understand the California Current well enough now to abandon these large-scale surveys in favor of more focused research, or will we always need large-scale surveys to provide a context for our field experiments and to monitor trends and low-frequency variability? And a final question is: Have we exhausted the information content of this time series, or is there more to learn?

EARLY SARDINE RESEARCH

Research on the California sardine began in the early part of this century. There was an explosive demand for canned sardines starting in 1915, as well as an increasing high return for sardine meal and oil. At the same time the mechanization of the fishing fleet allowed boats to venture farther offshore. Salmon and albacore were targeted first, and then the sardine. The California Fish and Game Commission, founded in 1870, was well funded and respected by the turn of the century.

In 1915, the Commission established the Department of Commercial Fisheries under N. B. Scofield. He was originally recruited to study the albacore, and he immediately hired W. F. Thompson to look at the sardines. Thompson set up the nation's first state-operated fisheries laboratory. He began a systematic collection of landing statistics, known from then on as the "pink tickets." He also trained several fisheries biologists who went on to work in the federal government—people such as Elmer Higgins and Oscar Sette.

In 1920, Thompson published a plan for studying the sardine. He was concerned about both stock overfishing and growth overfishing. But more important, he was concerned about the synergistic effects of the environment and harvest on the population. In 1929 and 1932, the Department of Commercial Fisheries collaborated with Hopkins Marine Station and conducted oceanographic and biological surveys of the early life stages of sardines. In 1937 the Department collaborated with Scripps to study surface currents off southern Cal-

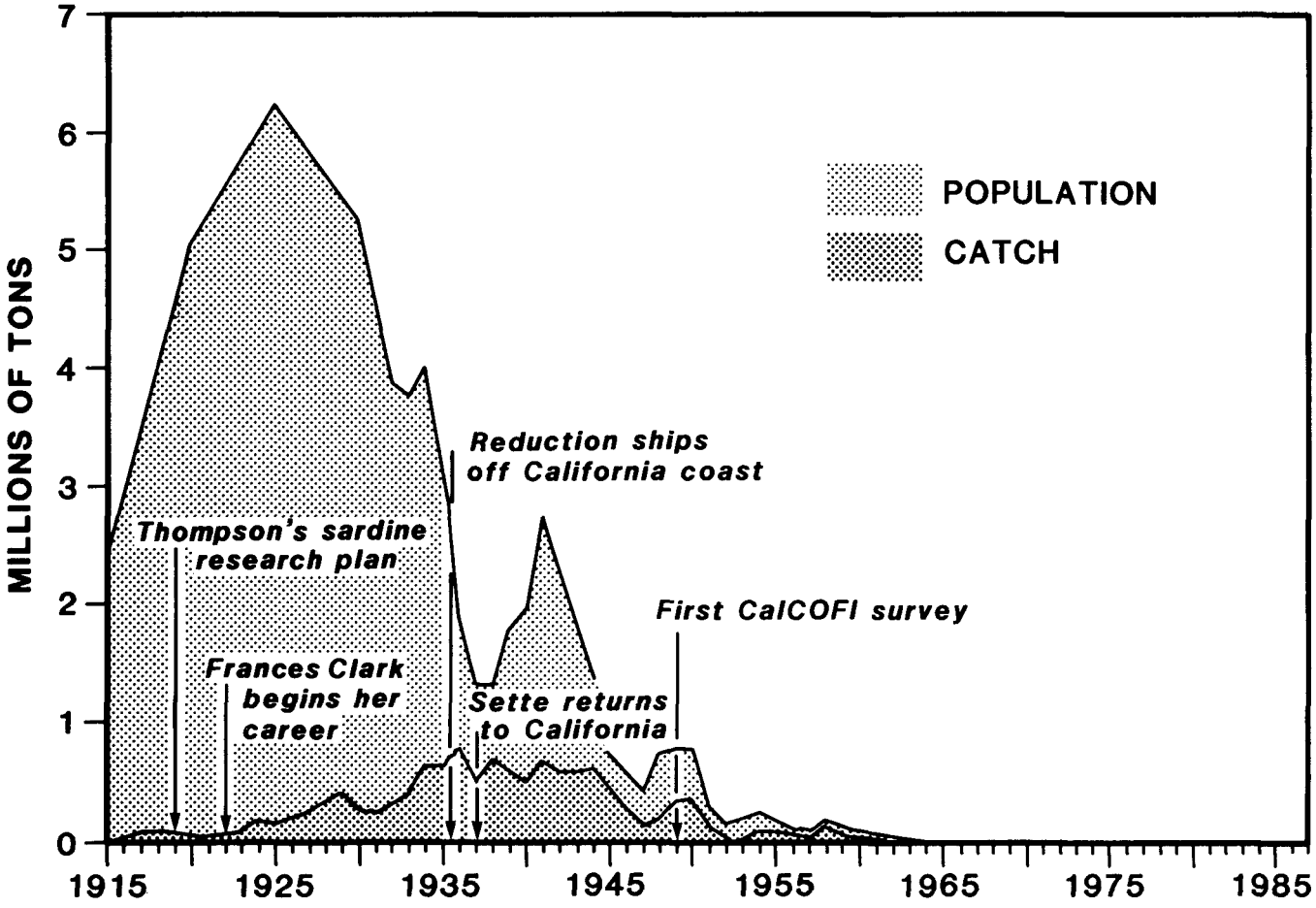

Figure 1. Pacific sardine abundance and commercial catch, since 1915 (from McEvoy 1986).

ifornia. But by the late 1920s, both Scofield and Frances Clark, who by this time had replaced Thompson, were concerned about depletion. They felt they were unable to control the fishery; the catch per unit of effort was down; and there were few older fish. In 1936 several bills were introduced to the U.S. Congress to prohibit offshore reduction ships, which were landing sardines outside the three-mile limit of California waters and reducing the fish to meal. At this time the harvest approached 790,000 tons per year. Congress asked the U.S. Bureau of Commercial Fisheries what it thought of the proposal, and Higgins, who was director at the time, refused to prohibit reduction ships on the grounds that there was insufficient evidence to curtail the commercial enterprise. The situation was further complicated in the late 1930s when there were several good year classes and the stock appeared to be recovering (Figure 1).

From 1937 through 1941 a series of ichthyoplankton cruises was conducted (Figure 2). The California Department of Fish and Game, the U.S. Bureau of Commercial Fisheries, and the Scripps Institution of Oceanography jointly participated in these cruises, which were conducted in the Southern California Bight—that is, between Point Conception and the international border. As a result of the sardine fishery's having been brought to the attention of Congress, the federal government decided to send Oscar Sette to California. Sette contributed to these cruises and eventually published a plan to determine how fishing affected the resource (Sette 1943). This plan is noteworthy because it considers all life stages of the sardines (Figure 3).

By this time, however, older fish were disappearing, and mortality was very high. With the onset of World War II, Sette was given full authority to set sardine quotas. There was a high demand for fish, and in September 1945 there were record sardine landings at Monterey. In October 1945, only one month later, the northern fishery completely collapsed. Steinbeck (1954) described this time by writing: "the canneries themselves fought the war

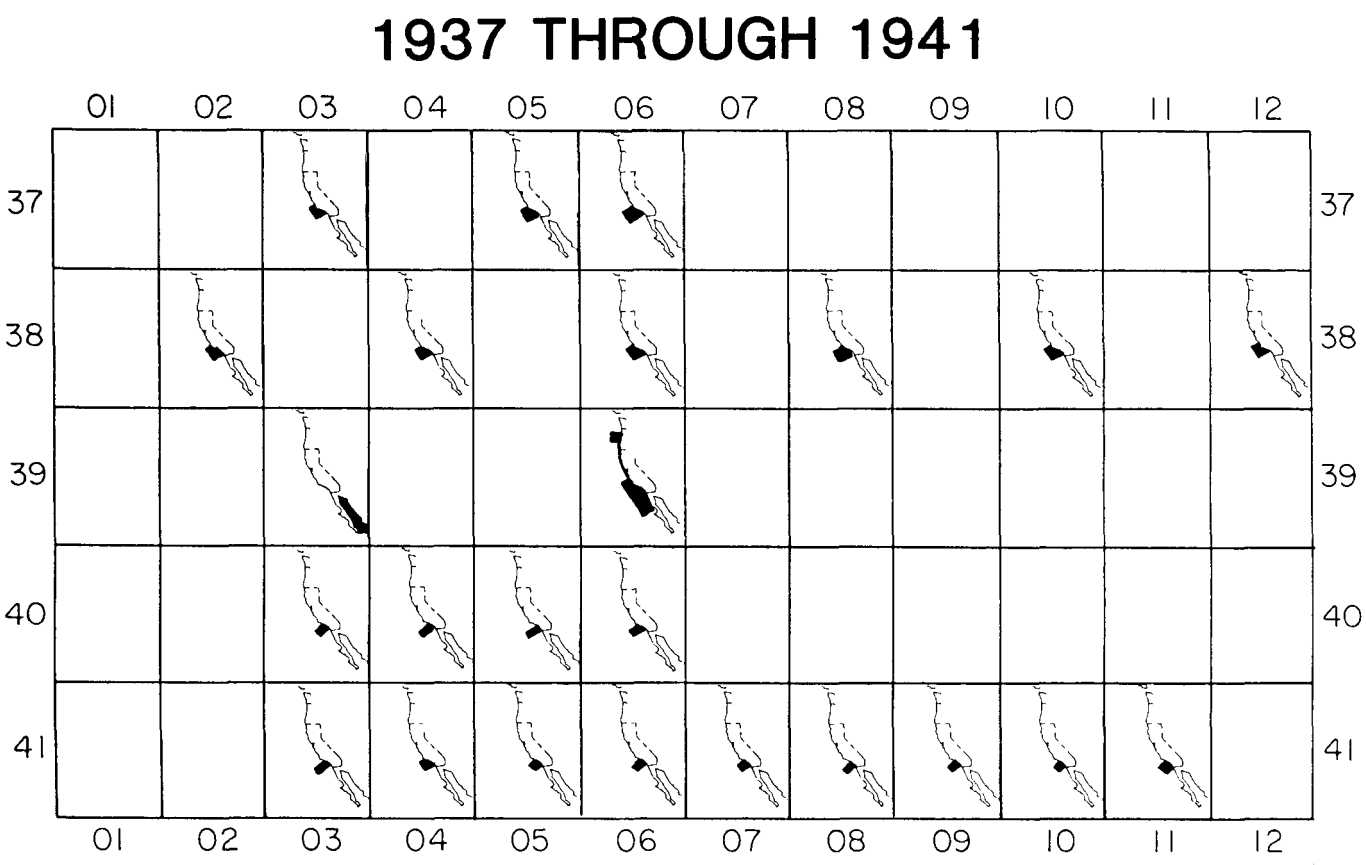

Figure 2. Ichthyoplankton cruises, 1937–41, based on information compiled by A. Mantyla at Scripps Institution of Oceanography. Shaded areas indicate geographic extent of cruises.

by getting the limit taken off the fish and catching them all. It was done for patriotic reasons, but that didn't bring the fish back."[1]

There were a few moderately successful spawnings after the war, but 1949 through 1951 produced reproductive failures, and the southern fishery was dead by 1952. As the sardine catches declined in the late 1940s, industry leaders became increasingly alarmed. They wanted a more coordinated focus among the several agencies that were independently working on the sardine.

CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS

At the same time, Governor Earl Warren established several committees to aid industry after World War II. Robert Sproul, president of the University of California, headed one of these committees on natural resources. An informal meeting was convened at the California Academy of Sciences to discuss the problems of the sardine industry. The industry—that is, the canners—wanted help, but they weren't sure how to go about getting it. Sproul's representative was willing to put a big item in the university budget, but only if the U.S. Bureau of Commercial Fisheries and the California Department of Fish and Game cooperated. He further conditioned that the industry would have to tax itself for a matching set of funds, and stipulated that the research could not be dictated by the industry. The industry responded that it would lobby the legislature for a landing tax to be spent solely on ocean research. It wanted these expenditures, however, to be governed by a board made up of industry representatives (the Marine Research Committee). The scientists themselves, from state, federal, and academic agencies, agreed to cooperate and to form a technical committee to guide the research. Each agency, however, insisted that it would govern its own research using its own money. The governor's representative agreed to all of this, only if it was in accordance with a law passed by the legislature, and only if the governor had the authority to appoint the Marine Research Committee. Thus began a tentative confederation

[1]Art McEvoy (1986) quoted this same passage, which succinctly captures the last major blow to the sardine population.

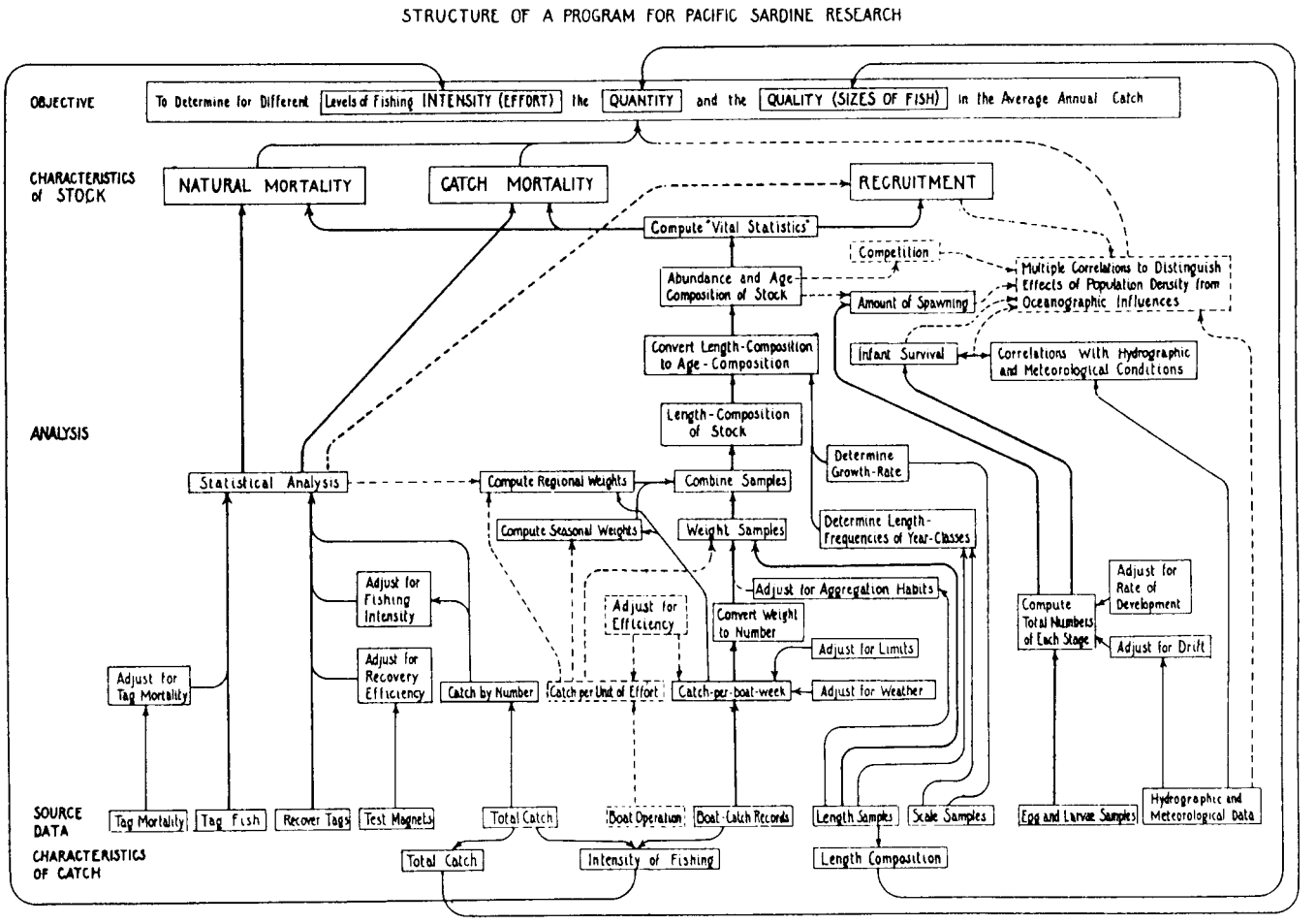

Figure 3. Conceptual model of how fishing affects the sardine resource (from Sette 1943).

among people and institutions with very different motives and objectives; it is a confederation that has productively endured for 40 years.

In 1949 the Marine Research Committee was established, and the CalCOFI program started; at that time it was called the California Cooperative Sardine Program. The technical committee—composed of scientists from the California Department of Fish and Game (CDFG), the U.S. Bureau of Commercial Fisheries (USBCF), the Scripps Institution of Oceanography (SIO), and the California Academy of Sciences (CAS)—laid out a rather ambitious program. The technical committee wrote that

> in order to develop plans for the responsible management of the sardine resource, and to attempt to derive workable methods of predicting where sardines will be found, and in what quantities, it is imperative to know certain underlying principles which govern the sardine's behavior, availability, and total abundance.

They further wrote that the four agencies participating in the program are

> investigating the sardine in relation to its physical and chemical environment, its food supply, its predators and its competitors, in attempting to evaluate the findings in terms of the survival of the young, and in terms of the distribution and availability of the sardines when they reach commercial size. (*California Cooperative Sardine Research Program Progress Report*, 1950)

This outline became known as the oceanographic approach to fisheries research. Essentially what the scientists wished to do was to correlate changes in water conditions with changes in sardine spawning, availability, and abundance. CAS researchers conducted laboratory studies on sardine behavior. CDFG staff monitored fishing effort and the size and age of the catch, as they had done since 1916. They also indexed recruitment from their bait-fishery surveys, collected adults for

stomach analysis and reproductive condition, and conducted acoustic surveys for both juveniles and adults. SIO scientists estimated currents, correlated upwelling and wind fields, measured nutrient content, and—most important—developed new instruments for biological and oceanographic observations. USBCF researchers attempted to get the plankton sorted within one month, so as to adjust the survey scheme for changes in the spawning pattern of the sardines. Hopkins Marine Station joined in 1951; its researchers began weekly surveys of Monterey Bay.

The CalCOFI field sampling protocol is essentially a collection of plankton and water samples obtained over a fixed grid of stations (Figure 4) at periodic intervals. In the early days, other studies were made as well, although not as consistently. Phytoplankton tows were conducted; dip net fishing was done under night lights; and albatross and marine mammal counts were maintained. All three agencies acquired new research vessels to support the CalCOFI cruises. In 1954 the landing tax was extended to mackerel, anchovy, and herring. In 1955 the Marine Research Committee was expanded to include recreational fishermen and fishermen's unions.

The program was reviewed in 1957, 1961, and 1966. Each of these reviews resulted in a change in the sampling protocol. The cruises conducted in 1949 and 1950 were essentially exploratory surveys, and the sampling grid was fixed in 1951. Almost every month was sampled in every year throughout the 1950s (Figure 5). Twenty-five percent of the money spent on marine fisheries research in California was spent on the sardine, and half of that money was for vessel time. By 1955, approximately $4 million had been spent on sardine research. Of that, $800,000, or one-fifth, had been dispersed by the Marine Research Committee, with three-quarters going to SIO and USBCF.

By 1957 it was apparent that research directions among the three agencies had diverged, and a committee—John Marr from USBCF, John Radovitch from CDFG, John Isaacs from SIO, and Oscar Sette as a consultant—was formed to review the program. They suggested that a permanent coordinator be hired to provide some cohesiveness to the program, and that a permanent three-person committee, now known as the CalCOFI Committee, be established. They urged more data processing, analysis, and reporting.

By 1961 the CalCOFI Committee was in place, and Garth Murphy was the CalCOFI coordinator. The surveys had changed to quarterly, and covered larger areas, less frequently (Figure 6). By this time, it had been suggested that the anchovy was replacing the sardine, based on the assumption that they were ecological equivalents. It was widely acknowledged that several cold springs plus an intense fishery may have contributed to the sardine's decline.

The CalCOFI Committee stated that the sardine should not be studied as isolated from its ecological associates. The Committee wrote that "the sardine is like the gold of California—a conspicuous, valuable, easily harvested element in the midst of less-conspicuous riches of far greater potentiality."

The Committee also wrote that the "research should be responsible to the needs of society, and that the ultimate goal was to gain sufficient understanding to guide society in its use of natural resources."[2]

In 1966 the CalCOFI Committee decided that more thorough seasonal coverage was necessary to describe the spawning cycles of several species. Quarterly cruises every year were replaced with monthly or bimonthly cruises every three years (Figure 7). The Committee decided to document and study the developing anchovy fishery, which it had proposed a couple of years earlier, and secondly, to continue large-scale surveys of the California Current. Species of particular interest included hake, jack mackerel, and squid.

EMERGENCE OF THE ANCHOVY

During this time, the northern anchovy emerged as a major coastal pelagic stock (Figure 8). In 1951, when the systematic surveys began, there were two sardine spawning centers—one off Cedros Island in southern Baja California, and another off northern Baja California and southern California. At this time, anchovy larvae and sardine larvae were equally abundant. By 1952 it was clear that the 1948 year class of the sardine was moderately strong, but that the 1949, 1950, and 1951 year classes were very poor—about one-sixth of the 1948 year class. The outlook of the fishery was "very bleak." By 1953, "very bleak" became catastrophic as the population contracted farther southward with a reduced age structure. In 1954 warm water appeared off California, sardines came north to spawn, and there were good catches along the coast. By this time, however, anchovy larvae had doubled in abundance, while sardines and Pacific mackerel continued to decline.

In 1955 Clark (CDFG) and Marr (USBCF)

[2]*Calif. Coop. Oceanic Fish. Invest. Rep.* 8 (1961).

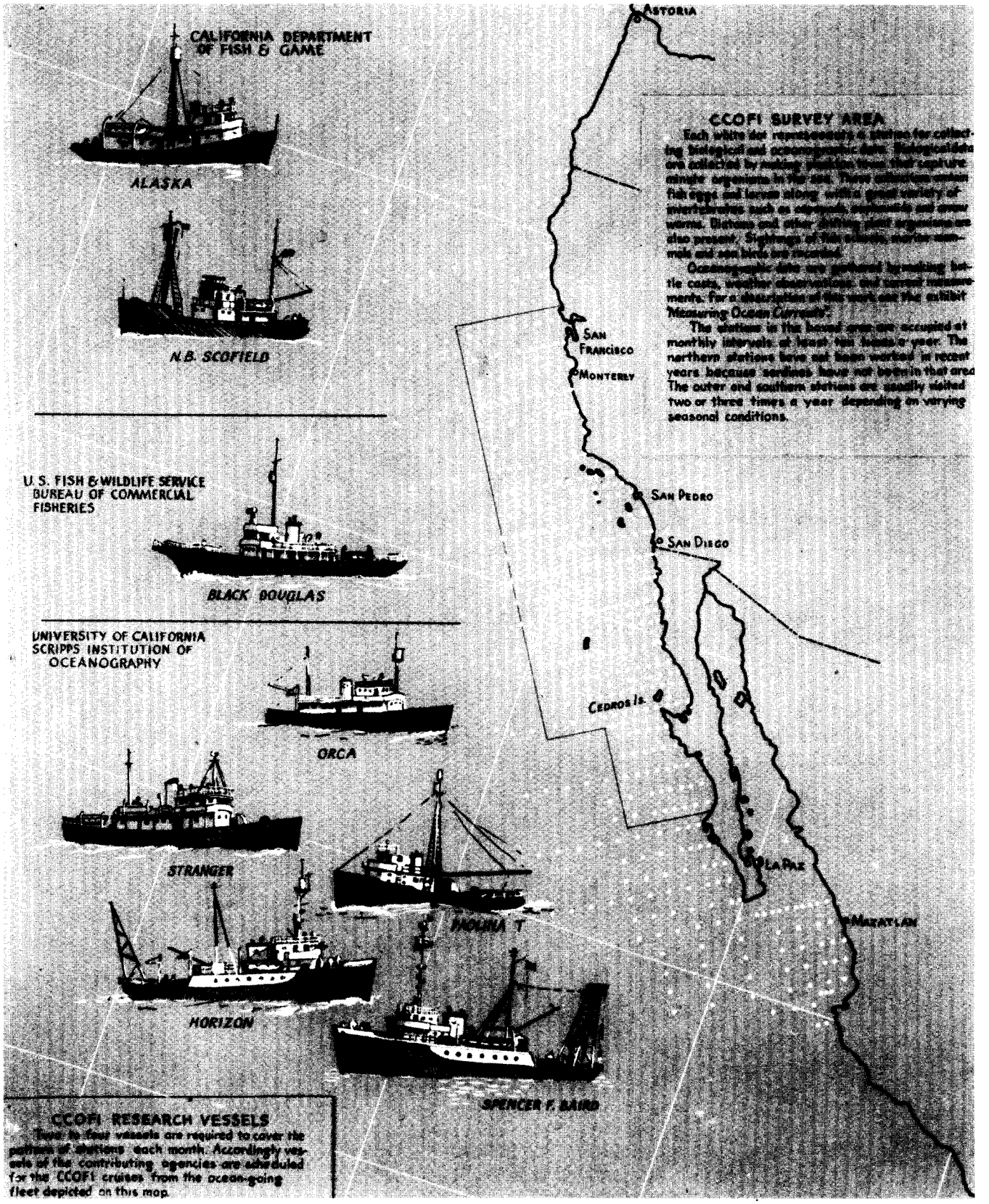

Figure 4. CalCOFI station grid, from 1951 to present.

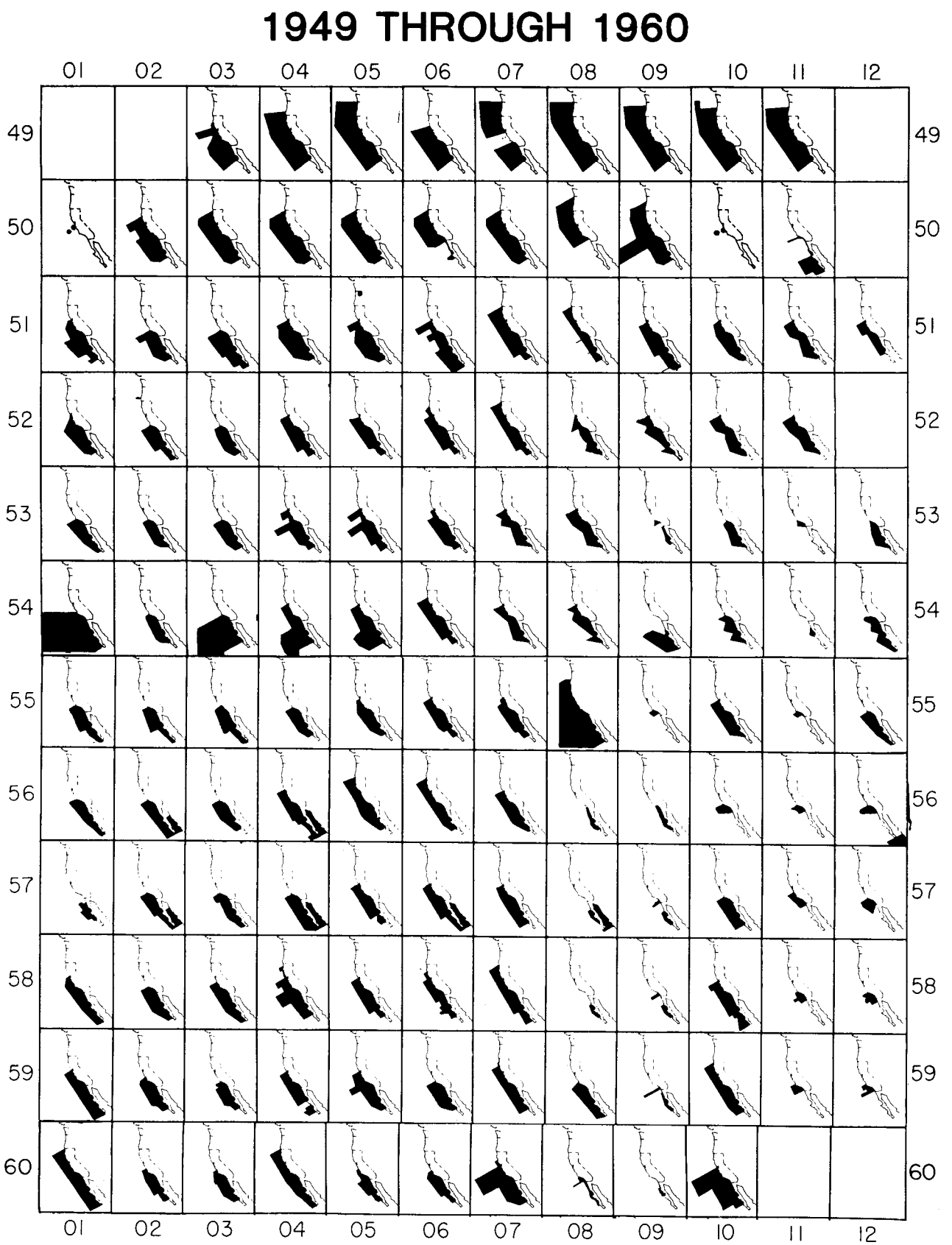

Figure 5. CalCOFI cruises, 1949–60, based on information compiled by A. Mantyla at Scripps Institution of Oceanography. Shaded areas indicate geographic extent of cruises.

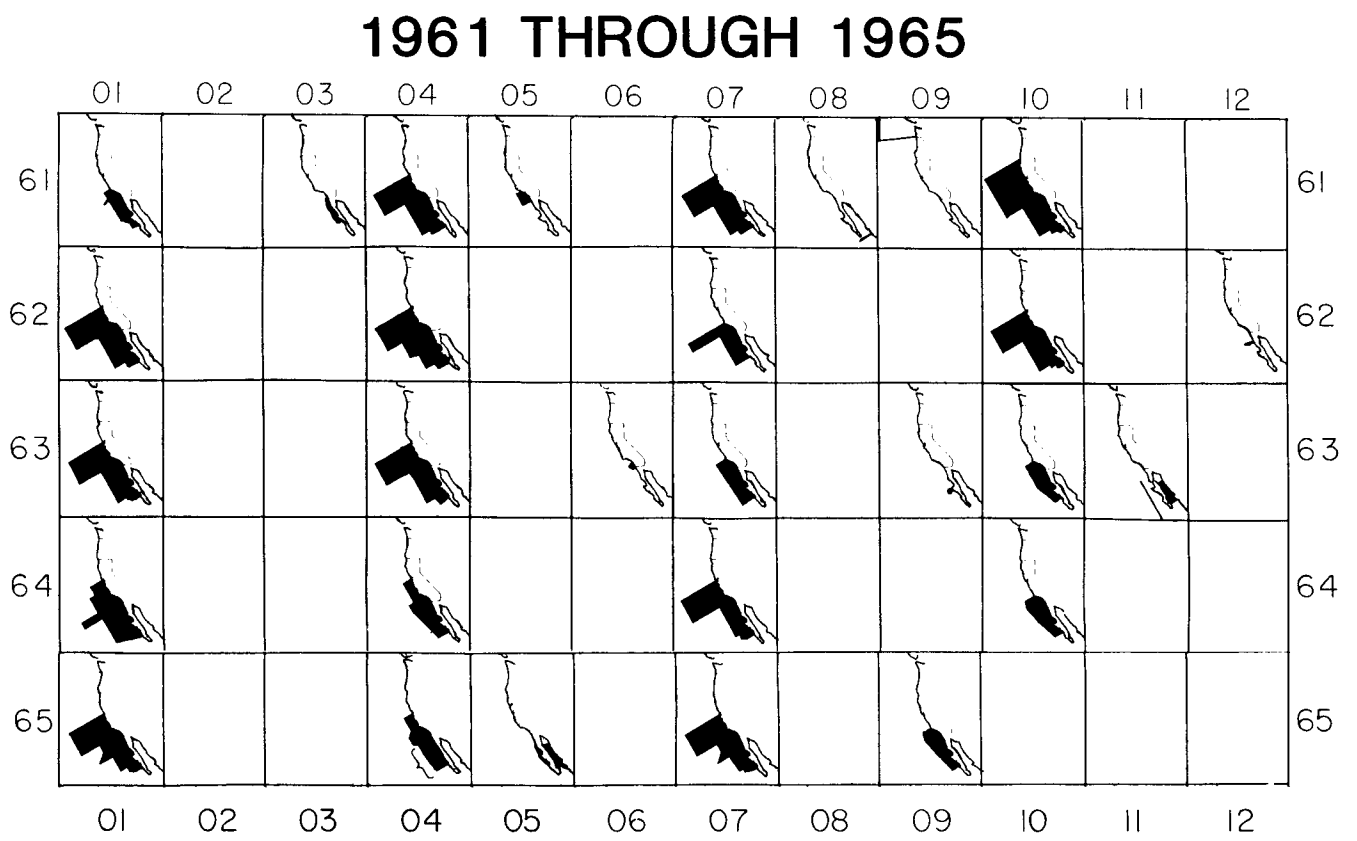

Figure 6. CalCOFI cruises, 1961–65, based on information compiled by A. Mantyla at Scripps Institution of Oceanography. Shaded areas indicate geographic extent of cruises.

jointly published a paper in which they agreed to disagree on the population dynamics of the sardine. The disagreement was essentially whether or not a relationship existed between sardine spawning stock size and recruitment—that is year-class strength. The arguments implied that either overfishing (Clark) or an adverse environment (Marr) caused the decline in sardine population. 1957 and 1958 brought another warm period, and the sardines spawned as far north as Monterey. There were good catches all along the coast.

In the late 1950s a picture began to emerge. Sardines spawning off southern California were thought to migrate north to Oregon and Washington; sardines spawning off Baja California were thought to migrate to northern California. The lack of spawning success off southern California since 1943 was probably the cause of the collapse of the northern fisheries. Poor spawning success was further thought to be due to low spring temperatures. In 1958, Reid, Roden, and Wyllie published their paper on the physics of the California Current. They suggested that increased winds, enhanced upwelling, and cooler temperatures may have been associated with spawning failures. Later that year CalCOFI sponsored a symposium on the changing Pacific Ocean, and most participants agreed that 1957 had terminated a monotonous decade of low temperatures and high winds in the North Pacific.

By the early 1960s, there was a general acknowledgement that overfishing for sardines had occurred, and the anchovy-sardine replacement hypothesis began to receive some interest. Both Isaacs (1965) and Ahlstrom (1967) published papers on the strong association between anchovy larvae and sardine larvae. By 1958 and 1959, anchovy larvae were three times as abundant as they had been in 1951, and they doubled again in the early 1960s. The anchovy-to-sardine ratio was 3 to one in 1952. By 1956, it was 10 to one; by 1959, 45 to one; and by 1962 there were 80 anchovy larvae for every sardine larva. The suggestion was made at that time that anchovy and sardine may together act as a single population, and that a large sardine-anchovy population may depress year-class strength.

In 1964 the CalCOFI Committee proposed an experimental anchovy fishery. They suggested annual harvests of 200,000 tons of anchovy and

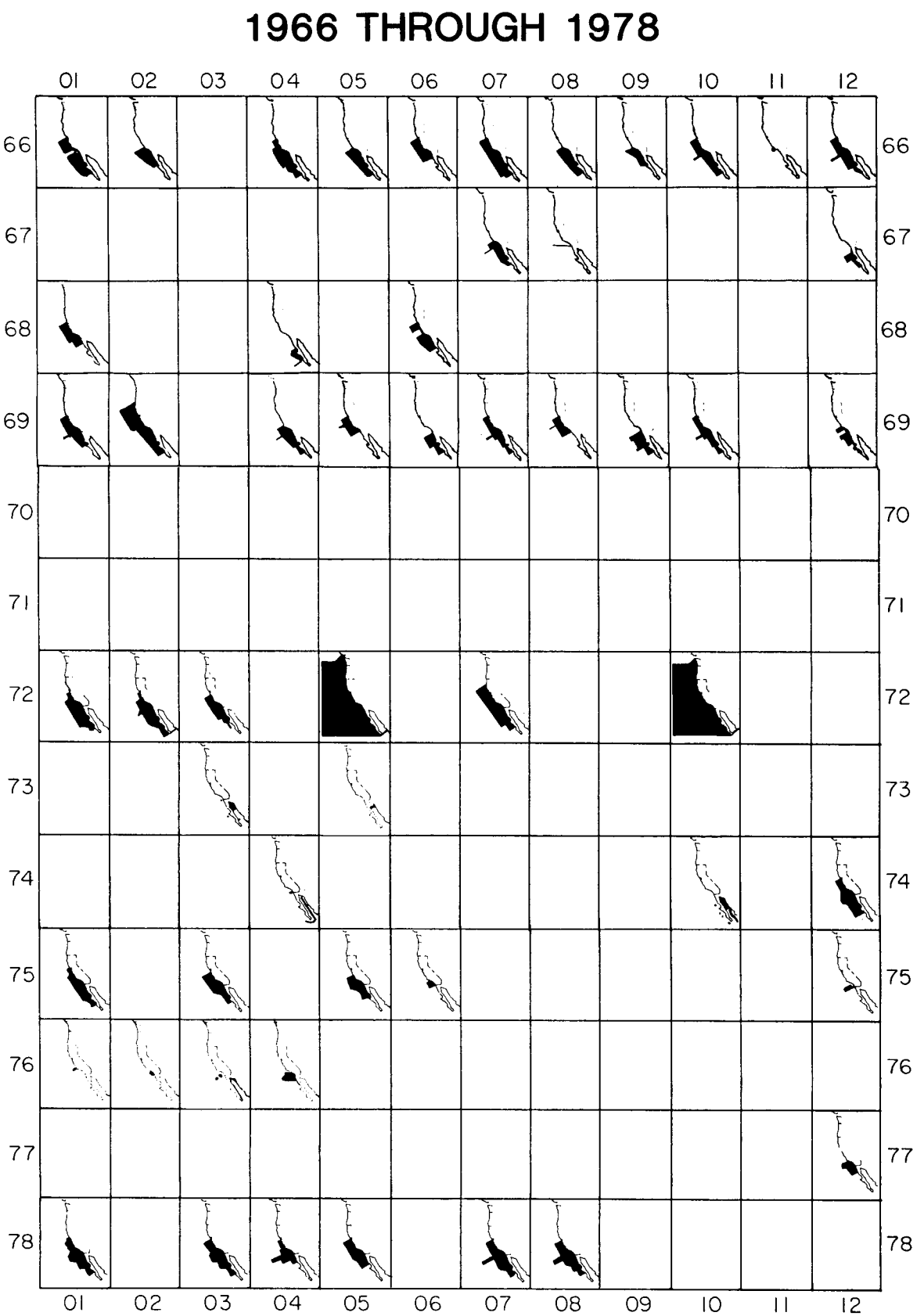

Figure 7. CalCOFI cruises, 1966–78, based on information compiled by A. Mantyla at Scripps Institution of Oceanography. Shaded areas indicate geographic extent of cruises.

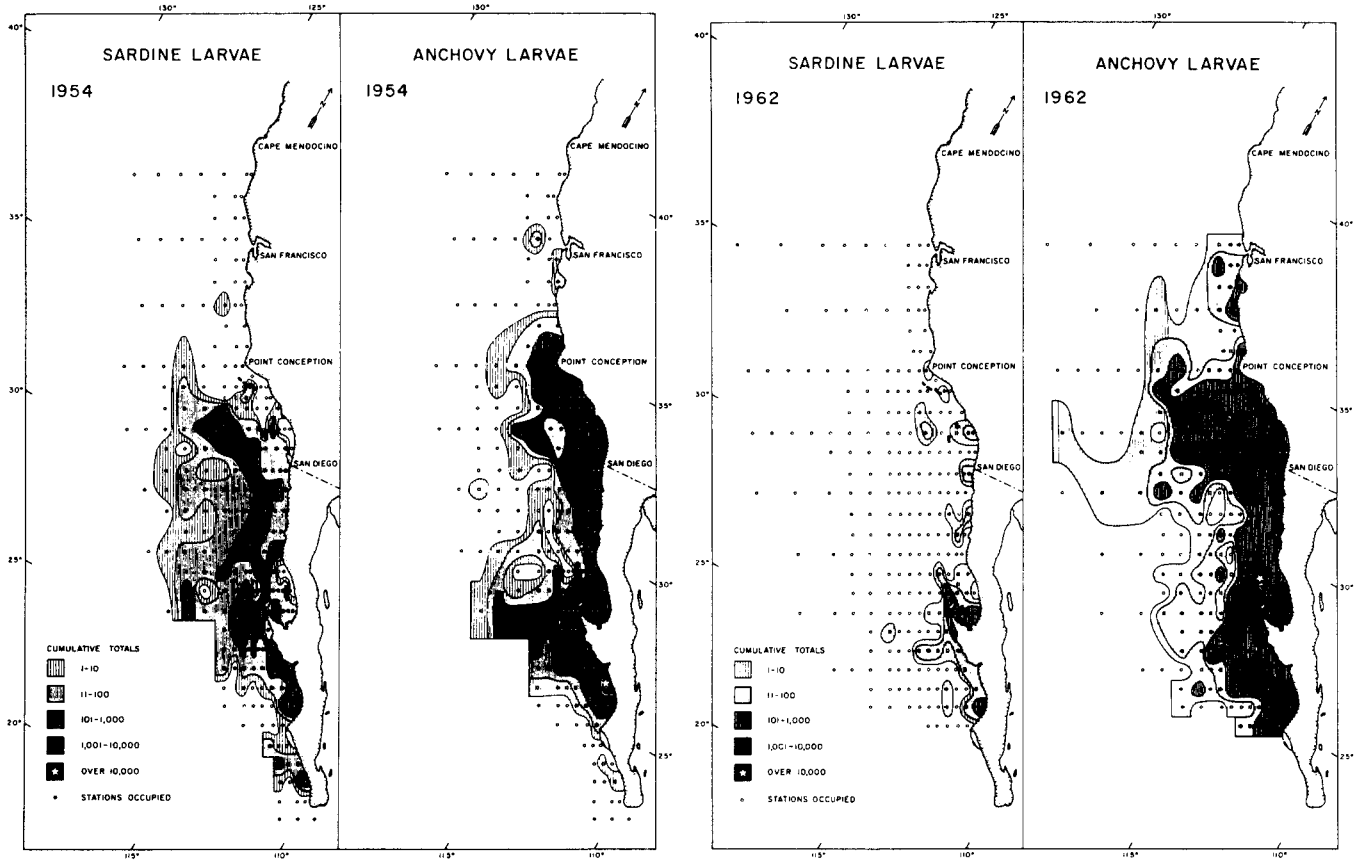

Figure 8. Distributions of sardine and anchovy larvae, 1954 and 1962 (from Ahlstrom 1966).

10,000 tons of sardines. These catches would be sufficient to reduce the anchovy biomass, and still monitor the sardine response. There was a strong negative reaction across the state, and the experiment never got off the ground.

Instead the CalCOFI Committee decided to continue work on the sardine-anchovy relationship, as well as to expand broadscale studies of the pelagic environment. Attention was directed toward other species such as saury, hake, jack mackerel, and squid. The Marine Life Research Program at Scripps expanded its studies into the North Pacific, and Joe Reid convened the 1966 CalCOFI symposium on wide-scale studies of the Pacific Ocean.

In the late 1960s the CalCOFI Committee was frustrated that the anchovy fishery had failed to develop, and they proposed research to identify factors that constrained the use of living marine resources in California. In 1967 CalCOFI sponsored a symposium on the magnitude, distribution, and susceptibility of living marine resources in the California Current. In 1968 the CalCOFI symposium covered the legal, sociological, and technical problems associated with the use of marine resources in the state of California. The 1969 symposium was on world population growth and the role of marine fisheries in providing food. The CalCOFI Committee wrote that there was an understanding of pelagic resources in the California Current sufficiently adequate for the scientific management of multiuse domestic fisheries, and yet the resources remained little used.

The committee suggested two reasons for this: the first was a general failure to appreciate the long-term economic benefits of a healthy domestic fishing industry; the second was misunderstanding and mistrust between users of the resource—essentially, a widespread apprehension that the state could not control a fishery once it got started. This fear was not groundless, given the sardine experience.

EXPORT OF TECHNOLOGY

By the 1970s, however, CalCOFI began to turn outward. In the 1950s, we were concerned about the decline of the sardine. In the 1960s we were concerned about the increase of the anchovy. In the 1970s, we were concerned about exporting

what we knew. CalCOFI became an international model for the study of pelagic populations and the large-scale oceanographic and meteorological events that affect them. USBCF became part of NOAA, an agency with a strong tradition of environmental mapping and monitoring. The MARMAP program was established to assess pelagic stocks off the eastern and gulf coasts; it was modeled after CalCOFI. The CalCOFI Committee established a relationship with Instituto Nacional de Pesca in Mexico, and eventually a Mexican anchovy fishery developed. The Sardine Anchovy Recruitment Program (SARP) is also an example of the worldwide influence of CalCOFI ideas.

In 1979 the Marine Research Committee was retired, and an abbreviated CalCOFI program continued by agreement between the state and federal agencies. Surveys and ship time were reduced to what was necessary to monitor certain populations (Figure 9), and a search was made for "indicator stations," that is, stations that could be routinely sampled to represent a much larger survey. By this time, the Marine Research Committee had distributed $3.5 million over its 30-year existence. A little less than $1 million of that came from the sardine, $1.2 million from the anchovy, $1 million from the mackerels, and $⅓ million from squid and herring.

CalCOFI continued as a forum to bring researchers together to collaborate and present results. *CalCOFI Reports*, published once a year, became a peer-reviewed journal. The CalCOFI Committee sponsored symposiums on nonconsumable resources in the California Current, climatic regimes and low-frequency events, mesoscale patterns and processes, eastern boundary currents as a class of phenomena, and nearshore patterns and processes. The goals were restated: to understand the physical and chemical environment and how it changes, to determine the productivity of the California Current ecosystem, and to make this information available in the form of *CalCOFI Reports*, conferences like this one, and data bases. The ultimate goal is still to understand and predict fluctuations in marine populations and to provide a basis for the wise use of these resources.

EGG PRODUCTION SURVEYS

We have changed some of our methods as well. In 1972 Paul Smith gave us a way to determine absolute abundance from ichthyoplankton surveys when he regressed larval census on Murphy's population estimates of the sardine. In this formulation, the numbers of larvae found in the sea are thought to be proportional to the adult spawning biomass. This assumes two things: (1) that every year there is a constant reproductive output per unit weight of adult, and (2) that the mortality of the young is constant from year to year. This technique became known as the larval census method.

The larval census method eventually evolved into the egg production method (Lasker 1985), by which the spawning biomass is proposed to be the quotient of the daily production of eggs in the sea and the daily specific fecundity of the adults. This method directly measures both the reproductive output of adults and the mortality of the young. The only assumption required is that we can sample without bias.

Reproductive output of adults is determined from a sample of adult fish. Various reproductive parameters are measured and combined to estimate the daily specific fecundity—the number of eggs spawned per day per unit weight of adult fish.

Egg production, the number of eggs spawned per day, is determined from high-density surveys conducted over the spawning habitat. Each of these surveys (Figure 10) comprises approximately 1,000 vertical egg tows yielding a rather precise estimate of egg abundance by developmental stage, from which we can determine egg production. These surveys are also part of the CalCOFI data base.

CALCOFI ON-LINE DATA SYSEM

CalCOFI data are available in a variety of hardcopy reports and papers. There are approximately 300 data reports, 30 atlases, and 29 volumes of *CalCOFI Reports*. In addition, at the Southwest Fisheries Center we have developed a computerized data search-and-retrieval system called the CalCOFI On-Line Data System. It is intended to give researchers the opportunity to explore the extent of the CalCOFI data set and to extract desired portions. Although it does not provide access to every CalCOFI data set, the major portion of the CalCOFI data (ichthyoplankton counts and hydrocast profiles) is available in this initial version.

The researcher is guided through the system by a series of menus (Figure 11). The main menu offers four options: (1) station index, (2) methodology, (3) ichthyoplankton data, and (4) hydrocast data. The station index option allows a researcher to peruse the extent of the data, providing access to information on the various cruises, the geographic sampling density (the extent of the area sampled during a particular cruise), and the temporal sampling density (how often a specific area was sampled throughout the time series). The

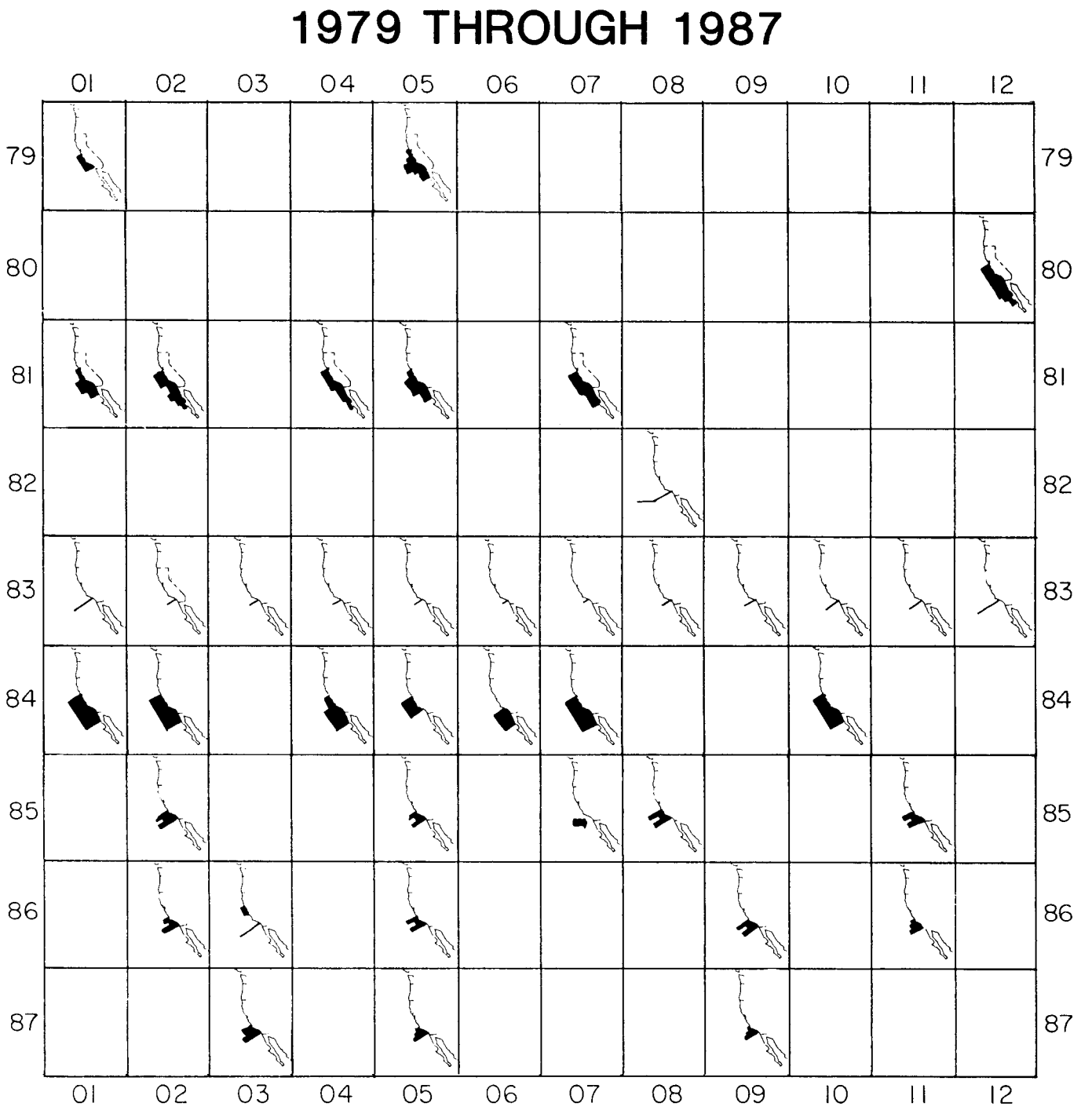

Figure 9. CalCOFI cruises, 1979–87, based on information compiled by A. Mantyla at Scripps Institution of Oceanography. Shaded areas indicate geographic extent of cruises.

methodology option allows a researcher to peruse descriptions of the data sets currently on line, cruise frequency and geographic coverage, gear design, sample sorting and archiving procedures, identification notes, and annotated references. The ichthyoplankton data option allows a researcher to actually extract data. Data are available on five major species of fish larvae enumerated by length, anchovy eggs enumerated by developmental stage, and the extensive collection of fish eggs and fish larvae identified to over 200 taxonomic categories. The hydrocast data option allows access to a data set of vertical profiles of temperature, salinity, oxygen, oxygen saturation,

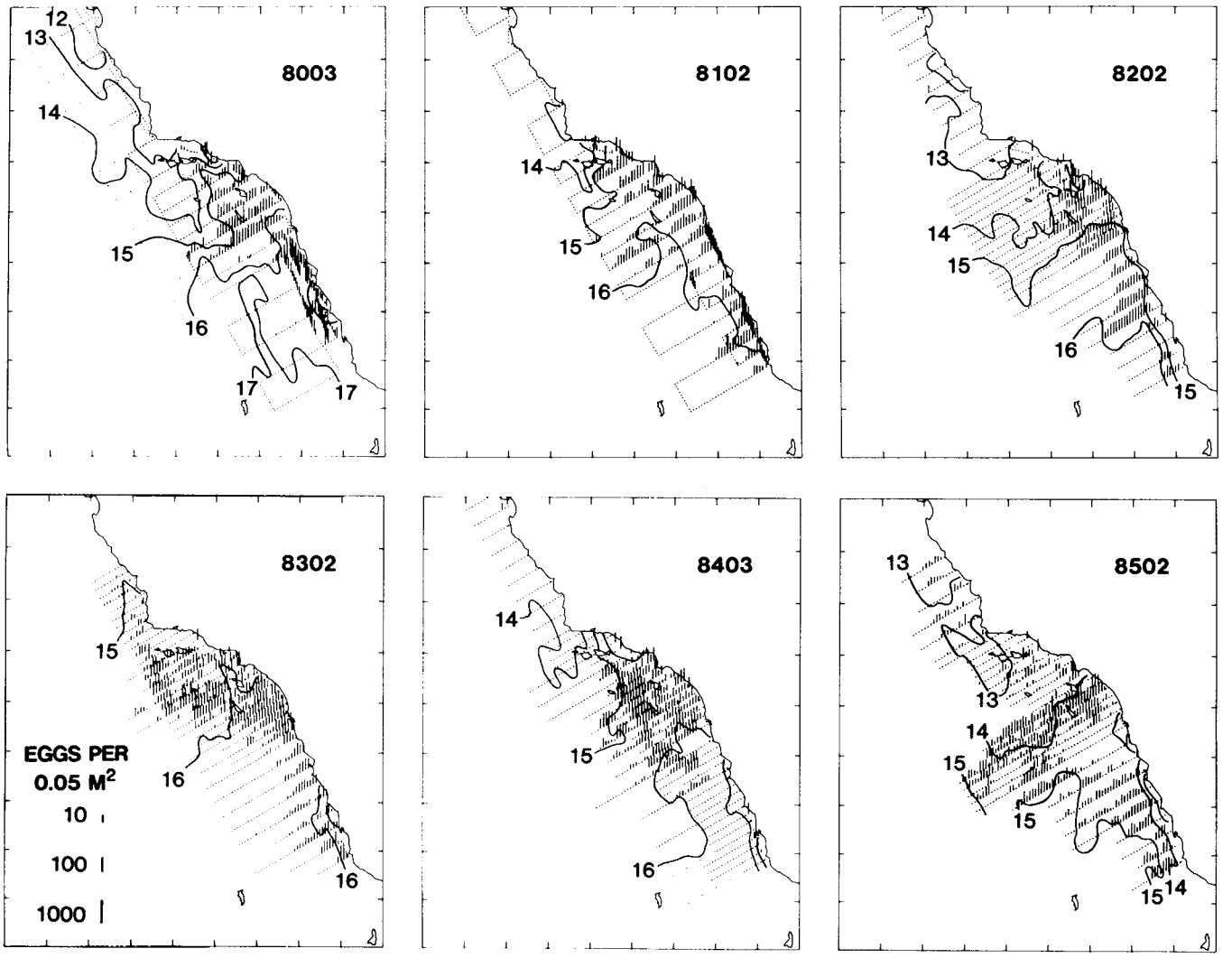

Figure 10. Northern anchovy egg production surveys, 1980–85 (from Fiedler et al. 1986).

density, and dynamic height determined at standard depths.

The data are the results of approximately 300 survey cruises during which 50,000 plankton tows and 10,000 hydrocasts were conducted. The data are displayed on a terminal screen in the form of tables and maps; they can also be written to a computer file for subsequent analysis or printing.[3]

LARGE-SCALE SURVEYS

I close by listing three reasons for conducting large-scale surveys and building a long-term time series like CalCOFI: (1) to determine what species reproduce when and where, what their distribution is, and something about how they recruit themselves—where survival is high and where it is low; (2) to characterize physical habitats, their seasonal and interannual change; and (3) to monitor long-term population trends and variability. These were the intentions of the first CalCOFI surveys, and I believe that they are still valid. Consideration should be given, however, to updating the sampling schemes and the tools that we use.

* * *

Question: Are the Gulf of California data in the CalCOFI On-Line Data System?
Hewitt: Not at the present time. That doesn't mean that the data can't be added later, but they are not there now. The Gulf of California cruises were

[3]User's manuals for the CalCOFI On-Line Data System may be obtained from the Southwest Fisheries Center, P.O. Box 271, La Jolla CA 92038.

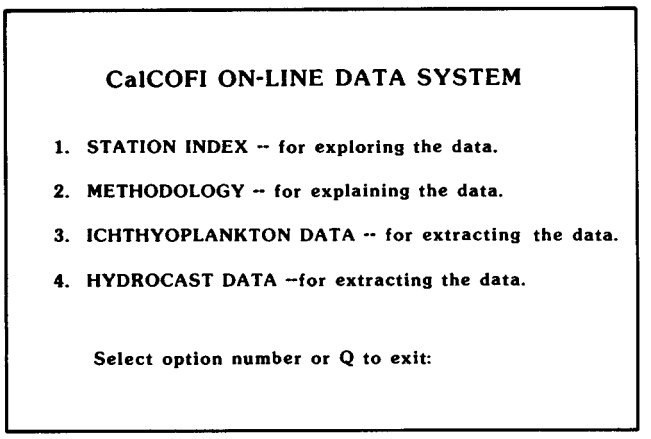

Figure 11. Main menu from the CalCOFI On-Line Data System (from Hewitt et al. 1988).

rather sporadic and don't constitute a continuous time series.

Dick Schwartzlose: One of the many things I would like to say, having been in CalCOFI for many years and having been in the administration of the Marine Life Research Program at Scripps for those many years also, is that you notice changes in the cruise frequency from almost every month to every quarter. A lot of people criticized the change and said that we should have continued the monthly cruises. Of course that would have been very nice to do, but at the time all of the agencies were coming under financial stress, and it was impossible to continue the ship operations at a high level, and also to supply the number of people necessary to go on all those cruises. The decision to shift the cruises to a quarterly frequency was not made just because we thought we didn't need them. There was also a consideration of what finances were available. This occurred again in the 1970s as more money and people were diverted to process-oriented cruises, and so there were other ships in the pattern of cruises. Since that time CalCOFI has been criticized for not continuing the monthly cruises. But of course we can't peer into the future to see what's best and what's going to happen.

Hewitt: One of the things that I hoped would come out today is a more rational discussion of what should be measured, how often, over how large an area, using what tools, and so forth. It would be based on a more rational approach to the problem at hand rather than an irrational response to budget restrictions.

Paul Smith: I think it should be pointed out that in 1957, when the Russians launched the Sputnik, the government of the United States launched a series of expenditures on oceanography which tended to double every year from 1957 to 1965. It was during this same period that the CalCOFI surveys were reduced to quarterly. So instead of a reduction in the absolute availability of funds, there was a reduction of the will to conduct the work. Individuals were awarded funds and carried out the work under the names of spin-off organizations. The money was carried away, as were a lot of the people at that time. So I don't think it was the shortage of funds; rather it was a shortage of will.

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