83

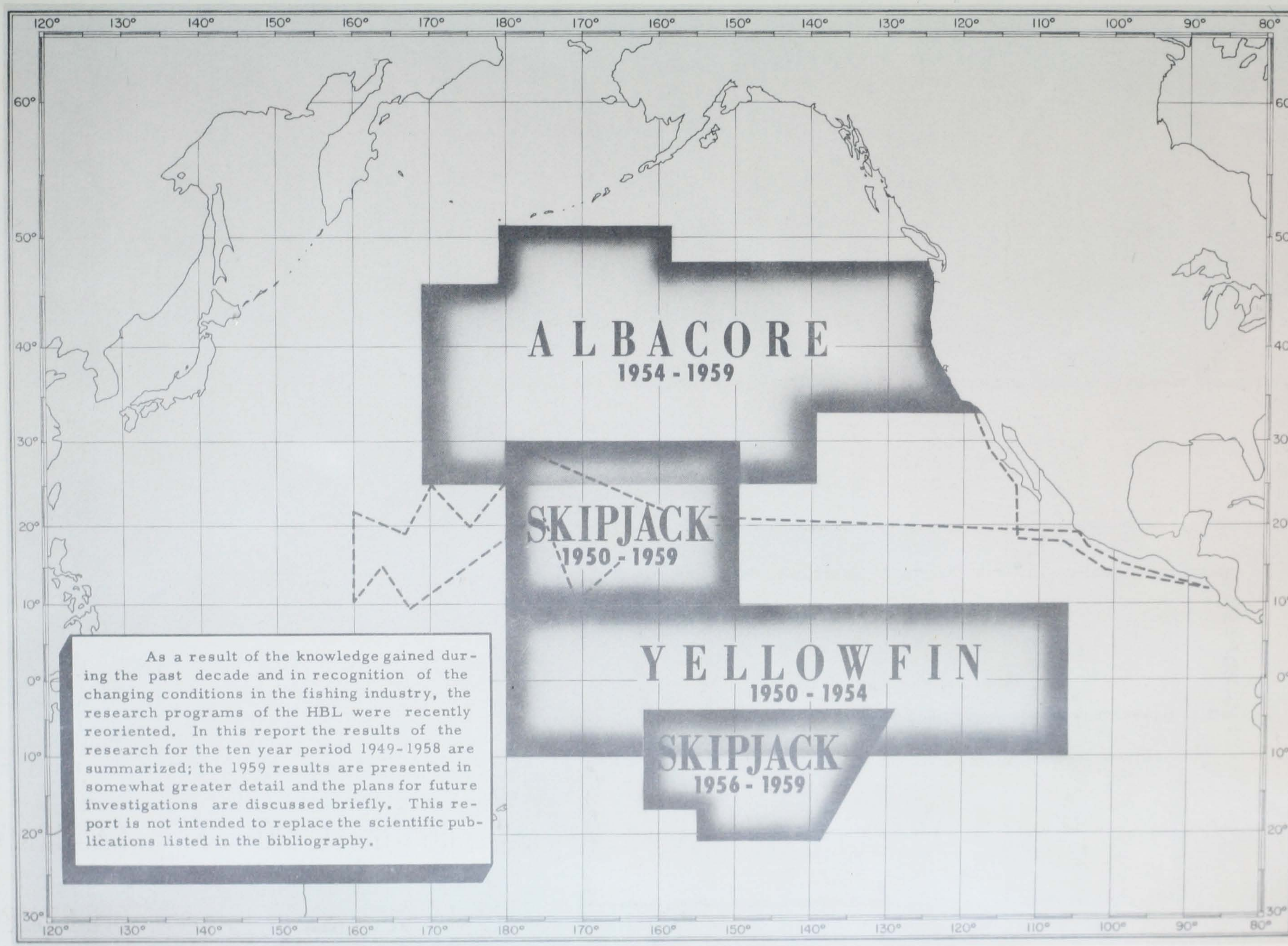
PAST 1949 - 1958

PRESENT 1959

FUTURE 1960 -

HONOLULU BIOLOGICAL LABORATORY
HAWAII AREA
U.S. BUREAU OF COMMERCIAL FISHERIES

FISH AND WILDLIFE CIRCULAR 83



As a result of the knowledge gained during the past decade and in recognition of the changing conditions in the fishing industry, the research programs of the HBL were recently reoriented. In this report the results of the research for the ten year period 1949-1958 are summarized; the 1959 results are presented in somewhat greater detail and the plans for future investigations are discussed briefly. This report is not intended to replace the scientific publications listed in the bibliography.

UNITED STATES DEPARTMENT OF THE INTERIOR, FRED A. SEATON, SECRETARY

FISH AND WILDLIFE SERVICE, ARNIE J. SUOMELA, COMMISSIONER

HONOLULU BIOLOGICAL LABORATORY

PAST (1949-1958)
PRESENT (1959)
FUTURE (1960-)

V. E. BROCK, HAWAII AREA DIRECTOR

J. C. MARR, LABORATORY DIRECTOR

Fish and Wildlife Circular 83

Hawaii Area Office

April, 1960

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PAST 1949 - 1958

Since late 1949, scientists at the Honolulu Biological Laboratory have studied the oceanic fishery resources of an area of the Pacific Ocean approximating 13 million square miles, an area over 4 times that of the continental United States. This postwar program of exploratory oceanographic and fishery surveys and accompanying biological studies of the ocean fishery resources, particularly the tunas, had its inception in a proposal for fishery research prepared in 1944 by the Territorial (now State) Division of Fish and Game. The proposal known as the Farrington Bill and passed by the 80th Congress (Public Law 329), resulted from general expressions of interest both on the continental United States and in Hawaii. Funds were appropriated to the Department of Interior and in August 1948 the Pacific Oceanic Fishery Investigations (POFI) was organized with headquarters to be located in Honolulu, Hawaii.

Public Law 329 authorized and directed the Secretary of the Interior to conduct fishing explorations and necessary related oceanographic, biological, technological, statistical and economic studies to insure maximum development and utilization of the high-seas fishery resources of the territories and island possessions of the United States in the tropical and subtropical Pacific Ocean and intervening seas.

The first work of this new fishery research laboratory included studies of the oceanography of the central tropical and subtropical Pacific, of the distribution, abundance and biology of the tunas, of their commercial potentialities, of technology and economics of the tuna industry. In 1950, after some preliminary results of these investigations were available, the technological and economic studies were eliminated and effort concentrated on the oceanographic and biological studies and on the commercial potentialities of the central Pacific. These three broad areas of research formed the basis of the Laboratory's programs from 1951 through 1957. In 1957, a fourth area of investigation, that of tuna behavior, was added.

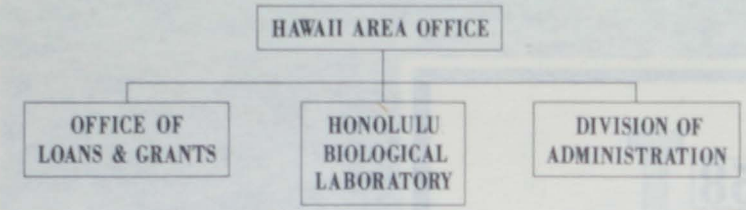


FIG. 1

These changes in the research naturally led to accompanying revisions in the organization of the Laboratory. In 1949, there were the Director's office and the sections of Biological Research and Development, Technological Research and Development, Exploratory Fishing and Administration. In early 1951, the staff was reorganized into three sections: Research and Development, Vessels and Gear and Administration. In 1958, as a result of the Fish and Wildlife Act of 1956, the Hawaii Area of the Bureau of Commercial Fisheries was established. The section of Administration was placed directly under the Area Director's office; the sections of Research and Development and of Vessels and Gear were reorganized into the Honolulu Biological Laboratory (HBL). The major divisions of the present organization of the Hawaii Area are shown in figure 1.

Dr. O. E. Sette was the first Director of the Pacific Oceanic Fishery Investigations, with Mr. F. Johnson as his Assistant Director. Mr. Johnson was transferred in June 1950 and the position was vacant until Dr. J. L. Kask was appointed in January 1951.

In 1955, Dr. A. L. Tester was appointed Director when Dr. Sette left to organize a new Bureau Laboratory in Palo Alto. At the same time, Mr. D. L. McKernan, who had been Assistant Director since Dr. Kask's transfer in December 1951, was appointed Administrator of the Alaska Commercial Fisheries.

Mr. G. I. Murphy, Assistant Director since 1955, became Director in November 1957, shortly after Dr. Tester left to become Chief of the Division of Biological Research in the Washington office. Mr. V. E. Brock became Assistant Director in January 1958. Nearly coincident with the establishment of the Hawaii Area office, Mr. Murphy accepted the position of Research Coordinator, California Marine Research Committee and Mr. Brock assumed the duties of Area Director. In June 1959, Mr. J. C. Marr, formerly Director of the Bureau's La Jolla Biological Laboratory, was appointed Assistant Area Director and Director of the Honolulu Biological Laboratory.

Physical facilities of the Honolulu Biological Laboratory consist of a main laboratory adjacent to the University of Hawaii, a docksite located at Honolulu 's Kewalo Basin, and the research vessel Charles H. Gilbert.

The main laboratory (figure 2) is a two-story stucco building of tropical architecture, completed in June 1950 at a cost of $235,000. It has 16,000 square feet of floor area and 50 rooms including biological and chemical laboratories, offices, a library and a photographic darkroom. An adjacent storage building houses extensive biological collections, six large concrete aquaria for experimental purposes, a cold storage refrigeration plant, a garage, and a work shop.

From 1948 to 1958, the docksite was located at Pier Howe 8 in the Pearl Harbor Naval Shipyard. Although these facilities were adequate in some respects, they were a considerable distance away from the main laboratory and from the center of activities of Hawaii's commercial fisheries.

FIG. 2

A new docksite facility was completed in July, 1958. The main building (figure 3) with 10,800 square feet of floor space includes a warehouse, machine shop, net loft, offices and a biological laboratory with sea water aquaria. Berthing spaces for research vessels are alongside. Adjacent grounds, 39,200 square feet in area, provide space for baitfish experiments and tuna holding tanks.

Part of the building is occupied by the Marine Section of the Bureau of Fisheries, Hawaii Division of Fish and Game.

Between 1950 and 1958, the laboratory operated three research vessels; two ex-Navy YP's, the Henry O'Malley and Hugh M. Smith, both of tuna clipper design, and a purse seiner, the John R. Manning. The O'Malley was sold in 1951 and the funds from its sale were used in constructing the Gilbert. The Manning was transferred to the Alaska Commercial Fisheries in 1958. The Smith was transferred to the California Area Office in June, 1959 and is now on loan to the Scripps Institution of Oceanography.

The Charles H. Gilbert (figure 4), designed for the Laboratory as a live bait and longline fishing vessel, was completed in April 1952 at a cost of $217,000. In 1953, it was lengthened 28 feet and a wet laboratory added. An additional alteration in 1959 included conversion of an after fuel tank into an underwater observation chamber. Installations of a bow underwater observation chamber and a new main engine are now in progress.

The Gilbert, 120 feet long, weighs 200 tons and has a cruising range of 10,000 miles. She carries a crew of 12 and can accommodate seven in the scientific field party. Besides fishing, the Gilbert is equipped for many types of meteorological, oceanographic and biological observations.

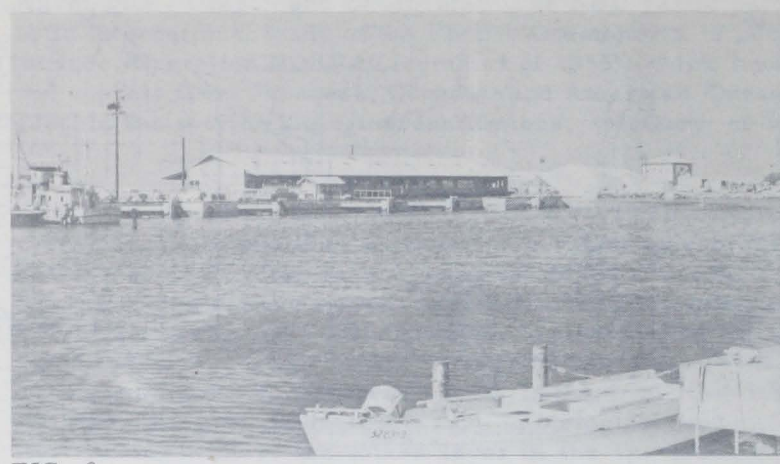
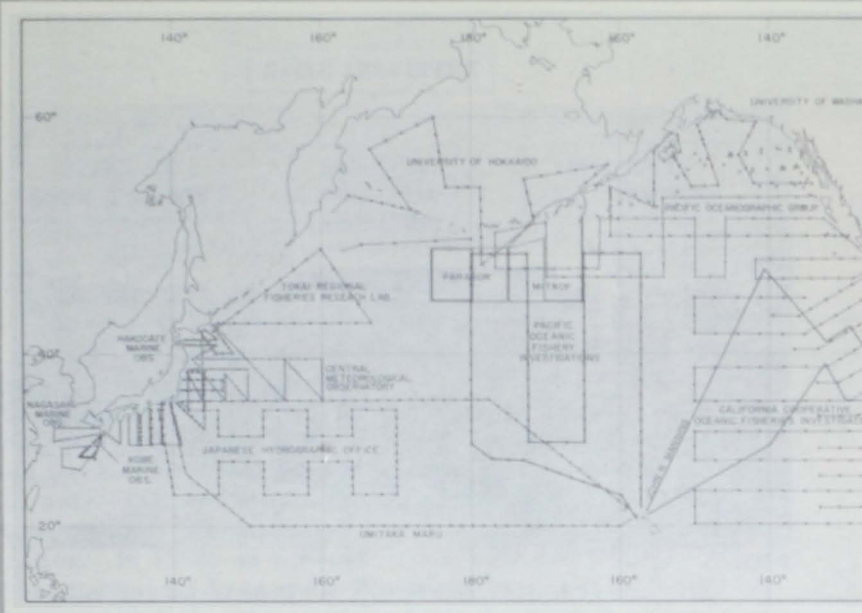
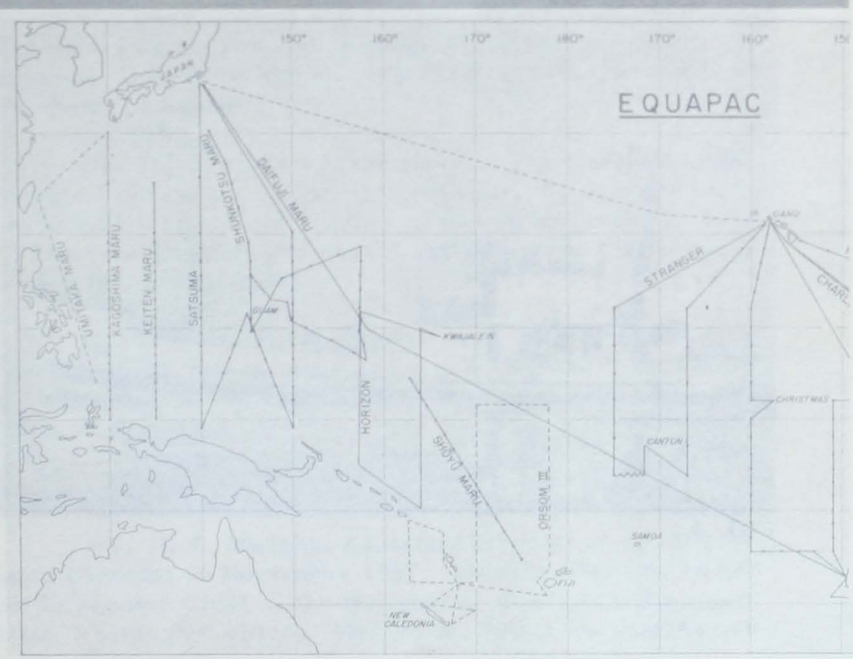


FIG. 3

FIG. 4





RESEARCH RESULTS

OCEANOGRAPHY

In 1958, a decade of exploratory oceanography by the HBL came to an end. Four general areas (see inside front cover) of the Pacific were investigated during this period:

(1) Central and eastern equatorial Pacific, with particular emphasis on oceanographic features at or near the equator;

(2) North central and eastern subtropical and temperate Pacific waters;

(3) The waters of French Oceania, particularly those near the Marquesan and Tuamotuan Archipelagos, and

(4) Hawaiian waters.

Each of the four investigations followed a similar pattern. Exploratory crusies were carried out during midsummer and mid-winter in order to observe maximum seasonal variations in the oceanographic conditions. Subsequent cruises and observations were planned to investigate conditions during periods of seasonal change and also to study those oceanographic features within the area which were revealed to be of particular biological significance.

Highlights of the results of these oceanographic research programs are:

Equatorial Pacific -- The geographical and seasonal variations in the circulation features of the surface waters, both horizontal and vertical, were investigated in the area between 10°N. and 10°S. latitude and between the 180th meridian and 120°W. longitude (1950-1953). A major oceanic current, the subsurface, easterly flowing Equatorial Undercurrent, was discovered (1951). The area of enrichment of surface waters along the equator, which results from upwelling of the subsurface, cooler enriched waters (divergence at the equator) was intensively studied and seasonal variations in this enrichment were observed. Studies of the divergence of the surface waters at the equator, the convergences to the north and south of the equator, and the relation between these biologically important oceanographic features and the trade wind system resulted in the formulation of a theoretical model to explain the wind-ocean interrelationships (Cromwell, 1953). In 1952, a scheme (figure 5) off the equatorial circulation features was completed. Subsequent surveys have provided data which permit refinement of the details, but the general features remain unchanged.

The subsequent surveys mentioned above were made by HBL vessels operating both independently and in cooperation with vessels of other research institutions. Three notable examples of such cooperative surveys are the EASTROPIC Expedition (1953) with participation by American and Peruvian vessels ; Operation EQUAPAC (1957) during which Japanese, French and American vessels participated in a quasi-synoptic oceanographic survey between 135°W. longitude and the Asiatic Coast and 20°N. to 20°S. latitude (Austin, 1957), and finally a detailed study of the Equatorial Undercurrent (4°N. to 4°S. latitude near 150°W. longitude) made by the HBL and the Scripps Institution of Oceanography (Knauss and King, 1959).

North Central and Eastern Pacific--Early in 1954, HBL began investigating the distributions, abundance and biology of the albacore in the north central and eastern Pacific, as well as the oceanography of the area. The first of the Laboratory's exploratory oceanographic cruises into the North Pacific was in January, 1954 in the area between the Hawaiian Islands and 45°N. latitude and 170°E. to 160°W. longitude. Subsequent cruises (1954 to 1959) extended the area northward to the Aleutian Islands and eastward to waters off the coasts of Washington, Oregon and California. The HBL participated in an international study of the Pacific Ocean north of 20°N. latitude, Operation NORPAC (summer of 1955), which involved vessels from Japanese, Canadian and American Oceanographic and marine biological institutions, (McGary et al., 1956).

The results of the 1954-1958 HBL North Pacific cruises reveal that there is a zone of transition between the subarctic and the central water masses. The southern boundary of this transition zone is located near 31°-32°N. in winter and 33°-34°N. in summer. This boundary is clearly discernable in the surface waters during winter, in subsurface waters during summer. Enrichment occurs in the transition zone and there is a proportionate increase in biological productivity. During winter, the mixed layer in the transition zone is deep. During spring, surface warming causes a marked shallow thermocline to develop, beginning at about 35°N. and progressing northward, until by late summer it reaches

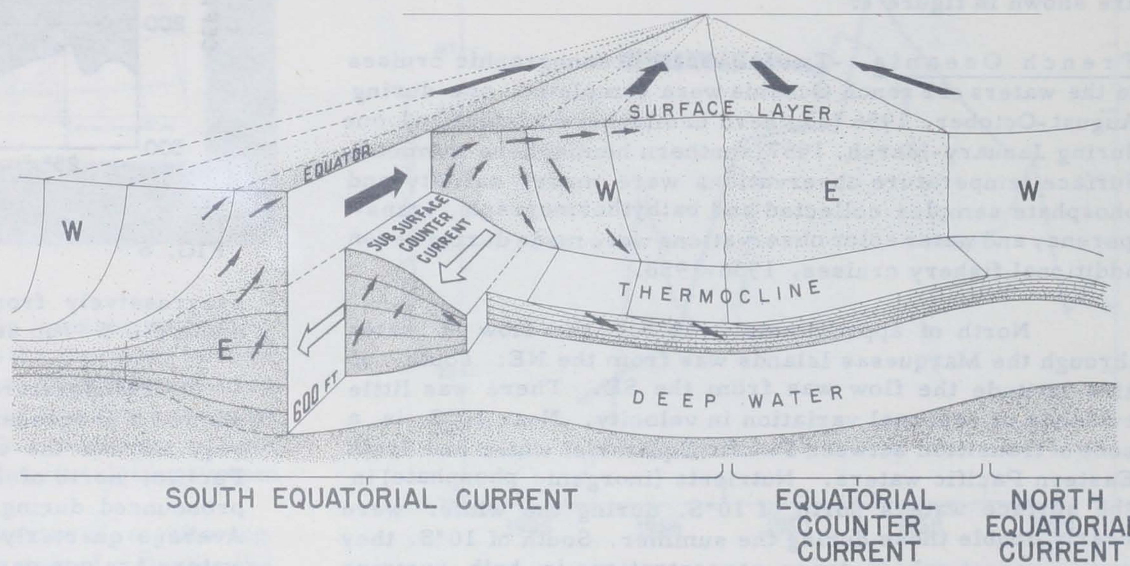
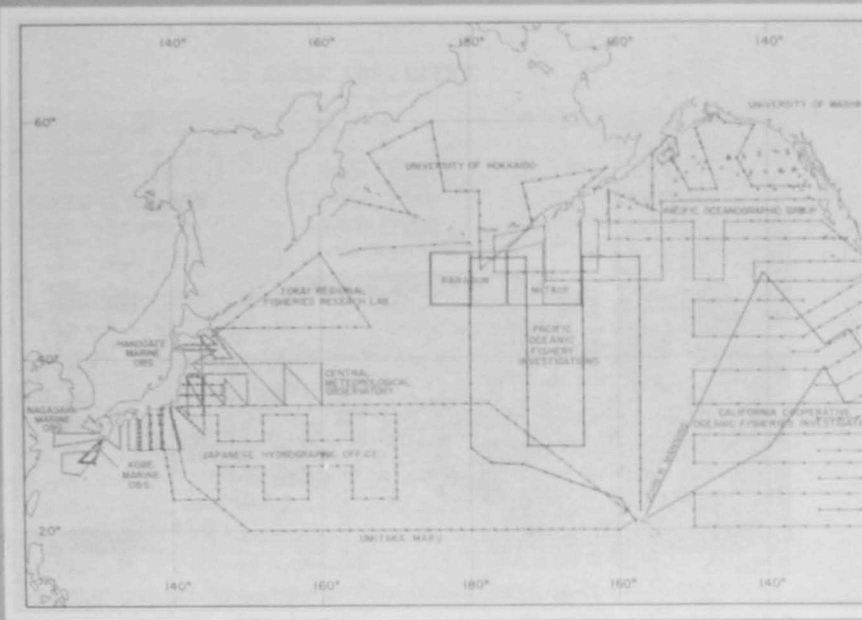
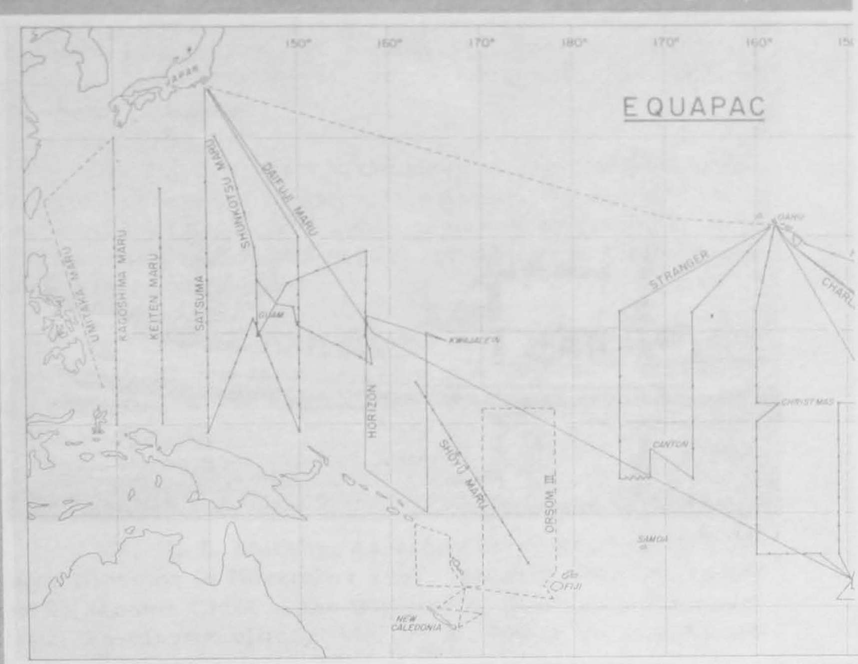


FIG. 5





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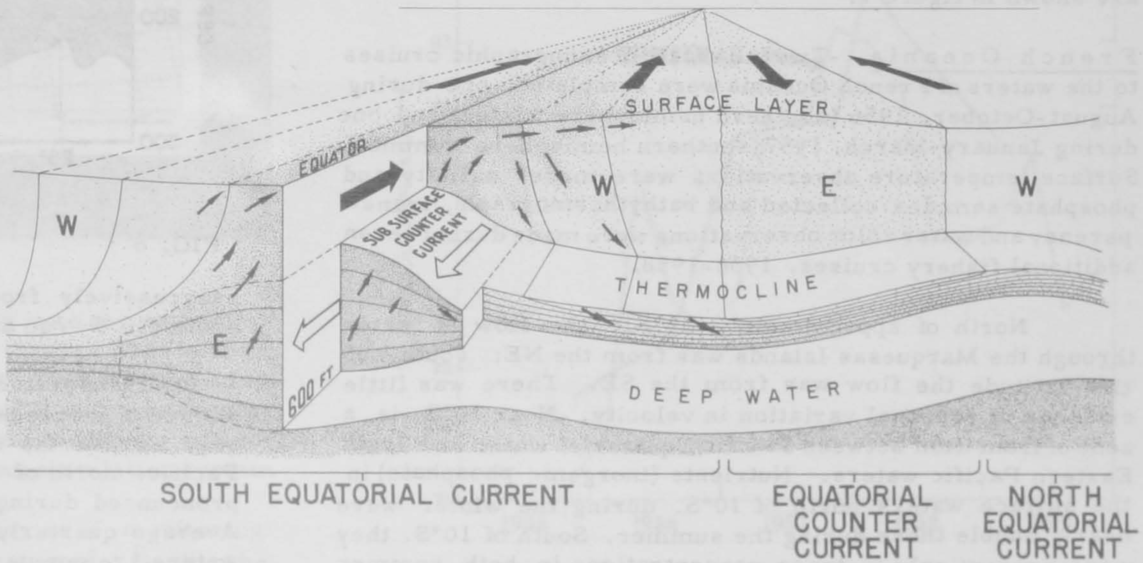


FIG. 5

47° to 48°N. (figure 6). Optimum conditions for phytoplankton and zooplankton production "follow" the northward progression of the surface warming and associated development of the thermocline (McGary et al., 1958).

Activities of fishing vessels in the North Pacific are often limited by strong winds. As an aid to the industry in evaluating average fishing conditions, an atlas showing mean (60-year period) monthly variations of observed wind speeds was prepared (McGary et al., 1957).

As sea surface temperatures may be an index to the presence or absence of albacore and as the month-to-month and year-to-year sequence of these temperatures reflect various oceanographic processes at work, a series of charts showing the average surface temperatures for each mid-month 10-day period and the anomalies for the particular month compared with the 30-year mean (H. O. 225) was initiated in October, 1957. In January, 1958, an additional chart showing the anomaly for the particular month compared with the same month for the previous year was added, and the historical charts (January to October, 1957) were completed. Examples of both the wind and temperature charts are shown in figure 7.

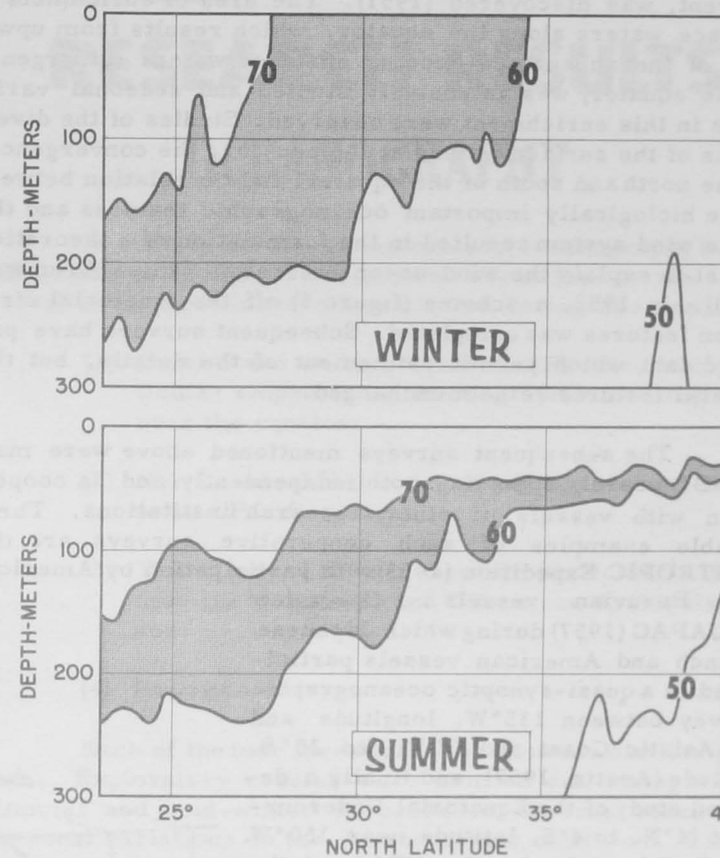


FIG. 6

French Oceania--Two full-scale oceanographic cruises to the waters of French Oceania were completed, one during August-October, 1956 (southern hemisphere winter) and one during January-March, 1957 (southern hemisphere summer). Surface temperature observations were made, salinity and phosphate samples collected and bathythermograph, transparency and water color observations were made during seven additional fishery cruises, 1956-1958.

North of approximately 10°S., the flow of water through the Marquesas Islands was from the NE: south of this latitude the flow was from the SE. There was little evidence of seasonal variation in velocity. Near 10°S. is a zone of transition between Pacific Equatorial water and South Eastern Pacific waters. Nutrients (inorganic phosphate) in the surface waters north of 10°S. during the winter were nearly double those during the summer. South of 10°S. they were present only in trace concentrations in both summer and winter. The salinity of the surface waters increased progressively from north (34.5 ‰ near the equator) to south (36.5 ‰ at 20°S.).

Temperatures in the surface waters of French Oceania showed a progressive warming during the period of the survey, as was the case over most of the eastern half of the Pacific, north of 20°S. latitude. This warming was most pronounced during the latter half of 1957 and all of 1958. Average quarterly surface temperatures of the Marquesan waters are compared in figure 8, with those recorded at the HBL Christmas Island station.

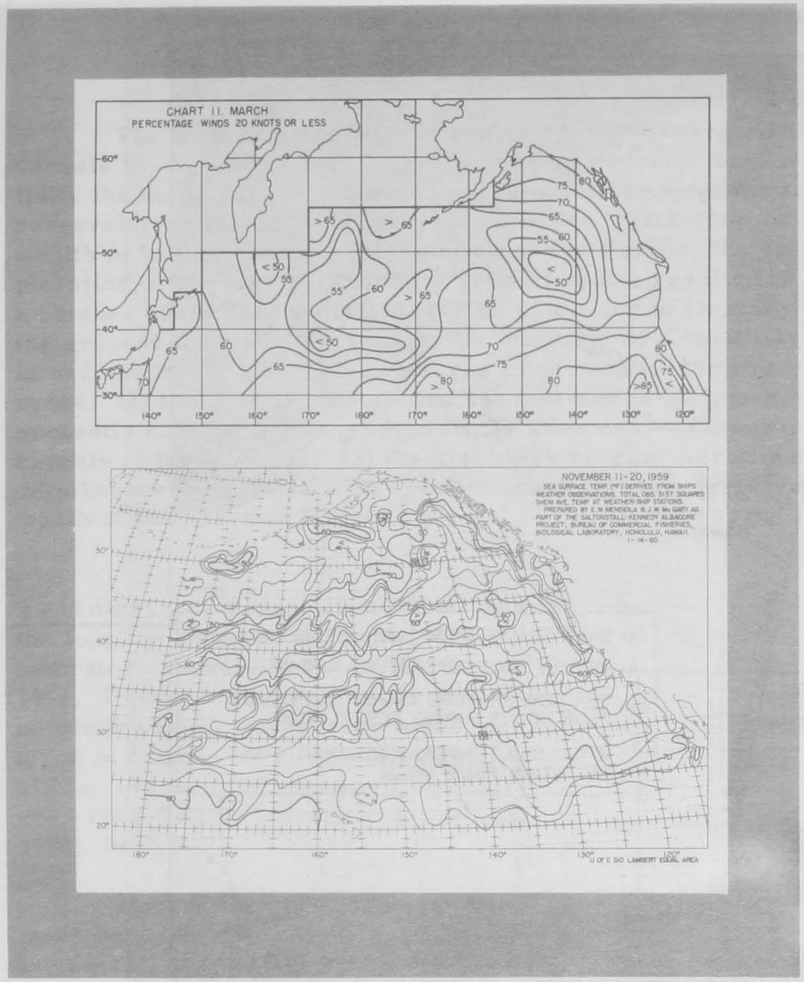


FIG. 7

Hawaiian Waters - - Oceanographic cruises extending several hundreds of miles offshore from the Hawaiian Islands were made at varying intervals from late 1949 through 1958. Results from these cruises demonstrated that there were no gross seasonal variations in oceanographic conditions or zooplankton volumes, but did reveal a complex circulation system.

In November, 1955, a 3-year series of monitoring cruises around the island of Oahu was started. During the same month, collections of weekly surface temperature and salinity measurements were initiated near Koko Head on the island of Oahu. These observations were augmented in 1957 by data from similar stations on the islands of Hawaii, French Frigate Shoals, Midway, Johnston and Wake, and by observations from Coast Guard and commercial vessels (figure 9). An oceanographic station in deep water off Oahu was occupied once each month during International Geophysical Year, June, 1957 through December, 1958.

Although the more extensive surveys in the open ocean around the Hawaiian Islands did not reveal any gross seasonal variations, the frequent observations at the monitoring stations did reveal significant but subtle seasonal changes. During the winter, the islands are normally bathed in waters of the western North Pacific (salinities in excess of 35.00 o/oo) and, during the summer, by the somewhat fresher (34.6 to 34.8 o/oo) waters of the California Current Extension. There are year-to-year variations in the time that the boundary between these two types of water moves through

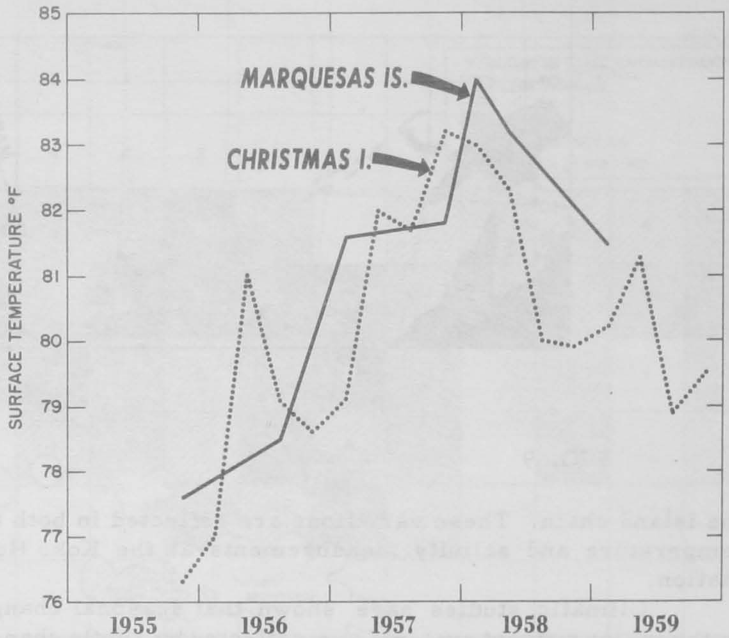


FIG. 8

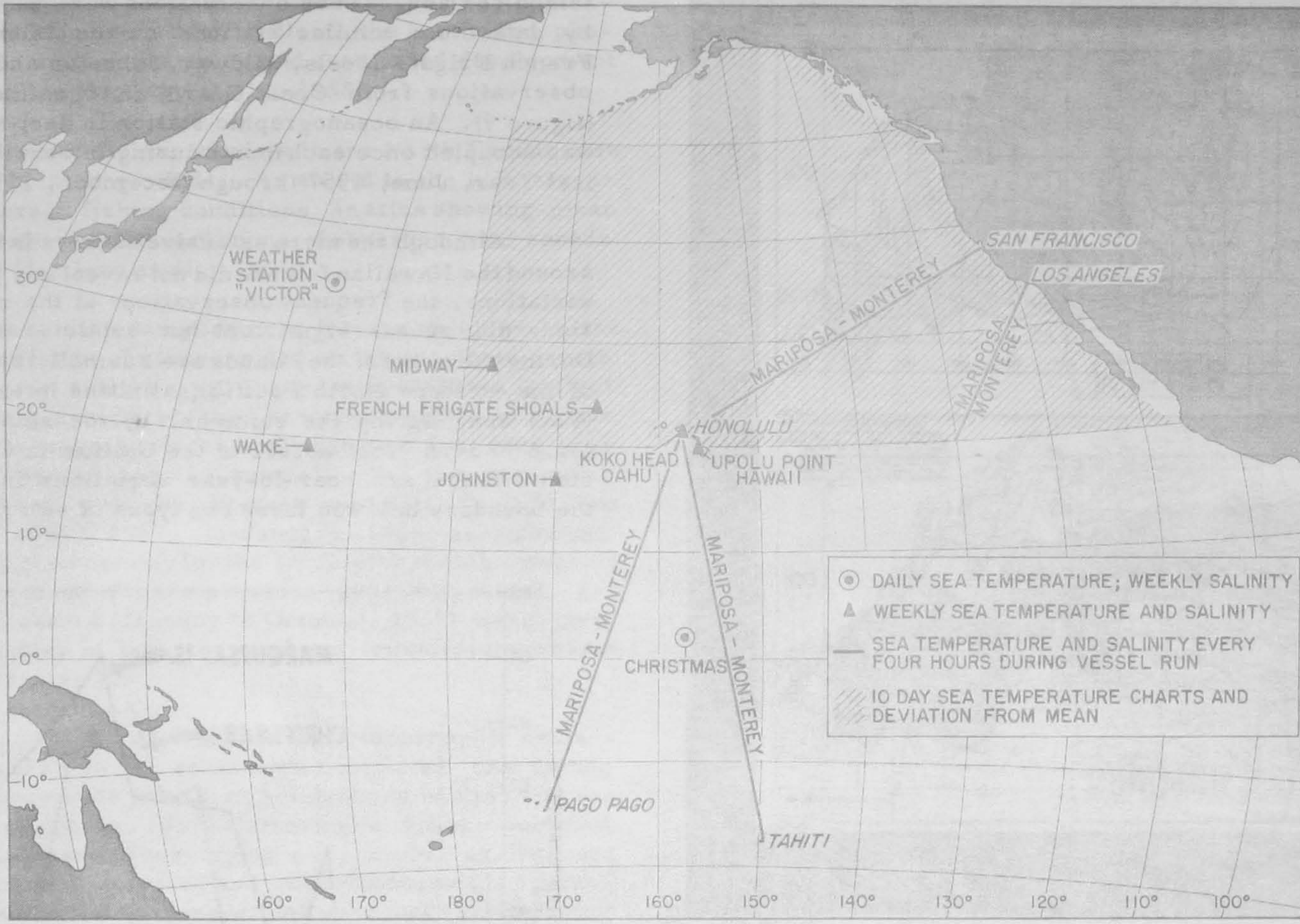


FIG. 9

the island chain. These variations are reflected in both the temperature and salinity measurements at the Koko Head station.

Climatic studies have shown that seasonal changes in the major current systems are reflected by subtle changes in the sea surface temperature measured at the Koko Head station. For example, the initial warming signifies that the boundary has started its northward movement. When this occurs in February, a well-developed California Current system has been experienced later in spring. Conversely, a weaker current system has been experienced with initial warming in March. This association has predictive value for both oceanic circulation features and the skipjack fishery in Hawaiian waters.

FISHERY RESOURCES

The first of many fishery exploratory cruises by HBL vessels took place in 1950. These cruises covered essentially the same areas as did the Laboratory's oceanographic research (see inside front cover). Besides gathering a wealth of basic scientific information on the Pacific, the exploration of the high seas fishery resources has resulted in a number of findings including: (1) the discovery of rich fishing grounds for yellowfin tuna in the vicinity of Christmas Island and of oceanographic features to account for their presence; (2) the determination that the mid-ocean skipjack, presently utilized only near Hawaii, is an extensive resource capable of large yields; (3) the discovery of concentrations of albacore associated with specific oceanographic features south of the Aleutian Islands.

Yellowfin - - Figure 10 summarizes the longline catch of yellowfin tuna by laboratory vessels between 1950 and 1956. Details of the exploratory cruises on which these catches were made are given in reports by Murphy and Shomura, 1953a, 1953b, 1955; Shomura and Murphy, 1955; and by Iversen and Yoshida, 1956, 1957.

Most of the good catches were made between 5°N. and 5°S. latitude. In general, the good fishing was associated with warmer water and poor fishing with cooler water. Variation in yellowfin abundance associated with variation in water temperatures has at least one logical explanation. Surface waters near the Equator, newly enriched by upwelling, are relatively cool. As this water ages or matures, the abundance of organisms in various successive trophic levels (phytoplankton, zooplankton and tuna forage) increases and tuna congregate to feed. A possible measure of aging, or time at the surface, is the rise in temperatures. The correlation between the catch and the age of the water suggests that this explanation may be correct, although to ascribe all variations in longlining in this area to changes in water temperature is undoubtedly an over-simplification.

The decline in catch of the yellowfin in the Hawaiian longline fishery and the associated increase in catch of big-eye tuna, investigated through the use of commercial catch statistics (Shomura, 1959), was shown to be the result of changes in fishing areas.

Skipjack - - Although there have for many years been fisheries for skipjack off the west coast of the Americas and near the Japanese Islands, the extent of the central Pacific skipjack resource remained largely unknown. Sightings of tuna schools by HBL vessels, particularly since 1956 in connection with the Marquesas Islands exploratory surveys,

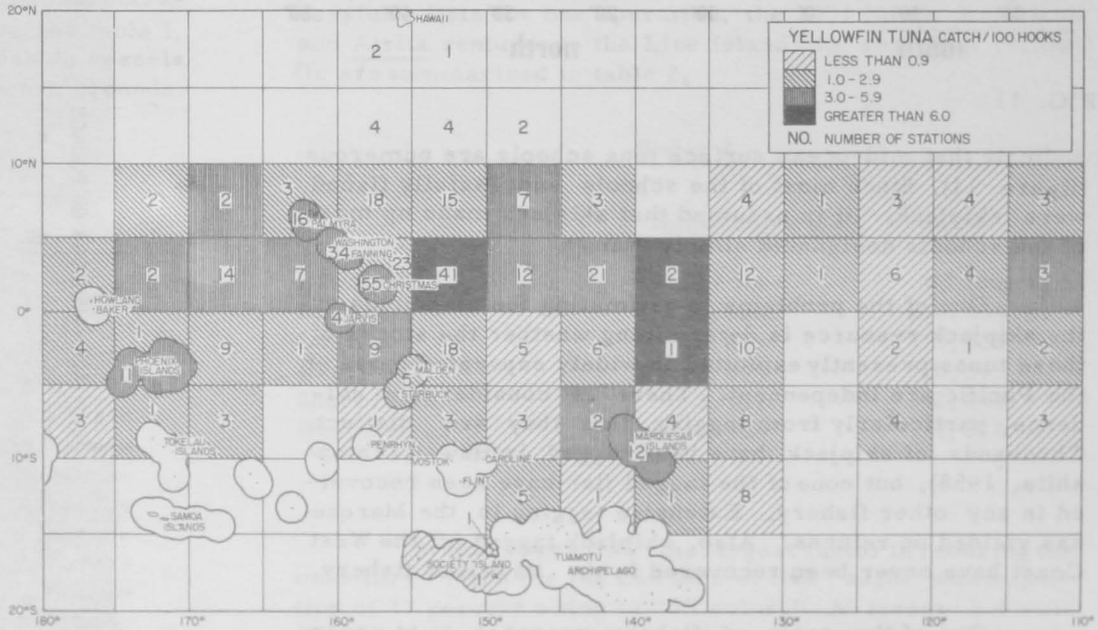


FIG. 10

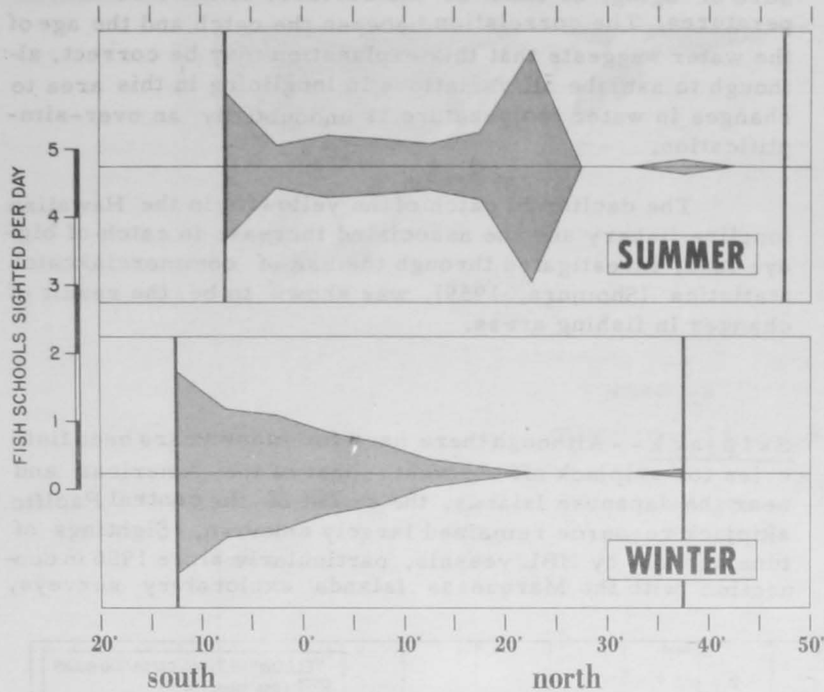


FIG. 11

indicate that mid-ocean surface tuna schools are numerous (figure 11). Since most of the schools successfully fished were skipjack, it is assumed that skipjack make up most of the schools designated simply "tuna".

One of the problems in estimating the magnitude of the skipjack resource is determining whether the stocks of these tunas presently exploited in widely separated parts of the Pacific are independent. There is considerable evidence, particularly from tagging, that they are distinct. Thousands of skipjack have been tagged in Hawaii (Yamashita, 1958), but none of the tagged fish have been recovered in any other fishery. Extensive tagging in the Marquesas yielded no returns. Also, skipjack tagged off the West Coast have never been recovered in the Hawaiian fishery.

One of the goals of fishery research is to understand some of the interrelationships among fish and their environment and to use such understanding as a means of predicting changes in the availability of fish. In an effort to develop such a prediction for the Hawaiian skipjack fishery, catch records for the post-war years provided by the Hawaii Division of Fish and Game were analyzed along with meteorological and oceanographic data for the Hawaiian area.

As one of the first results of these analyses, it was noted that a good season's catch was associated with low surface salinities in the waters near Oahu (figure 12). Subsequently, an empirical relationship, associating the seasonal availability of skipjacks in Hawaiian waters with the lower salinity waters of the California Current Extension, was developed.

As discussed on page 8, however, the prediction which evolved was primarily based on late winter variations

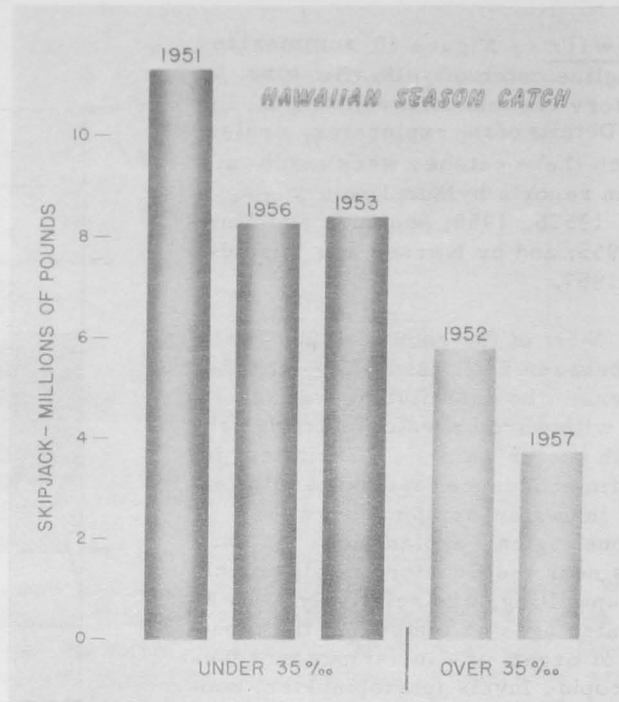


FIG. 12

in the sea surface temperatures near Oahu and not on the salinity/skipjack availability relationship. The reliability of this predictive technique received its first critical test in 1959. The results are discussed in the next section of this report.

Albacore -- Beginning in 1954 a study of the central North and Northeastern Pacific albacore resources was undertaken. Longlining, trolling and gillnetting fishing techniques were used.

Figure 13 indicates the abundance of albacore found in this area during the summer of 1955. During the summer of 1957, operation NEPAS (North East Pacific Albacore Survey) indicated that concentrations of albacore, some in commercial quantities, were present off the west coast of North America. Details of these surveys are given by Shomura and Otsu, 1956; Graham, 1957; McGary, Jones and Graham, 1958; Graham and Mann, 1959; Callaway and McGary, 1959.

A logical extension of laboratory exploratory fishing was to assess the economic potentials of the concentrations thus revealed. Such activities, as shown by table 1, were encouraged by chartering commercial fishing vessels for trips to the yellowfin, skipjack and albacore grounds.

Table 1

Vessel	Year	Area	Species
Cavalieri	1952	Central Equa Pac	Yellowfin
North American	1954	Central Equa Pac	Yellowfin
Alrita	1954	Central Equa Pac	Yellowfin
Lancing	1957	Northeastern Pac	Albacore
Gypsy	1957	Northeastern Pac	Albacore
Flicker	1957	Northeastern Pac	Albacore
Lynn Ann	1957	Northeastern Pac	Albacore
Rowland R., Sr.	1957	Northeastern Pac	Albacore
Allen Cody	1957	Northeastern Pac	Albacore
Luella	1957	Northeastern Pac	Albacore
Paragon	1958	Central North Pac	Albacore
Cape Falcon	1959	French Oceania	Skipjack

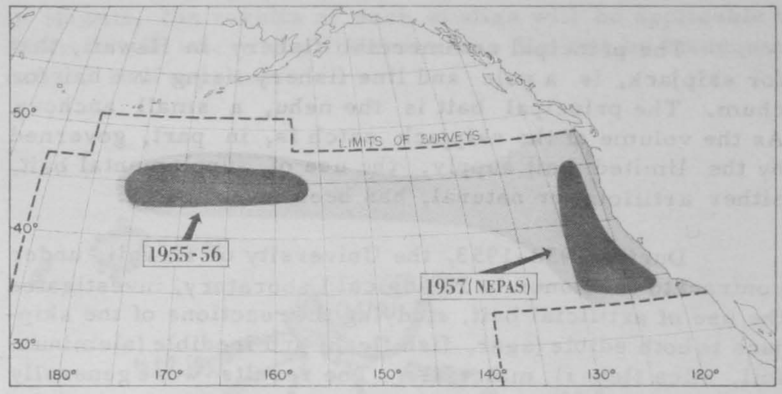


FIG. 13

Space does not permit the detailed discussion of all these charters, some of which proved moderately successful. Data for one operation, the 1954 North American and Alrita venture to the Line Islands in search of yellowfin are summarized in table 2.

Table 2

	North American	Alrita
Landings	127 tons	83 tons
Income	$ 35,000	$25,054
Contract	16,875	13,125
Expenses	13,899	10,315
Share/man	3,151	2,077
Boat shares	15,030	7,512

In this operation, the largest factor in reducing the monetary return for the 210 tons of fish caught was rejection of 17 percent owing to "off color." A lesser but still important factor was loss of fish and fishing time because of breaks in the longline gear.

BAIT SUPPLEMENTS

The principal commercial fishery in Hawaii, that for skipjack, is a pole and line fishery using live bait for chum. The principal bait is the nehu, a small anchovy. As the volume of the skipjack catch is, in part, governed by the limited bait supply, the use of supplemental bait, either artificial or natural, has been investigated.

During 1952-1953, the University of Hawaii, under contract to the Honolulu Biological Laboratory, investigated the use of artificial bait, studying the reactions of the skipjack to both edible (agar, fish flesh) and inedible (aluminum foil, mica flakes) materials. The results were generally negative or inconclusive (Tester et al., 1954).

Three species of potential natural bait supplement, tilapia, Marquesan sardine and threadfin shad, have been investigated.

TILAPIA

Tilapia-- Tilapia, a fish native to East Africa, was brought to Hawaii in 1951 and released in various ponds and reservoirs in the State. They are prolific breeders. From 1954 through 1956, the HBL in cooperation with the State Division of Fish and Game and the Hawaiian Tuna Packers, Ltd., conducted sea tests to determine the effectiveness of tilapia as skipjack bait. The young tilapia proved to be an adequate baitfish for catching skipjack, especially the larger (18-24 pounds) "season" fish.

In 1956, a small scale hatchery to determine the economics of rearing tilapia was constructed at the Honolulu laboratory. During 1957-1958, a larger hatchery was operated on the island of Maui. The Maui plant (figure 14) was a cooperative venture involving Maui Fisheries and Marine Products, Ltd., the Hawaii Division of Fish and Game and the HBL. In addition, experiments were conducted at the Kewalo facility in 1958-1959 to determine food requirements and the influence of temperature, salinity, male/female ratio and degree of crowding on reproductive rate.

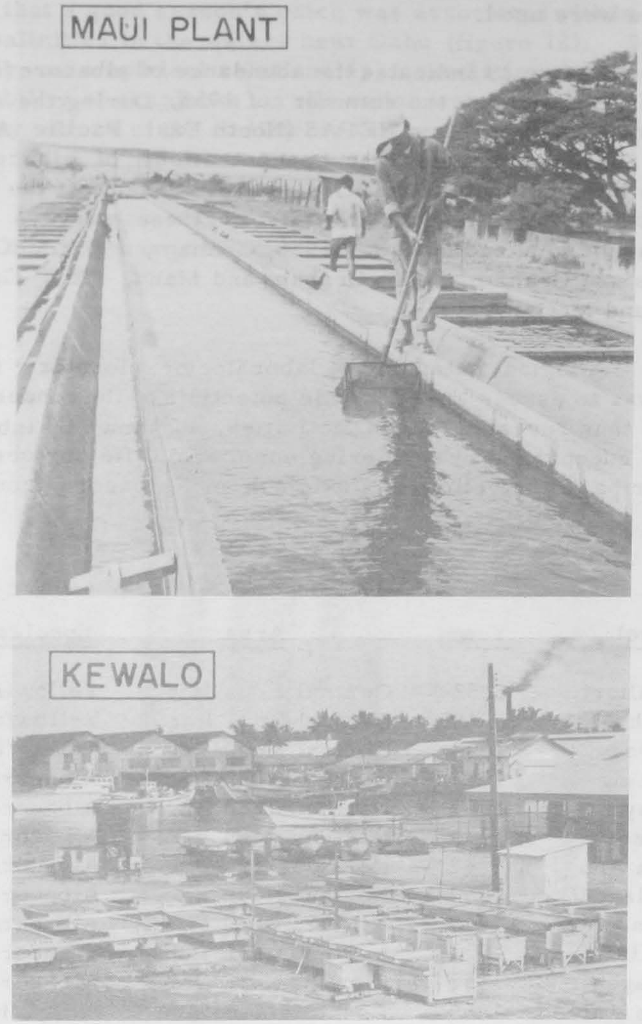
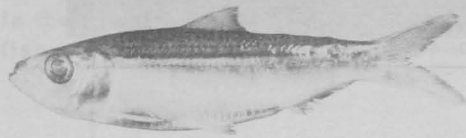
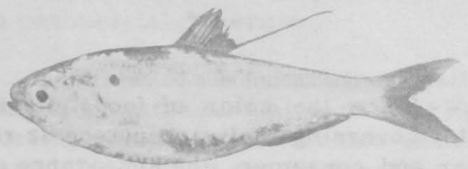


FIG. 14



MARQUESAN SARDINE

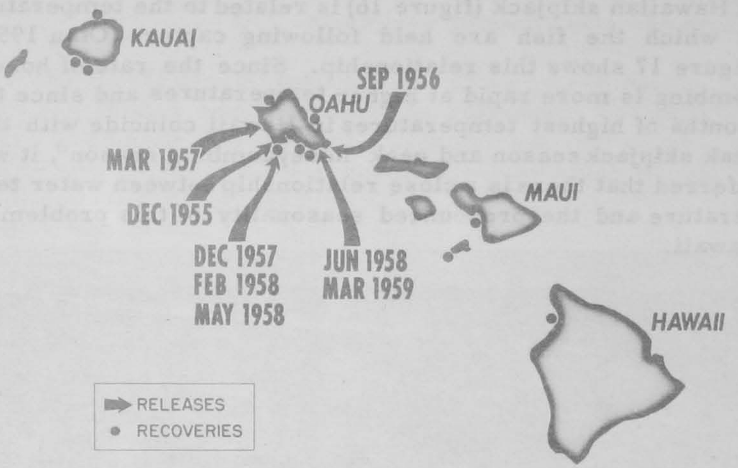
Marquesan Sardine--The excellent live-bait qualities of the Marquesan sardine were demonstrated from HBL vessels fishing for skipjack in Marquesan waters. Hawaiian waters appeared to provide a suitable habitat for this species. Accordingly, in late 1955 the first introduction of Marquesan sardines into Hawaiian waters was made. Additional plantings were made during 1956, 1957 and 1958. Adults in spawning condition were recaptured from various embayments and harbors around the island of Oahu during 1957; islands of Oahu, Maui and Kauai in 1958 and 1959. Planting and capture sites are shown on figure 15. Small fish have also been collected, indicating successful local spawning. The frequency of recapture, the distribution among the islands and the occurrence of successful spawning demonstrate that this transplanted marine species has become established in Hawaiian waters.



THREADFIN SHAD

Threadfin Shad--Shipments of threadfin shad, a small fish found in the Gulf of Mexico and Atlantic drainages of the United States, have been received at the HBL and introduced into various tanks, ponds, reservoirs and rivers in the islands. As this potential live bait species can tolerate fresh or sea water, is prolific and has been proven by sea tests to be an excellent bait fish, it shows considerable promise as a bait supplement for use by the Hawaiian skipjack fishermen.

Although these studies of potential live-bait supplements were designed to alleviate the bait shortage problem in Hawaii, the results of such studies will be applicable to other areas where the fisheries are limited by inadequate natural bait supplies.



Marquesan Sardine - Releases & Recoveries

FIG. 15

TECHNOLOGY

HBL technological research has considered only a few subjects, including honeycombing in Hawaiian skipjack, green or off-color tuna and the canning quality of large size yellowfin and bigeye tunas.

Honeycombed Tuna--The appearance of honeycombing in Hawaiian skipjack (figure 16) is related to the temperature at which the fish are held following capture (Otsu 1957). Figure 17 shows this relationship. Since the rate of honeycombing is more rapid at higher temperatures and since the months of highest temperatures in Hawaii coincide with the peak skipjack season and peak "honeycombing season", it was inferred that there is a close relationship between water temperature and the pronounced seasonality of this problem in Hawaii.

FIG. 16

The results suggested that a modest amount of icing on the boats would prevent honeycombing. The almost immediate application of these results by the industry has been particularly gratifying.

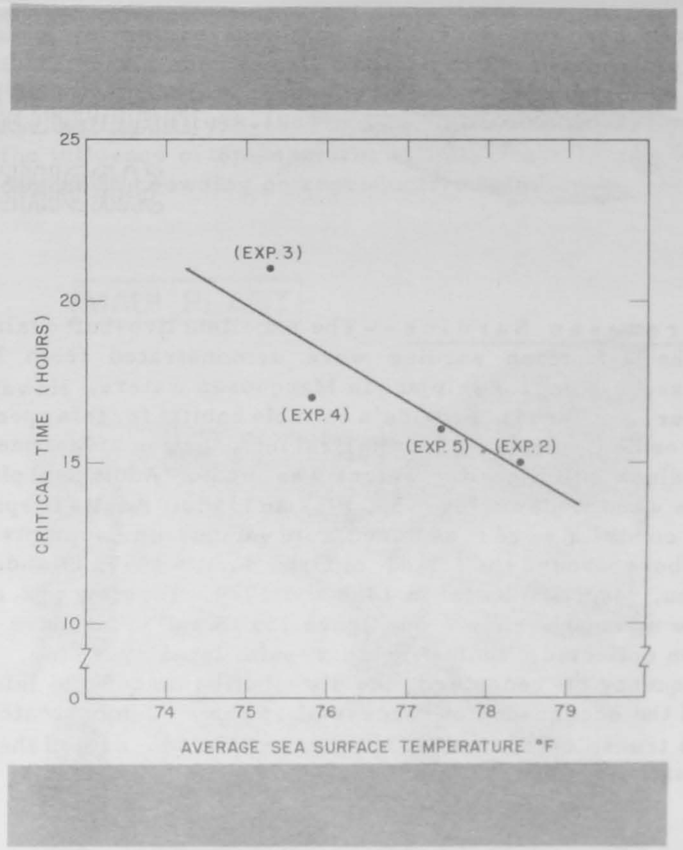


FIG. 17

Greening in Tuna--Since the color of foodstuffs is often an important factor governing their acceptance or rejection by the processor and consumer, the appearance of off-color or greening in precooked tunas was investigated under research contract with the University of Hawaii's Department of Chemistry.

The study showed that greenness is an actual color condition, rather than a lack of pigment or off-color, which occurs when the heme protein present in tuna flesh is oxidized during precooking (Naughton, Frodyma and Zeitlin 1956, 1957). Greening in tuna is similar to the greening process that occurs in other meats.

Canning Qualities of Large Tunas--A problem associated with longlining for large, deep-swimming tunas is the occasional high rate of rejection by canneries of these fish. Figure 18 shows the acceptance of yellowfin and bigeye

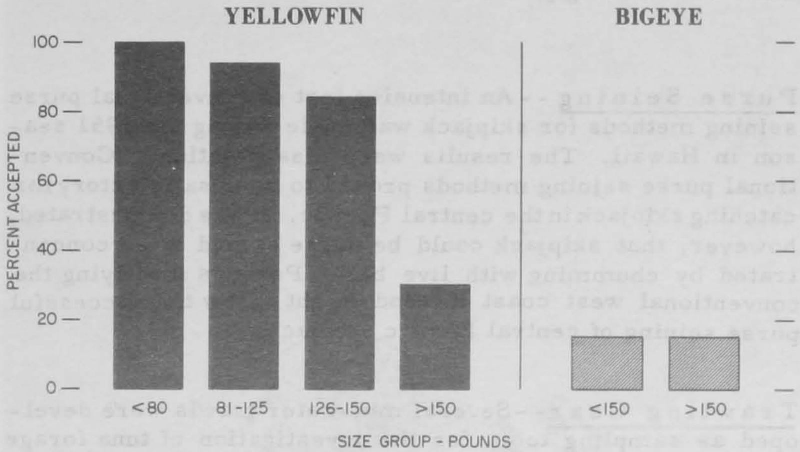
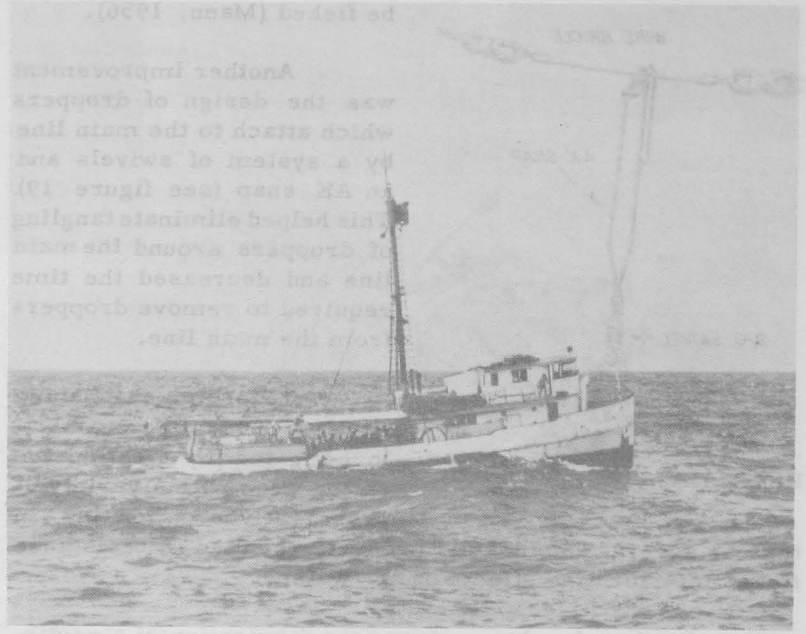


FIG. 18

caught in the central equatorial Pacific in 1952 by the Cavalieri. Since the bigger tunas make up a large portion of such catches, their rejection is economically significant to commercial fishermen.

A test of the suitability of yellowfin captured by HBL longlining in the central equatorial Pacific was made by recording conditions under which each fish was landed and by examining them at successive steps in processing. The fish considered unsuitable for canning after precooking did not come from any specific locality nor sex. Further, the method of handling the fish prior to freezing had no relation to their rejection. There were indications that size influenced the acceptabliity of the fish, i.e., more large fish were rejected.

Three separate tests of the canned product permit the following statements: (1) Bleeding the fish while alive and after landing on the vessel did not improve the product. (2) A comparison of the canned product of four sizes of yellowfin (80, 100, 120, 140 pounds) indicated that the larger fish produced a slightly inferior product with respect to texture. However, in general, the large fish produced a product comparable to commercial packs. (3) Fish which were off-color subsequent to the precooking produced an off-color pack of canned fish, but the peculiar color of the flesh was less noticeable after canning.



Cavalieri

GEAR DEVELOPMENT

Research and development of fishing gear, having as an objective the increase in efficiency of catching tunas, have been an important part of the Laboratory's program.

HBL gear development projects have included longline fishing, purse seining, trawl modifications, electrofishing and echo-ranging equipment.

Longline Gear - - One of the first efforts (1952) was redesigning the conventional, Japanese type, 6-hook per basket gear so that the number of baskets and number of hooks per basket could be easily changed under varying conditions. With this method from 1 to 13 hooks per basket can easily be fished (Mann, 1956).

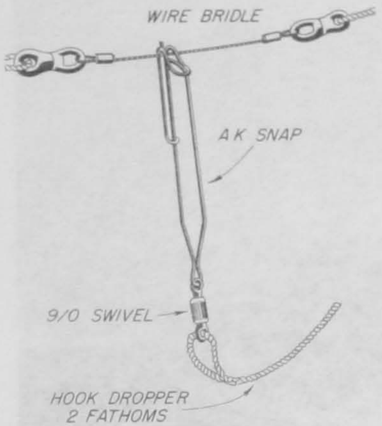


FIG. 19

Another improvement was the design of droppers which attach to the main line by a system of swivels and an AK snap (see figure 19). This helped eliminate tangling of droppers around the main line and decreased the time required to remove droppers from the main line.

Extending the fishing lifetime of longline gear was investigated by treating the cotton gear with a variety of preservatives. Soaking in tars or several commercial products resulted in resistance to the deteriorating effects of sea water.

Another development was the fabrication of a continuous longline made of steel. However, as a completely satisfactory steel longline is not yet a reality, the idea of a continuous main line was applied to cotton gear and a continuing investigation begun in 1954. This application utilizes a radical departure from previous methods in that the main line is stored in a large tub (figure 20) which revolves as the gear is set and hauled (Mann, 1958). Use of such gear should permit as few as 4 or 5 men to fish 1,100 or 1,200 hooks per day as compared with 500 hooks or less with regular gear. A catch rate of 5 tunas per 100 hooks could produce a catch of 3-1/2 tons of yellowfin per day, which should make such fishing profitable.

Purse Seining - - An intensive test of conventional purse seining methods for skipjack was made during the 1951 season in Hawaii. The results were disappointing. Conventional purse seining methods proved to be unsatisfactory for catching skipjack in the central Pacific. It was demonstrated, however, that skipjack could be purse seined when concentrated by chumming with live bait. Perhaps modifying the conventional west coast method might allow the successful purse seining of central Pacific skipjack.

Trawling Gear - - Several mid-water trawls were developed as sampling tools for the investigation of tuna forage organisms. These included a 6-foot beam trawl, 1-meter ring trawl and modified 6- and 10-foot Isaacs-Kidd trawls. An unmodified Nanaimo-type mid-water trawl showed particular promise. During 1958, 39 juvenile tunas were captured on one equatorial cruise. This was more than had been obtained by trawling during any previous HBL cruise.

Electrofishing - - Investigations in ponds were begun on some of the basic problems involved in the use of electrofishing gear (Miyake and Steiger, 1957). This study showed it was possible to induce electrotaxis in small yellowfin. It also included a theoretical study of the potential, electric field, and current density for spherical electrodes deeply submerged in a large body of water. The results showed that the power requirements necessary to use this technique in tuna fishing were too great for immediate practical application.

Echo-ranging - - Development of experimental echo-ranging equipment for tuna schools was investigated, but prevalence of trade wind-induced vessel motion and other difficulties have forestalled immediate use of such gear.

FIG. 20

BIOLOGY OF THE TUNAS

Tuna biology studies have sought the answer to such questions as: Along what routes do the fish migrate? Are the various fisheries (American, Japanese, etc.) exploiting the same population or separate populations? Are the stocks in the northern and southern hemispheres separate, one stock, or do they intermingle? How rapidly do they grow? Where do they spawn? When? How often? How many eggs are extruded in a single spawning? At what size do they first spawn? What are their feeding habits? The following sections describe some of our efforts to answer these questions.

Yellowfin Tuna-- During the past decade HBL studies have added considerably to the rather meager information available on the biology of the yellowfin tuna. Results from exploratory efforts in the eastern central Pacific have delineated the distribution of these tuna in the equatorial Pacific. To understand the relationship between stocks, the body proportions of yellowfin tuna from various parts of the Pacific have been compared (Royce, 1952). Large differences between the west coast yellowfin and those of the central Pacific and between the latter and yellowfin taken from further west suggest the absence or a low rate of mixing between areas.

Sexually mature yellowfin have been taken throughout a large part of the Pacific. Ova maturation studies have shown that yellowfin as small as 70 cm. (15 pounds) can be sexually mature. However, the greater percentage of fish attain this stage at sizes greater than 120 cm. (74 pounds). The spawning season in the central Pacific extends throughout most of the year with November, December and January the months of lowest spawning intensity (figure 21). This extended spawning season probably relates to the fact that a single yellowfin spawns more than once a year. Depending on the size, from 2 to 8 million ova are extruded in a single spawning.

Coincident with the wide-spread distribution of sexually mature yellowfin, the larvae of this species have been taken with plankton nets throughout the equatorial waters.

Food studies (Reintjes and King, 1953; King and Ikehara, 1956) indicate that while there are some differences in the kinds of food organisms eaten according to depth of capture, distance from land and size of fish, the yellowfin generally accepts a great variety of food.

Data on yellowfin growth imply a tremendous intake of food and/or high effeciency as evidenced by a gain of as much as 60 pounds per year (Moore, 1951).

Skipjack Tuna--Analyses of the stomach contents of Marquesan and Hawaiian skipjack showed that the food items were comparable for skipjack in the different areas, with fish, crustaceans and mollusks occurring in that order of importance. Approximately 30 percent of the food-containing stomachs of Marquesan skipjack were found to contain juvenile skipjack and other tunas. However, most of the fish in skipjack stomachs were those commonly associated with the presence of land. No comparable figures were

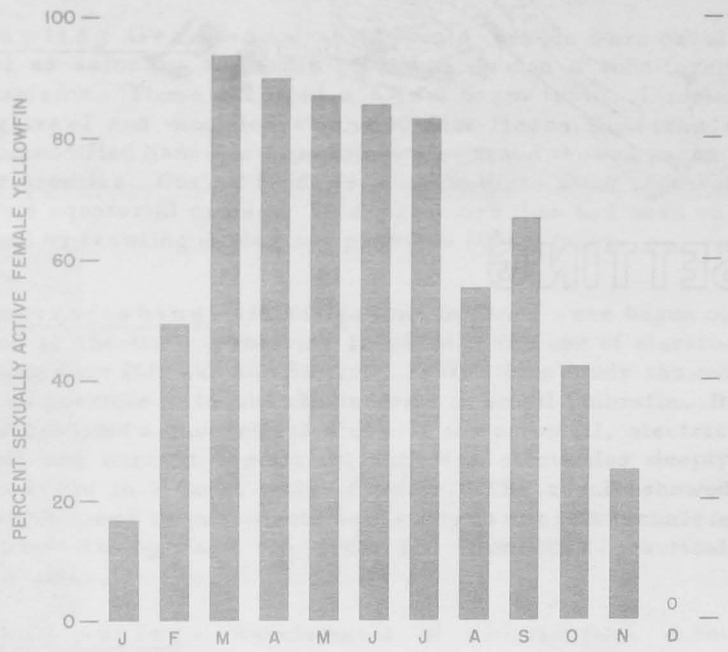
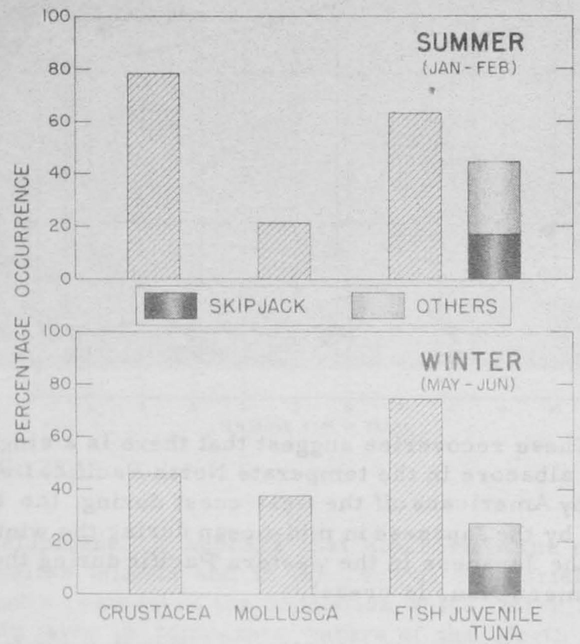


FIG. 21

available for the Hawaiian skipjack, although land associated species were reported to have occurred in the stomach contents from 38 percent (13 out of 34) of the schools examined (figure 22).

There is a seasonal variation in spawning of Marquesan skipjack. Using the stage of maturity of ovarian eggs as an index, advanced or "soon to spawn" eggs were found in the ovaries during November through April. During the remainder of the year, the eggs were characterized as "developing" or "early developing." Advanced eggs were recorded over a size range of fish from 43 cm. (3.5 lbs.) to 75 cm. (about 20 lbs.). Similar observations have been made on Hawaiian skipjack.



FOOD OF MARQUESAN SKIPJACK

FIG. 22

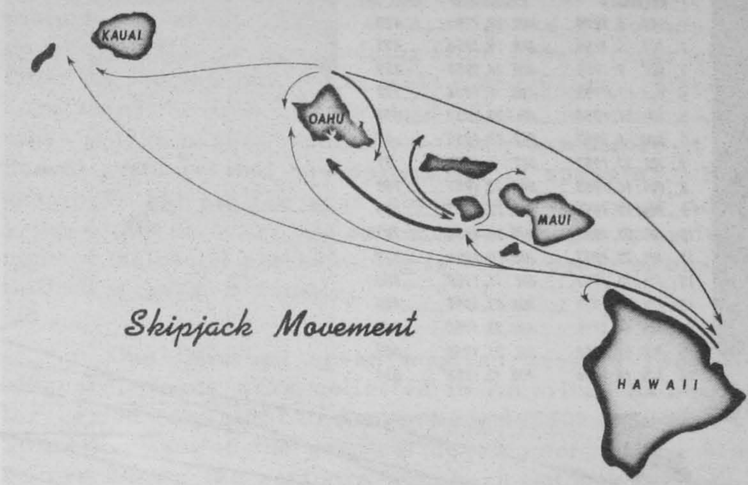


FIG. 23

Estimates of the growth of Hawaiian skipjack were obtained from recoveries from a group of 3,200 fish tagged within a period of one week off Hilo, Hawaii. Tagged fish were recaptured over a period of several months and showed a growth of from 4 to 15-pounds in about 13 months (see figure in section on 1959 progress).

Migrations of skipjack were studied by tagging over 13,000 fish in Hawaiian waters and about 4,600 in the Marquesas and Tuamotus with the D-2 dart tag developed at HBL. Recoveries from the Hawaiian releases totaled over 1,300, while none of the Marquesas and Tuamotus releases have been recovered. The recoveries indicated considerable interisland movement within the Hawaiian Islands (figure 23). The spotty recovery pattern suggested, however, that some schools roamed around the Hawaiian Islands for a time, while others moved rapidly through the area and became unavailable to the local fishermen. The complete absence of returns from fish tagged in the Marquesas and Tuamotus area, contrasted to the large numbers of recoveries from fish tagged in the Hawaiian area, indicate that the Marquesan and Tuamotuan fish represent a relatively unexploited resource.

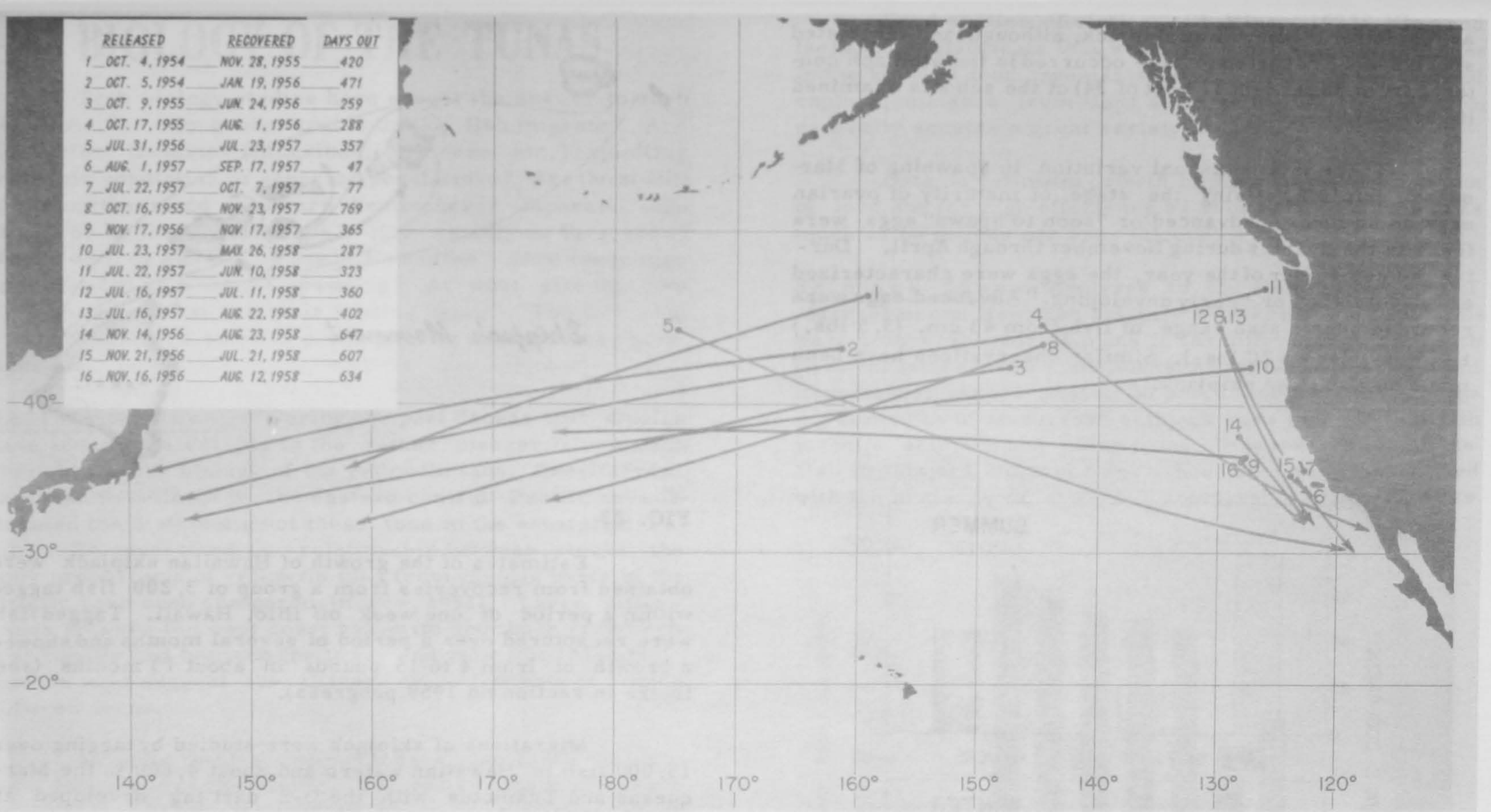


FIG. 24

Albacore--One thousand two hundred albacore were tagged in the temperate North Pacific Ocean between January, 1954 and August, 1957. Sixteen tagged fish (1.3 percent) have been recovered (figure 24). These recoveries indicate considerable movement of fish in the North Pacific. Albacore tagged in mid-ocean north of Hawaii have been retaken in the American west coast fishery as well as in the Japanese fisheries. Other recoveries were of fish tagged by HBL and west coast organizations which migrated across the Pacific from the American west coast to the vicinity of Japan. As yet, although large albacore have been tagged in the western Pacific, none have been recovered in the American fishery.

These recoveries suggest that there is a single population of albacore in the temperate North Pacific, fished seasonally by Americans off the west coast during the summer and fall, by the Japanese in mid-ocean during the winter, and also by the Japanese in the western Pacific during the spring and summer (Otsu, in press).

Attempts to estimate albacore growth rates from hard parts have been unsuccessful for the following reasons: (1) The rings on the scales and bones cannot be counted with reasonable consistency. (2) The increments that are noted do not appear to give either a reasonable or a consistent pattern of growth. (3) The results are not consistent with growth as shown by tag returns (Otsu and Uchida, 1959a).

The best estimate of albacore growth stems from tag recoveries (figure 25). These indicate they are a relatively slow-growing species and also confirm that the growth studies made by the use of markings on hard parts, which tend to show linear growth rates, are not valid (Otsu, in press).

Examination of albacore gonads from three general areas, the North Pacific, Hawaiian Islands, and the central equatorial Pacific, showed that albacore do not spawn in temperate waters. However, good evidence of spawning was found in Hawaiian fish taken during the month of June and July. Central equatorial Pacific albacore showed intermediate development. It appears that albacore in the region of the Hawaiian Islands and in the central equatorial Pacific represent a segment of the population which, after attaining a certain size in temperate waters of the North Pacific, moves south into tropical and subtropical waters to spawn. Based on evidence obtained from this study, it appears that spawning occurs in the general latitude of the Hawaiian Islands, an area under the influence of the North Equatorial Current (Otsu and Uchida, 1959b).

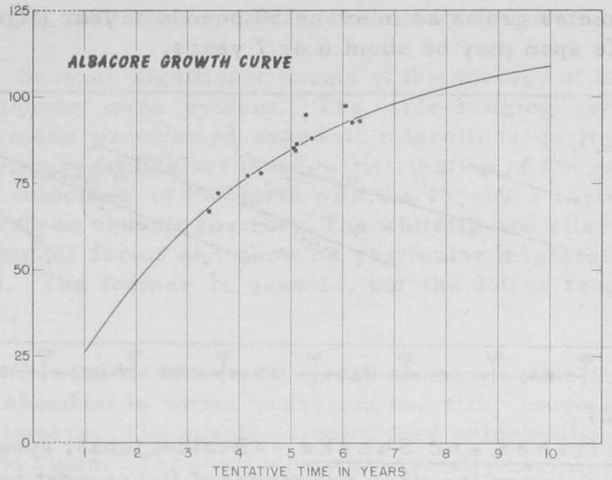


FIG. 25

The minimum size at which albacore attain sexual maturity is about 90 cm. or a weight of 33 pounds. This corresponds to an age, judging from growth rates obtained from the tagging data, of at least 5 or 6 years. Since albacore enter the fishery at around 50 cm. in length, a year-class is thus exploited for about four years before it attains sexual maturity and can participate in spawning. If it be assumed that all the eggs comprising the most advanced group within an ovary are extruded in a single spawning, the number released per spawning is in the order of one to two million eggs per female.

One thousand seven hundred seventy two pairs of albacore gonads were collected in American Samoa during the period July, 1957 to September, 1958. Laboratory examination showed the greatest development of the ovaries occurs during the southern summer, October to February. The areas of capture (figure 26), considered along with the relative stages of maturity of the ovaries, indicated

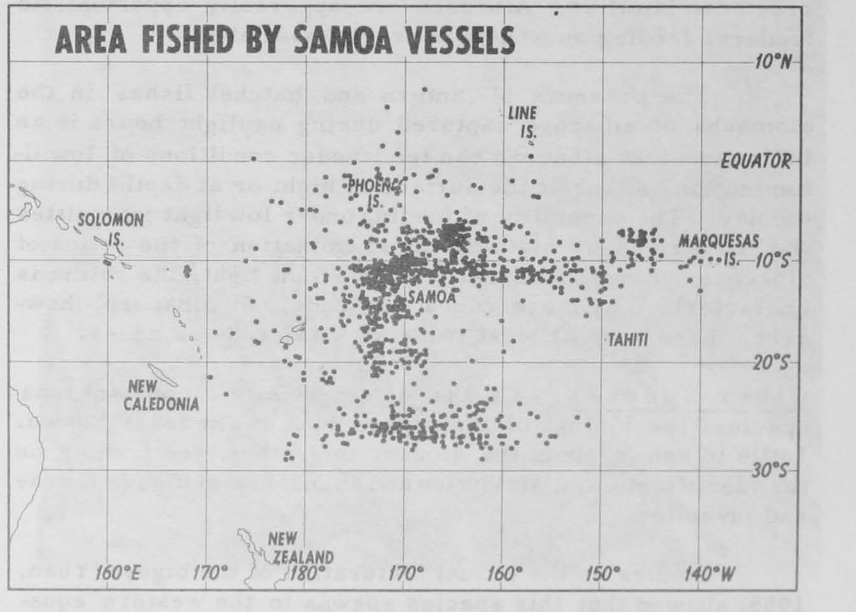


FIG. 26

that the South Pacific albacore probably spawn between 10°S. and 20°S. latitude and at least between 140°W. and 170°E., the eastern and western limits of the area from which samples were received. Those samples of fish caught between 20°S. and 30°S. had ovaries in nonadvanced stages of development.

While there may be some intermingling of albacore stocks across the Equator, the October-February (southern summer) spawning season in the South Pacific, as contrasted to the suspected May-August (northern summer) spawning season of the North Pacific, suggests that the stocks in the two hemispheres may be separate. The results of the HBL albacore gonad studies in the South Pacific and of the distribution and size composition of albacore in both hemispheres, along with data available from other research activities and from commercial fisheries, all support the hypothesis that there are separate albacore stocks in the two hemispheres and that their distribution approximates a mirror image.

Albacore, like the yellowfin and bigeye tunas, eat a great variety of food. In 542 albacore stomachs examined, there were representatives of 34 fish, 10 mollusk, and 14 crustacea families. Albacore are apparently opportunistic feeders, feeding on whatever prey is available.

The presence of lantern and hatchet fishes in the stomachs of albacore captured during daylight hours is an indication that albacore can feed under conditions of low illumination, either at the surface at night or at depths during the day. The capability of feeding under low light intensities was confirmed by histological examination of the retina of albacore. Among fish that feed in bright light, the retina is characterized by more cones than rods. In albacore, however, there were at least twice as many rods as cones.

Other Species -- Of the commercially important tuna species, the biology of the bigeye tuna is the least known. Little is known about the stocks, migration, and nothing on the identification, distribution and abundance of bigeye larvae and juveniles.

Studies on the sexual maturation of the bigeye (Yuen, 1955) showed that this species spawns in the western equatorial Pacific, central equatorial Pacific and at locations 400 miles southeast of Hawaii. The extent of the spawning season could not be determined with certainty, but bigeye tuna in advanced stages of maturity were found in the central equatorial Pacific in January, February, July, August, September, and October. The size at which bigeye first spawn was found to be about 30 to 45 pounds.

Bigeye utilize a great variety of animal food ranging from plankton to large squid and fish (King and Ikehara, 1956). A comparative study of yellowfin and bigeye stomach contents revealed a striking similarity in the food of both species (figure 6, King and Ikehara). When occupying the same general area, the two species have essentially the same feeding habits.

By examining the size frequency distributions of bigeye taken in the Hawaiian Islands, it was estimated that this species grows as much as 50 pounds a year (figure 27). The life span may be about 6 or 7 years.

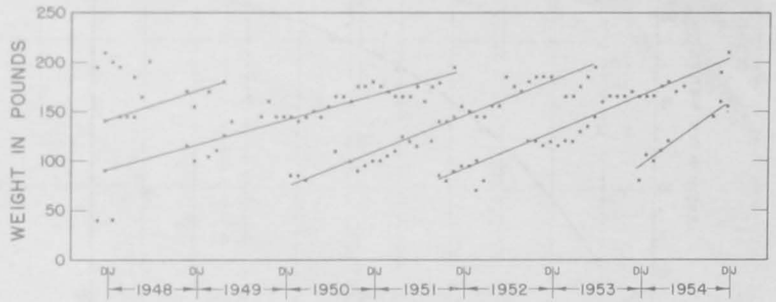


FIG. 27

Spearfishes and Sharks -- Besides tunas, spearfishes and sharks were the other two groups of fishes most commonly taken by HBL longline fishing methods (Royce, 1957 and Strasburg, 1958).

The spearfish investigation considered the taxonomy, distribution, size, food and spawning habits of this group, together with an extensive review of Japanese and other literature on the subject.

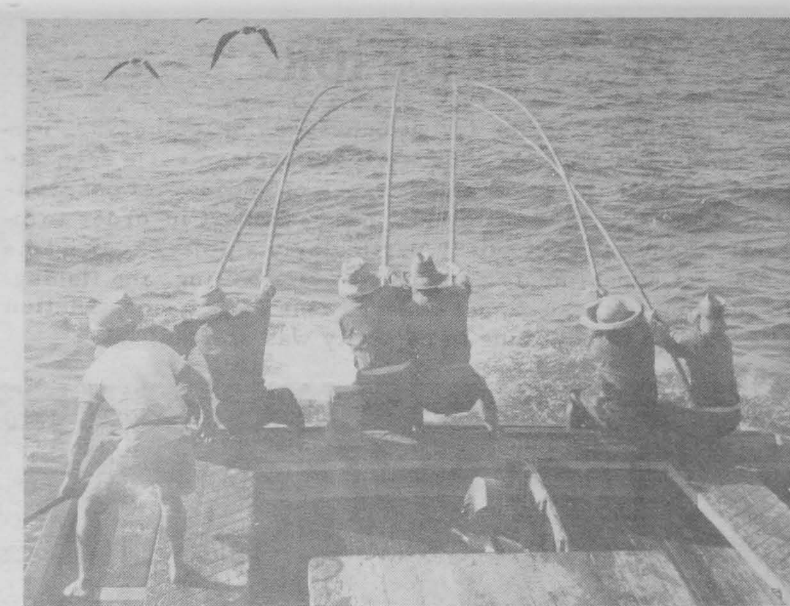
Six species were recognized: swordfish (Xiphias gladius), shortnose spearfish (Tetrapturus angustirostris), sailfish (Istiophorus orientalis), black marlin (Istiompax marlina), striped marlin (Makaira audax), and Pacific blue marlin (Makaira ampla).

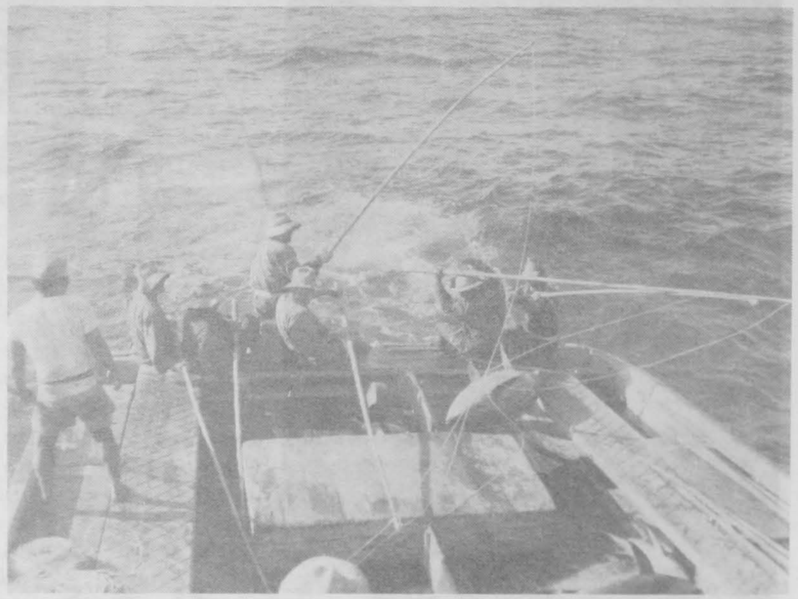
All six species were shown to be fishes of the high seas, with wide distribution in the Pacific, but with different centers of abundance. The swordfish and striped marlin frequent the more temperate waters, the Pacific blue marlin the equatorial regions, and the black marlin the coastal areas off Asia, America, and Australia. All are broadly carnivorous on fish and cephalopods. The Pacific blue marlin probably spawns throughout most of the year in equatorial waters.

The distribution and abundance of central Pacific pelagic sharks was investigated during 1952-55. More than 6,000 sharks (of 12 species) were caught. Great blue, whitetip, and silky sharks predominated. Bonito, thresher, mackerel, and other species were uncommon or rare.

Several significant facets of the biology of the common sharks were evident. The wide-ranging great blue shark made pronounced seasonal migrations during which sexual segregations occurred. Distribution of the great blue shark coincided in the north with the 45°-69°F. isotherms; it is truly an oceanic species. The whitetip and silky sharks are tropical forms and show no particular migratory tendencies. The former is oceanic, but the latter tends to be neritic.

In equatorial waters, great blues and whitetips were more abundant in warm years and the silky more abundant in cold years. The species studied feed principally on small fish and squid. The great blue was virtually harmless to the tuna catch. Only 1 percent of the catch was damaged where it abounded, as compared with 20 percent damaged in regions where the whitetip and silky sharks were dominant.





BEHAVIOR

A tuna behavior investigation was begun in 1957. Emphasis during 1957 and 1958 were on development of adequate tools and techniques. Various types of underwater observation chambers were installed on the Gilbert in order to directly study tuna behavior, particularly skipjack, during the course of experiments performed while baiting and fishing. In addition to these direct observations at sea, construction of facilities to hold tuna in captivity was started.

Preliminary Results --Prior to use of underwater observations, behavior studies were made from the decks of fishing vessels. These studies revealed that the duration of skipjack response to chum was found to be negatively correlated with volumes of stomach contents and the stage of digestion of the dominant component of the stomach contents (Yuen, 1959). Skipjack feeding on fast-swimming fish were caught at a faster rate and fished for a longer period than those feeding on a slow-swimming fish.

First attempts at underwater observation were made from a platform that was swung into the water on the port

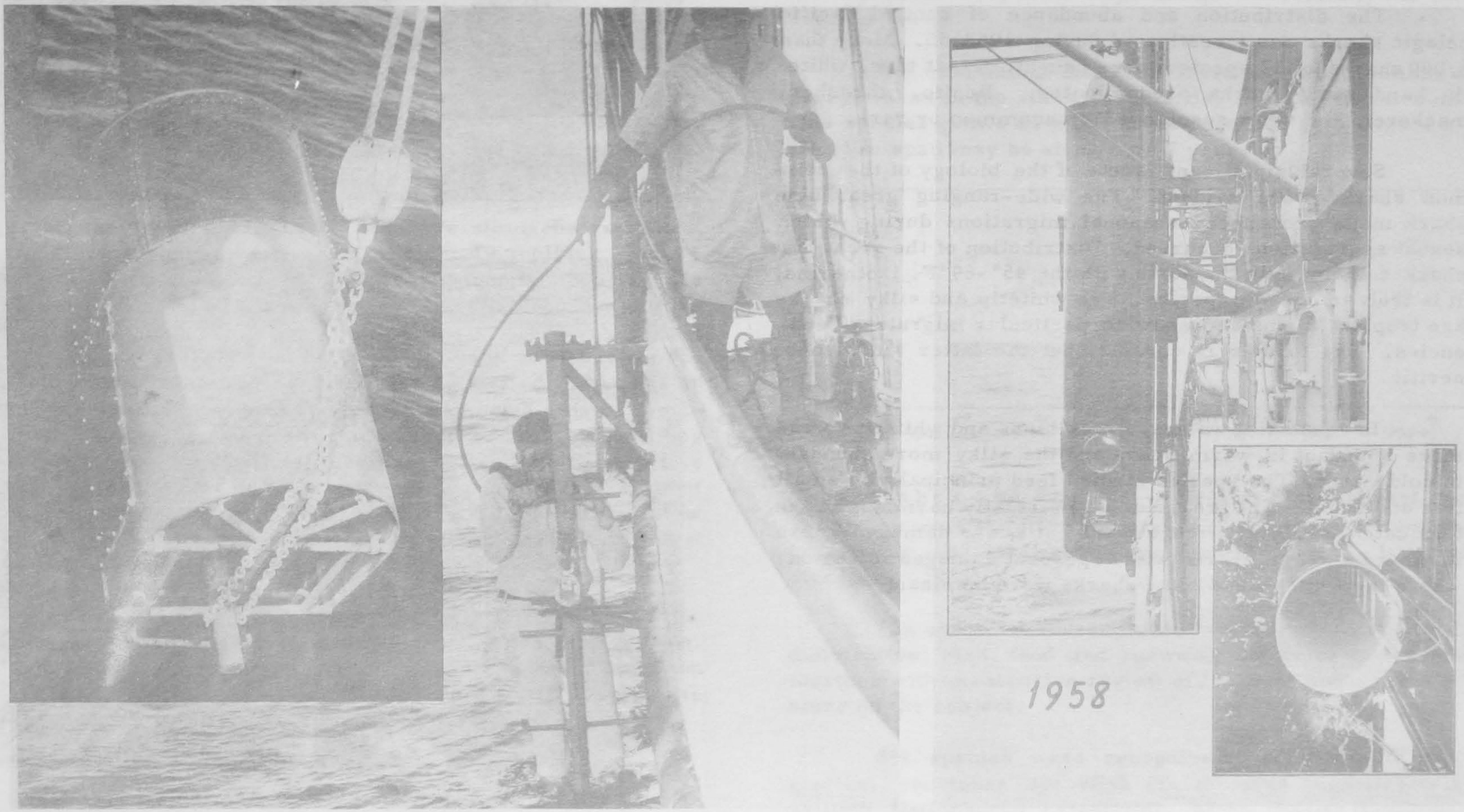
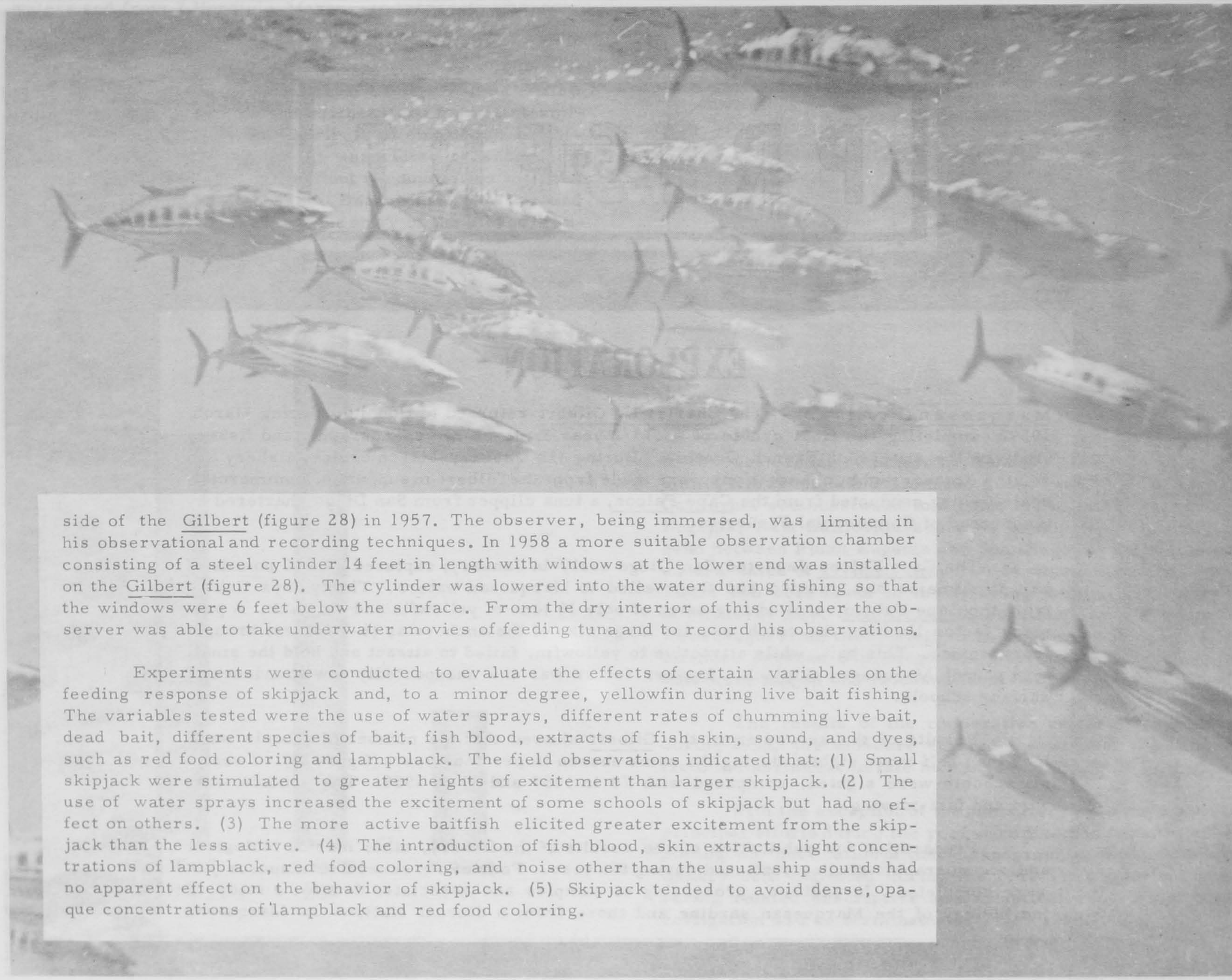


FIG. 28



side of the Gilbert (figure 28) in 1957. The observer, being immersed, was limited in his observational and recording techniques. In 1958 a more suitable observation chamber consisting of a steel cylinder 14 feet in length with windows at the lower end was installed on the Gilbert (figure 28). The cylinder was lowered into the water during fishing so that the windows were 6 feet below the surface. From the dry interior of this cylinder the observer was able to take underwater movies of feeding tuna and to record his observations.

Experiments were conducted to evaluate the effects of certain variables on the feeding response of skipjack and, to a minor degree, yellowfin during live bait fishing. The variables tested were the use of water sprays, different rates of chumming live bait, dead bait, different species of bait, fish blood, extracts of fish skin, sound, and dyes, such as red food coloring and lampblack. The field observations indicated that: (1) Small skipjack were stimulated to greater heights of excitement than larger skipjack. (2) The use of water sprays increased the excitement of some schools of skipjack but had no effect on others. (3) The more active baitfish elicited greater excitement from the skipjack than the less active. (4) The introduction of fish blood, skin extracts, light concentrations of lampblack, red food coloring, and noise other than the usual ship sounds had no apparent effect on the behavior of skipjack. (5) Skipjack tended to avoid dense, opaque concentrations of lampblack and red food coloring.

PRESENT 1959

EXPLORATION

Marquesan Program--The Charles H. Gilbert returned to Honolulu during March, 1959, completing the final cruise of a 2-1/2 year exploratory oceanographic and fishery study of the waters of French Oceania. During the January-March cruise, fishery and routine oceanographic observations were made from the Gilbert in support of commercial-scale fishing conducted from the Cape Falcon, a tuna clipper from San Diego chartered by the Bureau of Commercial Fisheries.

The Cape Falcon departed San Diego early in January; captured 24,000 pounds of bait in Almejas Bay, Mexico and then sailed to Marquesan waters. Thirty days fishing from the Cape Falcon resulted in a catch of only 16 tons of yellowfin and skipjack. A primary factor limiting the catch was the large size of the anchovetas (6-7 inches) brought from Mexico. This bait, while attractive to yellowfin, failed to attract and hold the small (6-8 pound) Marquesan skipjack. Another factor was the unexpectedly low abundance of surface schools.

Results of the survey from the Gilbert showed that the number of schools were less than half those sighted during the same season in previous years (figure 29). Twenty-six schools were sighted, compared with 79 in 1957 and 99 in 1958. The schools were wild and fast-moving.

Preparation for publication of the results of the fishery, other marine biological and oceanographic studies continued during the year. Four of six scheduled manuscripts were completed. In addition, processing of samples and associated data for a study of the biology of the Marquesan sardine and those from 6 diurnal stations in Marquesan waters and from 7 Honolulu-Marquesan transects was completed. Manuscripts describing the results were begun.

North Pacific Albacore Investigations --In June, 1959, the Hugh M. Smith returned to Honolulu from a cruise to the north central and northeastern Pacific, terminating a 5-year study of the distribution, abundance and biology of the albacore and of the associated oceanographic conditions. This cruise, carried out in cooperation with the N. B. Scofield of the California Department of Fish and Game, was planned to intercept the entry of the albacore into the west coast commercial fishery. Fishing from the Smith, first along a line from 600 miles west of Point Arena, California southeastward to a point 350 miles west of Punta Eugenia, Baja California and then in the 350 mile offshore band between Punta Eugenia and San Diego (figure 30) resulted in a catch of 17 tuna, only two of which were albacore. These two were taken on the first leg about 500 miles west of Monterey Bay, California. Approximately, 300 albacore were caught from the Scofield in an area extending 300 miles offshore between San Diego and Cape San Martin. Viable tuna were tagged and released from both vessels.

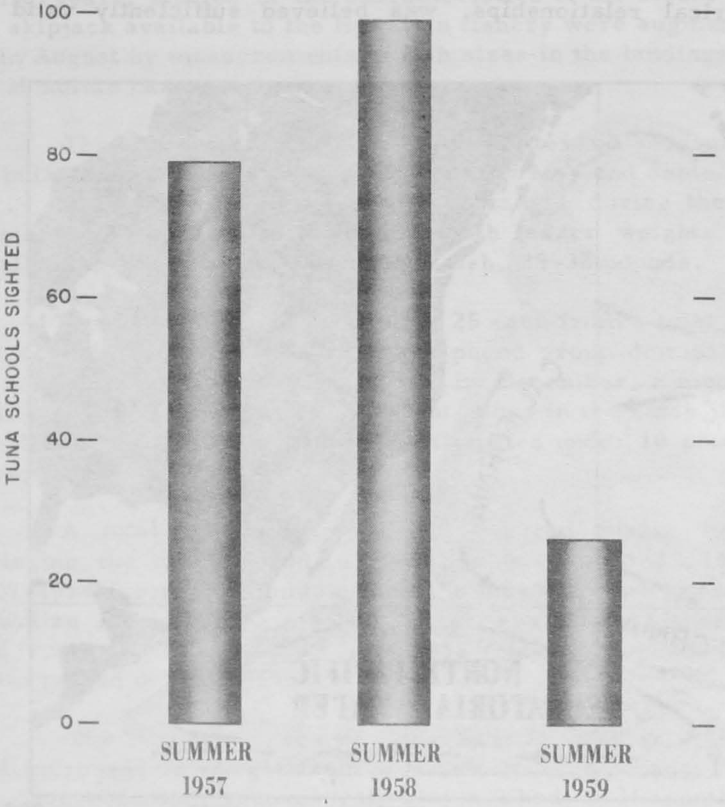


FIG. 29

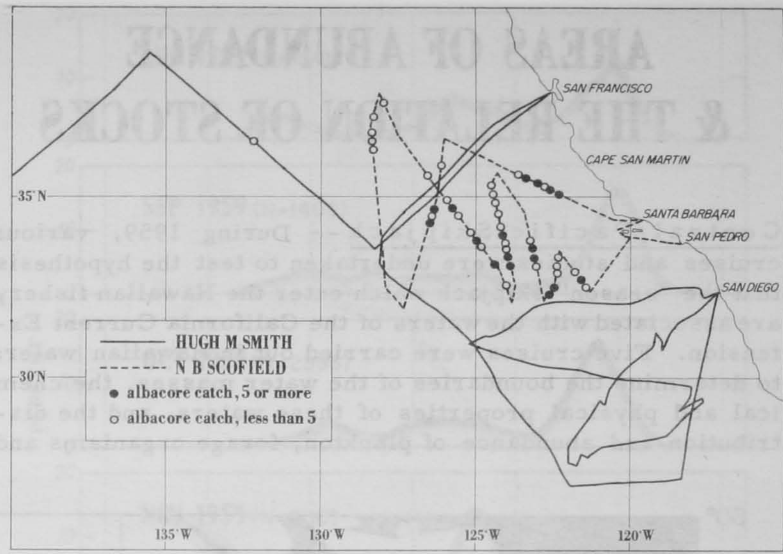


FIG. 30

The results of the cooperative venture suggest that during 1959, the albacore entered the area of the fishery from the northwest in late May or early June.

With the exception of the one survey mentioned above, principal efforts during the year were directed towards completing the publication of the oceanographic, biological and fishery data collected during the 1954-1959 study and preparing related descriptive and analytical reports. The investigation will be terminated in June, 1960.

AREAS OF ABUNDANCE & THE RELATION OF STOCKS

Central Pacific Skipjack-- During 1959, various cruises and studies were undertaken to test the hypothesis that the "season" skipjack which enter the Hawaiian fishery are associated with the waters of the California Current Extension. Five cruises were carried out in Hawaiian waters to determine the boundaries of the water masses, the chemical and physical properties of these waters, and the distribution and abundance of plankton, forage organisms and tuna in each. In an effort to trace the fish as they enter the Hawaiian fishery, tagging of skipjack in waters 100 miles or more from the islands was also carried out.

The draft of an atlas of ocean climate for Hawaiian waters (30°N. - 10°N., 180°W. - 150°W.) was completed. Describing the seasonal and year-to-year variations of the physical and chemical characteristics of the marine environment, this study serves as a basis for interpretation of the results from the cruises and various monitoring stations (figure 9, this report). Figure 31, showing the details of the circulation features in Hawaiian waters, is made possible by the preparation of the atlas.

The above-mentioned hypothesis, based upon empirical relationships, was believed sufficiently valid to

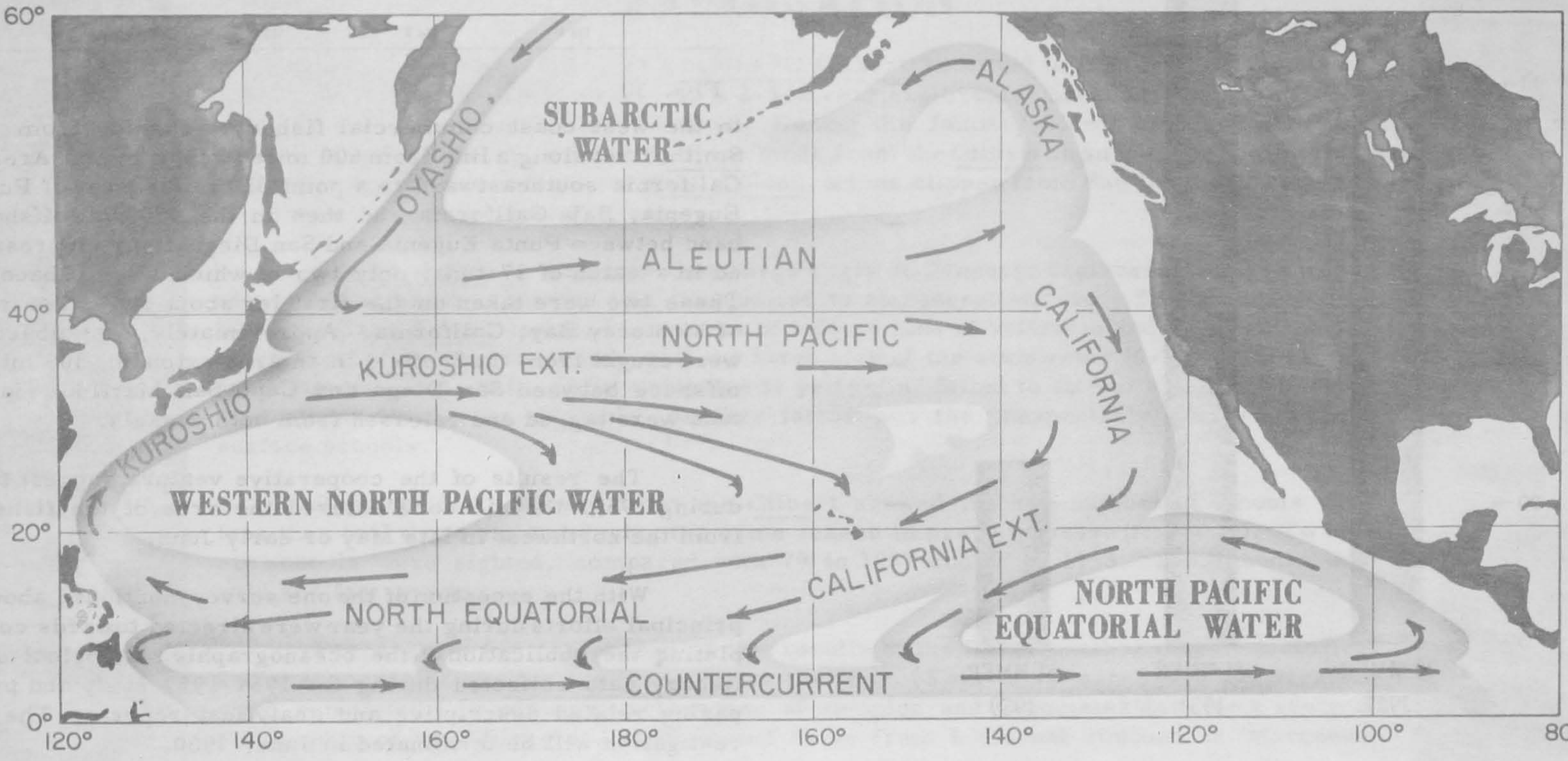


FIG. 31

permit a prediction of the 1959 Hawaiian skipjack landings. In March, therefore, it was predicted that the landings would be better than those for an average season. With incomplete statistics at hand, the partial landings for the year totalled 11,429,350 pounds. The total average landings for the years 1948 to 1958 were 9,800,000 pounds. Only the 1951 (12,900,000 pounds) and the 1954 (14,000,000 pounds) landings exceeded those for 1959. The higher-than-average 1959 catches were made from a reduced fleet of 20 sampans as compared to 28 in 1951 and 27 in 1954.

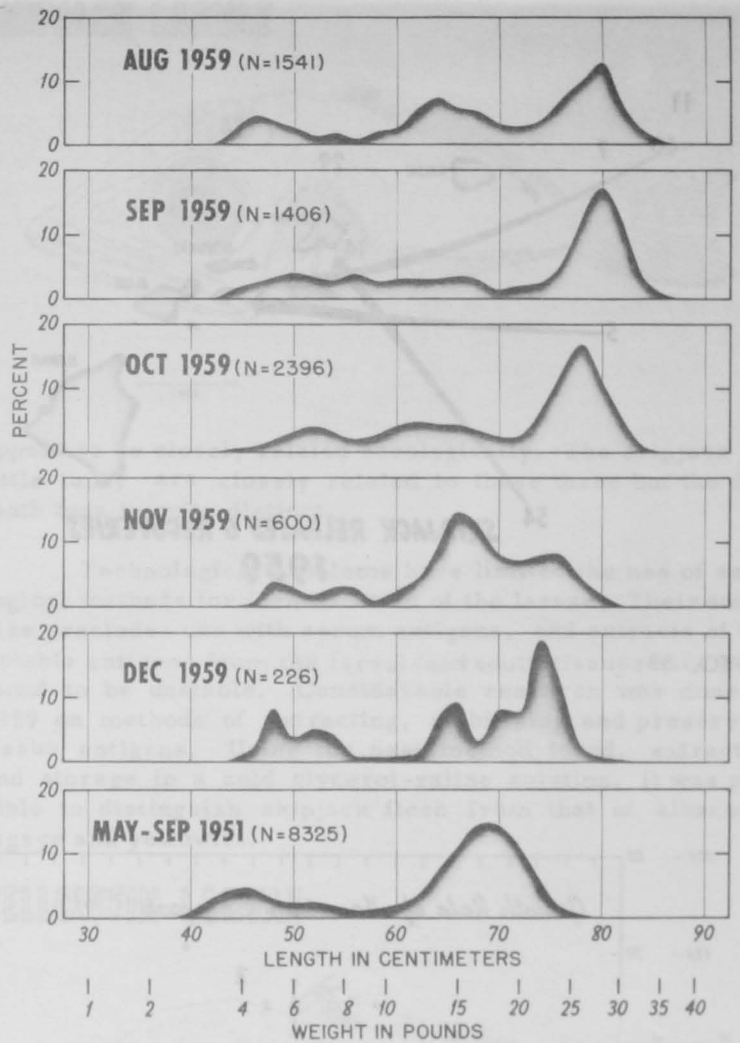
The prediction was primarily based on late winter variations in the temperature of the sea surface (page 8). In order to strengthen the reliability of this prediction for future years, studies of the characteristics of the stocks of the skipjack available to the Hawaiian fishery were augmented in August by measurements of fish sizes in the landings at the Honolulu cannery.

The skipjack fishery in Hawaiian waters is seasonal; the bulk of the annual catch is made between May and September. A large percentage of the fish caught during these months are normally 18-22 pounds with lesser weights of small fish, 4-8 pounds, and of large fish, 28-32 pounds.

The 1959 size measurements, 25 each from a total of 248 schools, revealed that a 24-31 pound group dominated the catch through October (figure 32). By December, a month well into the offseason, the dominant group in the catch was 15-25 pound fish rather than the anticipated under 10 pound group.

A total of 236 skipjack were tagged during 1959 (bringing the total tagged in Hawaiian waters to 13,500, 1957-1959), generally outside of the present limits of the Hawaiian fishery (figure 33). There were 17 recaptures: one from a 1957 release, 13 from 1958 releases, and 3 from those tagged during 1959.

The long-term recovery (tagged in September, 1957) had increased in weight from 4 pounds to 18.8 pounds. In the case of another recovery, the skipjack had, in 16 months, increased from approximately 19 pounds at time of tagging to 22.5 pounds at time of recapture. Skipjack growth data



Skipjack Length Frequencies

FIG. 32

realized from HBL tag returns are summarized in figure 34.

Pacific-wide Albacore--The field work for a study of the sexual maturity and time and area of spawning of albacore in the central south Pacific Ocean was completed in

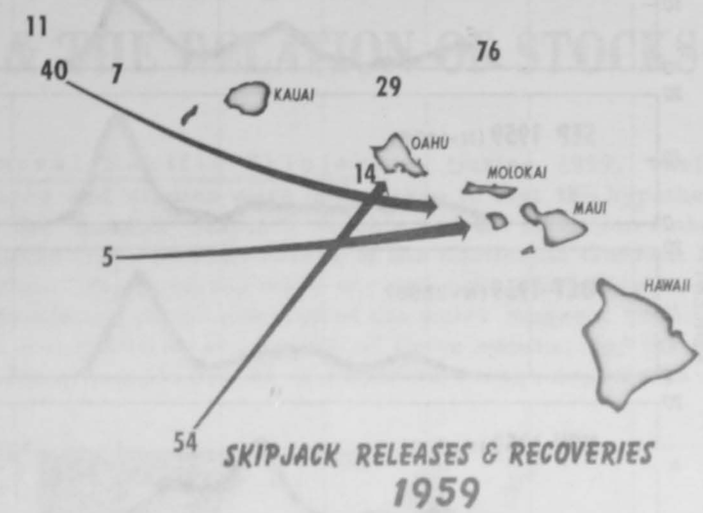


FIG. 33

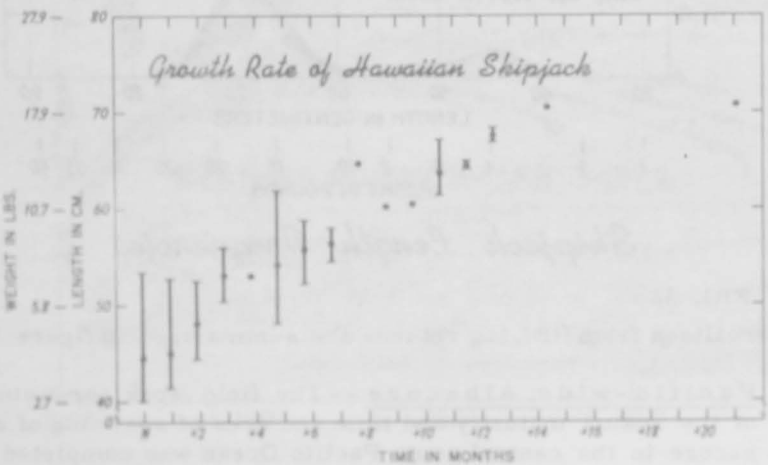


FIG. 34

September, 1958. This study was based on the examination of 1,772 pairs of albacore gonads collected from fish landed in American Samoa during the period July, 1957 to September, 1958.

Preliminary analyses of the data resulting from examination of these gonads reveal that the proportion of ovaries in the "late development" stage increased from July, 1957 to a maximum in December-January and declined to a minimum in May (figure 35).

The areas of capture (figure 26, this report), considered along with the relative stages of maturity of the ova, indicate that the South Pacific albacore probably spawn between 10°S. and 20°S. and at least between 140°W. and 170°E., the limits of the area from which samples were received.

While there may be some intermingling of albacore stocks across the Equator, the results of this study, along with those from the North Pacific, suggest that the stocks in the two hemispheres may be separate. This separation is further suggested by the scarcity of fish between 20°N. and 10°S. latitude as revealed from catches of both commercial and research vessels.

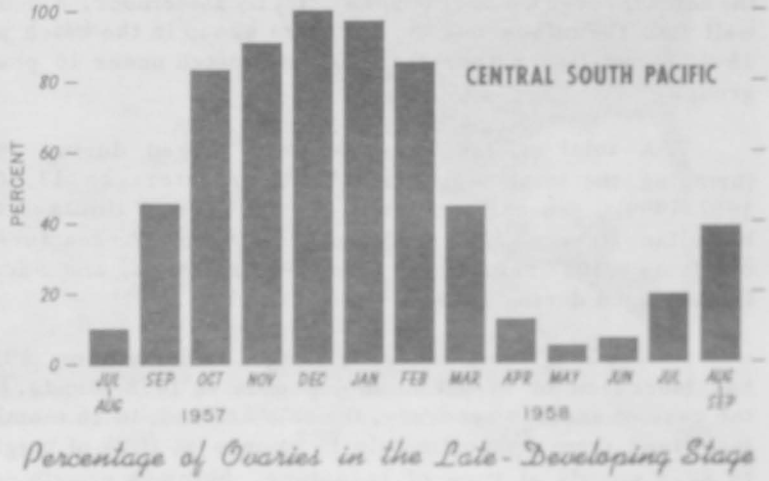


FIG. 35

Supporting Programs -- The HBL studies of tuna larvae and juveniles are of value not only in furthering the knowledge of the tuna life history but also as an aid to studies of the distribution and abundance of the adults. The latter is particularly true for those oceanic areas where sampling of the adult populations is not presently practicable.

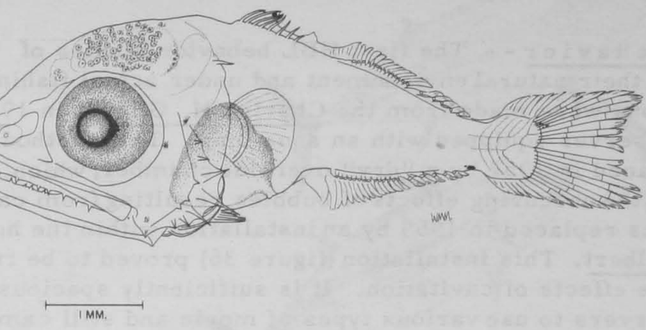
Larval studies require adequate quantitative and qualitative sampling methods. Various types of nets have been used, including 45 cm. and 1-meter plankton nets and mid-water trawls with a mouth opening of 1,200 square feet. By exchange with various research organizations, additional larvae and juveniles have been obtained for study. The laboratory has received, on a loan basis, the collection of larval scombroids made from the Dana.

Larval studies, whether they be related to life history or to the distribution and abundance of the adults, require identification of the species involved. On the basis of morphological characteristics, positive identification has been made of the following tuna and tuna-like larvae: skipjack, yellowfin, black skipjack and the frigate mackerel. Yet to be identified are larvae of albacore, bigeye, bluefin and of such closely related forms as the dogtooth tuna.

In addition to studies of morphological features, larval identification has been attempted by means of paper chromatography and serological techniques. The applicability of these techniques to species indentification of adults was simultaneously investigated. It was found possible to identify the adults of albacore, bigeye, frigate mackerel, yellowfin, skipjack and black skipjack through chromatography. Technological problems limited its use with larvae. However, the chromatograms for the two species of larvae tested, skipjack and yellowfin, did show a general similarity to those for the adults of these species.

A contract was negotiated with Dr. George Ridgway, Seattle Biological Laboratory, to test the applicability of serological techniques for identification of larval and adult tunas. Results show that the species of adult tuna are serologically identifiable and that their identification by serum reactions shows a marked parallelism to relationships inferred from morphology. Albacore, yellowfin and bigeye

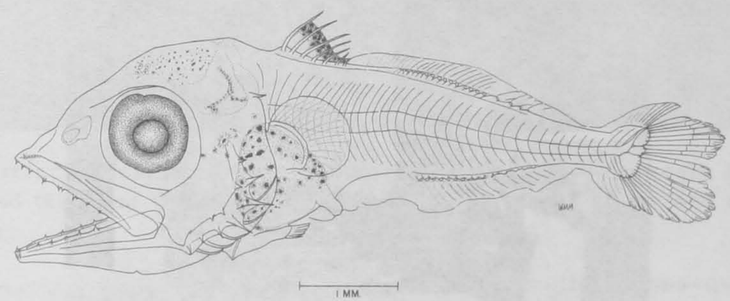
SKIPJACK LARVAE



appear to be closely related serologically. The skipjack and little tunny are closely related to these three but the dogtooth tuna is quite distinct.

Technological problems have limited the use of serological methods for identification of the larvae. Their small size precludes use with serum antigens, and extracts of the soluble antigens from the larval (and adult) tissues have been found to be unstable. Considerable research was done in 1959 on methods of extracting, stabilizing and preserving tissue antigens. Using the best method found, extraction and storage in a cold glycerol-saline solution, it was possible to distinguish skipjack flesh from that of albacore, bigeye and yellowfin.

YELLOWFIN LARVAE



EFFICIENCY OF CAPTURE

Behavior -- The first HBL behavior studies of skipjack in their natural environment and under actual fishing conditions were made from the Charles H. Gilbert in 1956 by an observer equipped with an aqua lung. This method was replaced in 1957 by a "dry" overside chamber, which, because of the obscuring effects of bubbles resulting from cavitation, was replaced in 1959 by an installation within the hull of the Gilbert. This installation (figure 36) proved to be free from the effects of cavitation. It is sufficiently spacious for observers to use various types of movie and still cameras for photographing the behavior of fish during normal fishing operations and under experimental conditions. The school of skipjack shown on the front cover of this report was photographed from the inboard chamber.

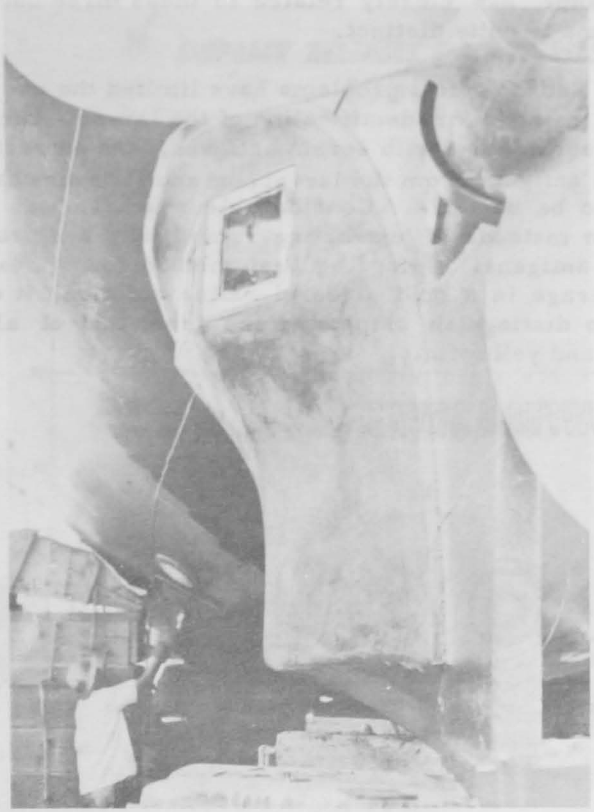


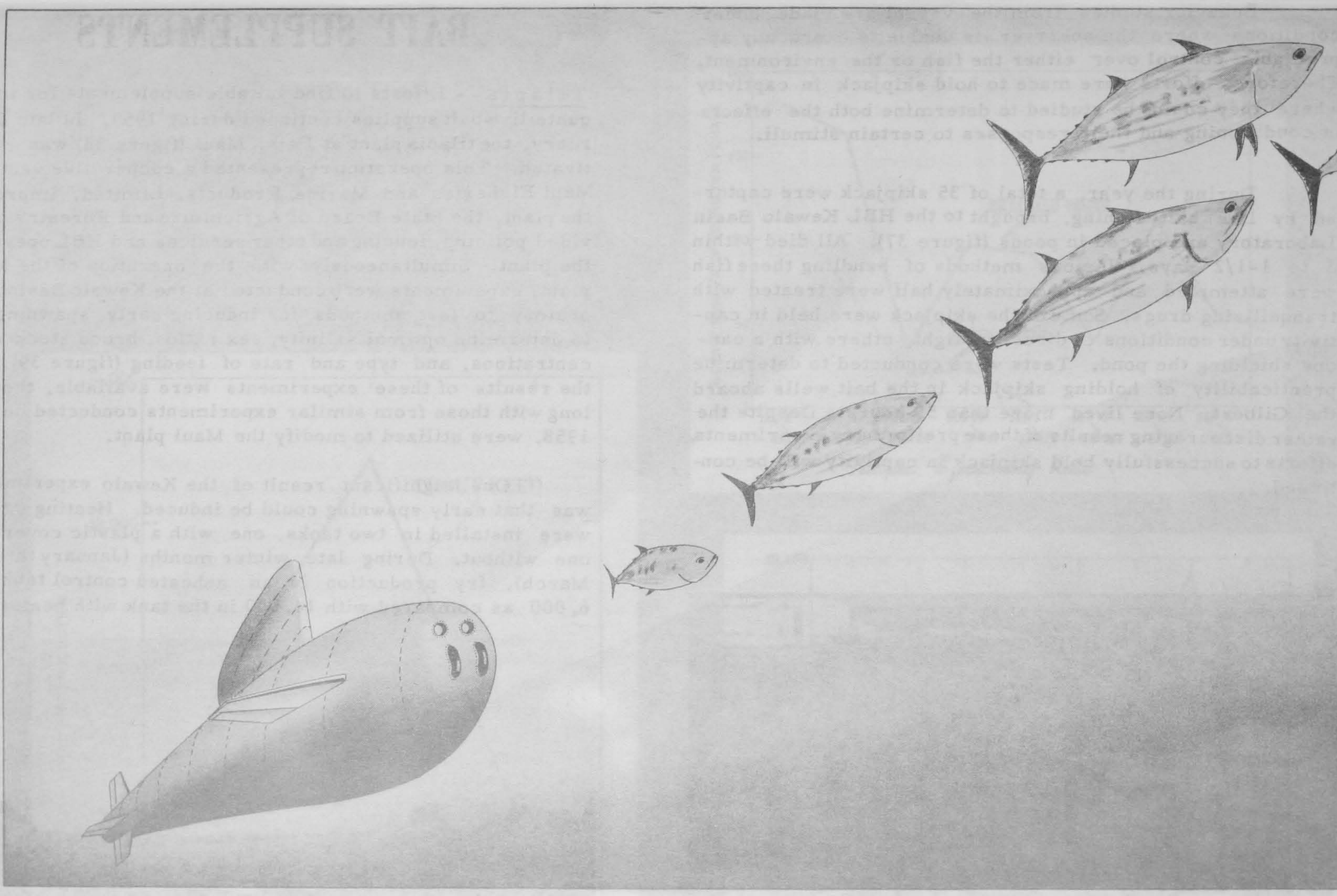
FIG. 36

Studies were made of the effectiveness of television cameras compared with visual observations and photographic records from the chamber. Two types of vidicon TV cameras were used, one enclosed in a watertight housing and suspended over the side of the Gilbert, the other a normal camera used from the observation chamber. In neither case did the results from the television cameras compare favorably with visual observations or with movie cameras.

Preliminary analyses of various types of behavior studies have been completed. For example, iao (silversides) was compared with nehu (anchovy) as live bait. When nehu was thrown as chum, large skipjack (25-30 pounds) would move comparatively slowly and along straight paths while the smaller tuna (4-10 pounds) would move quickly and erratically. When iao was used, the reactions of the larger skipjack were similar to those of the small fish toward nehu.

The relative effectiveness of live and dead nehu was also examined. Skipjack schools, previously chummed to the stern of the vessel with live nehu, would immediately leave when dead nehu only were used. A mixture of dead and live nehu could be used to a limited extent.

In one effort to supplement the limited supply of natural bait, the use of "bait enhancers" was tested. Tinsel glitter was thrown into the water along with live nehu, dead nehu and without bait. The skipjack, as observed through the ports of the chamber, moved toward the glittering particles and began feeding on the live nehu; showed no interest in the glitter and dead nehu; showed some alertness to the glitter alone, but did not exhibit feeding reactions.



Direct observations of tuna behavior from installations on surface vessels, such as that in figure 36, are severely limited. Other equipment necessary to such observation or to finding and tracking the schools, including television, sonar and cameras all have limitations when used from surface vessels.

One obvious solution is a specially designed submarine - a small, speedy, highly maneuverable submersible. Consequently, early in 1959 inquiries were sent to several companies presently engaged in manufacturing submarines. From their response, it now appears that such a submarine may be practicable and preliminary design studies are presently underway.

Behavior studies from the vessel are made under conditions where the observer is unable to exert any appreciable control over either the fish or the environment. Therefore, efforts were made to hold skipjack in captivity where they could be studied to determine both the effects of conditioning and their responses to certain stimuli.

During the year, a total of 35 skipjack were captured by live bait fishing, brought to the HBL Kewalo Basin Laboratory and placed in ponds (figure 37). All died within 1 to 1-1/2 days. Various methods of handling these fish were attempted and approximately half were treated with tranquilizing drugs. Some of the skipjack were held in captivity under conditions of direct sunlight, others with a canopy shielding the pond. Tests were conducted to determine practicability of holding skipjack in the bait wells aboard the Gilbert. None lived more than 50 hours. Despite the rather discouraging results of these preliminary experiments, efforts to successfully hold skipjack in captivity will be continued.

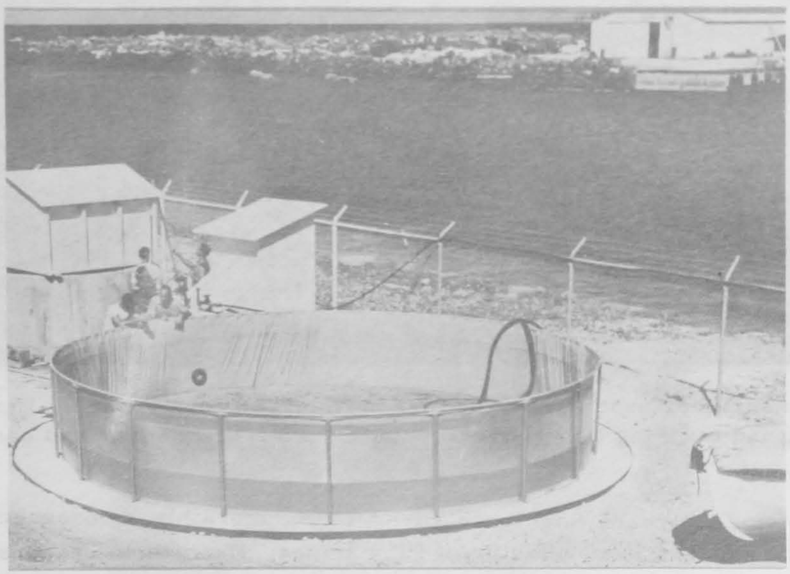


FIG. 37

BAIT SUPPLEMENTS

Tilapia - - Efforts to find suitable supplements for inadequate live-bait supplies continued during 1959. In late February, the tilapia plant at Paia, Maui (figure 38) was reactivated. This operation represented a cooperative venture. Maui Fisheries and Marine Products, Limited, improved the plant, the State Board of Agriculture and Forestry provided policing, fencing and other services and HBL operated the plant. Simultaneously with the operation of the Maui plant, experiments were conducted at the Kewalo Basin Laboratory to test methods for inducing early spawning and to determine optimal salinity, sex ratios, brood stock concentrations, and type and rate of feeding (figure 39). As the results of these experiments were available, they, along with those from similar experiments conducted during 1958, were utilized to modify the Maui plant.

One significant result of the Kewalo experiments was that early spawning could be induced. Heating cables were installed in two tanks, one with a plastic cover and one without. During late winter months (January through March), fry production in an unheated control tank was 6,000 as compared with 14,000 in the tank with heater and

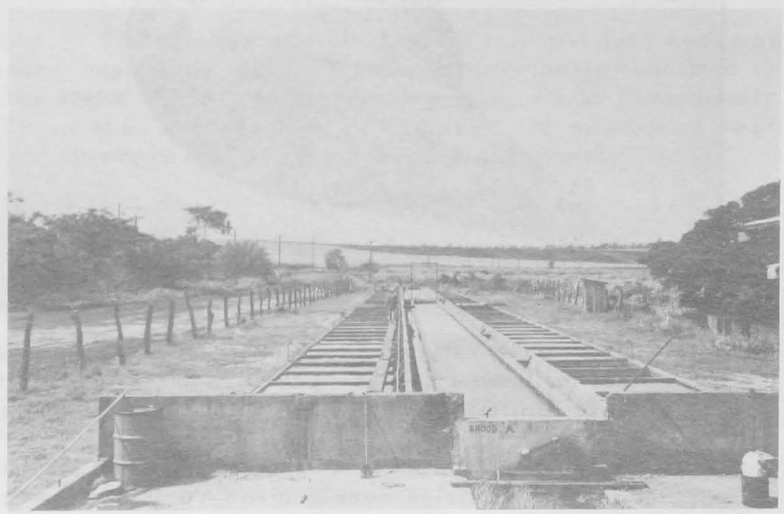
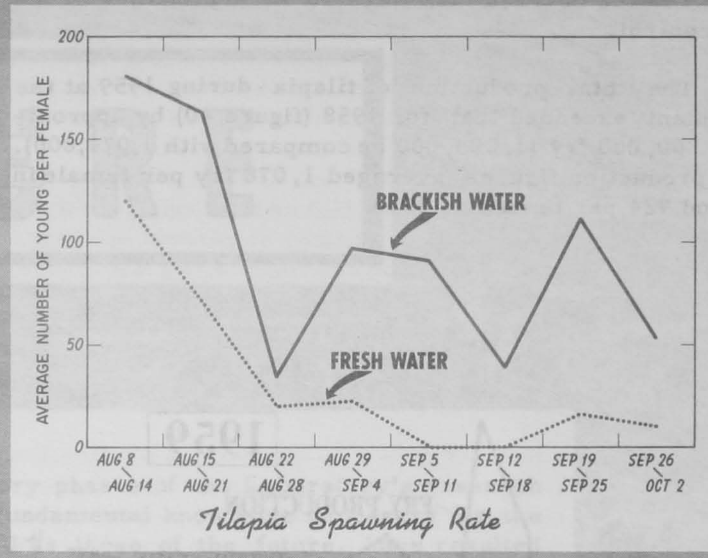
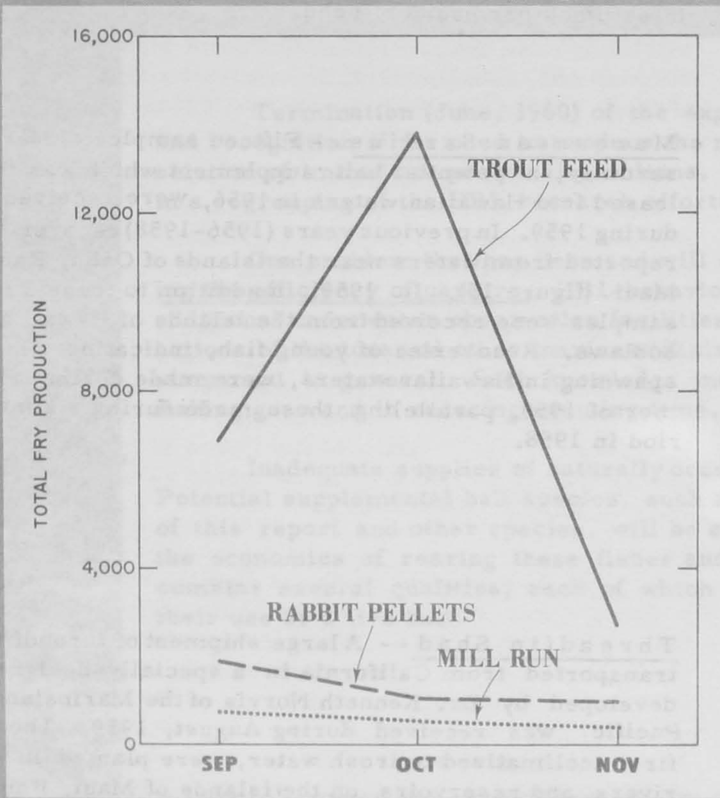


FIG. 38


200
150
100
50
0
AVERAGE NUMBER OF YOUNG PER FEMALE
BRACKISH WATER
FRESH WATER
AUG 8 AUG 14
AUG 15 AUG 21
AUG 22 AUG 28
AUG 29 SEP 4
SEP 5 SEP 11
SEP 12 SEP 18
SEP 19 SEP 25
SEP 26 OCT 2
Tilapia Spawning Rate


16,000
12,000
8,000
4,000
0
TOTAL FRY PRODUCTION
TROUT FEED
RABBIT PELLETS
MILL RUN
SEP
OCT
NOV

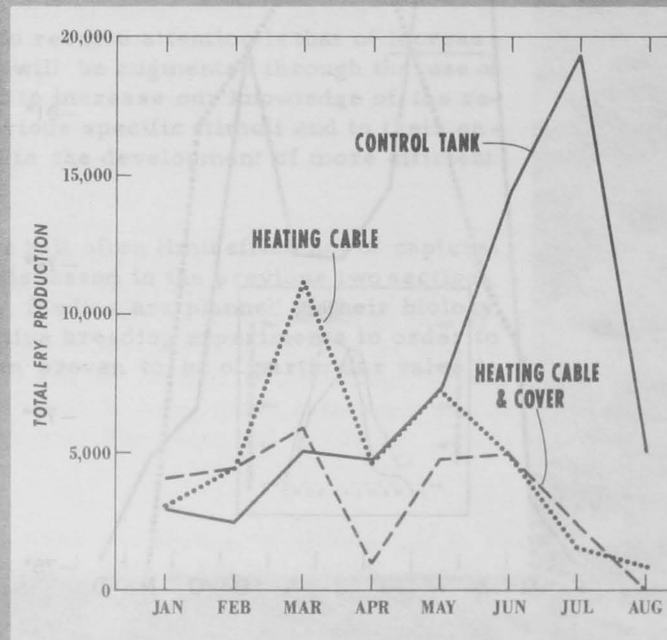

20,000
15,000
10,000
5,000
0
TOTAL FRY PRODUCTION
CONTROL TANK
HEATING CABLE
HEATING CABLE & COVER
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG

FIG. 39

cover and 15,000 in the tank with only the heater. The temperatures in the covered tank were 10°F. higher than those in the control.

The total production of tilapia during 1959 at the Maui plant exceeded that for 1958 (figure 40) by approximately 300,000 fry (1,293,000 as compared with 1,074,000). These production figures averaged 1,078 fry per female in 1959 and 724 per female in 1958.

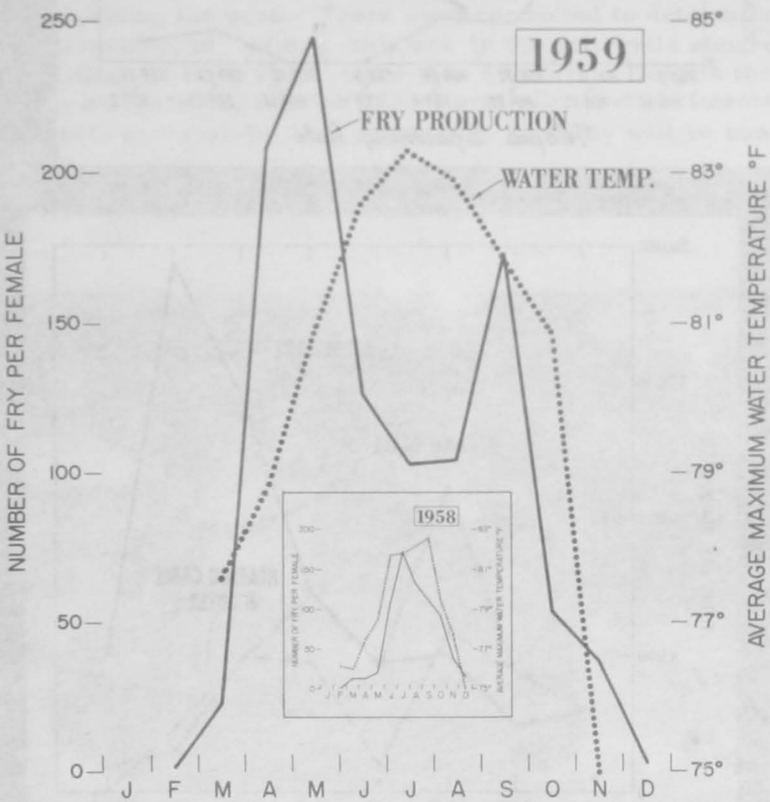


FIG. 40

While the application of results from the Kewalo experiments to the operation of the Maui plant (such as lower concentrations of brood stock, heating and aeration and more optimal male/female ratio and rates of feeding) undoubtedly contributed to the higher 1959 production; a warmer spring with proportionately more days of sunlight was a contributing factor.

Tests to determine the effectiveness of tilapia as live bait were started during 1958 and considerably augmented during 1959. In 1958 the average catch was 46 pounds of skipjack per pound of tilapia used as live bait; in 1959 the results were 50 pounds per pound of tilapia. Comparable figures for nehu were 50 (1958) and 57 (1959) pounds of skipjack per pound of nehu.

Marquesan Sardine - - Fifteen samples of Marquesan sardines, a potential bait supplement which was first released into Hawaiian waters in 1956, were received at HBL during 1959. In previous years (1956-1958) recoveries were reported from waters near the islands of Oahu, Kauai, and Maui (figure 15). In 1959, in addition to these 3 islands, samples were received from the islands of Hawaii and Kahoolawe. Recoveries of young fish, indicating successful spawning in Hawaiian waters, were made during late summer of 1959, paralleling those made during a similar period in 1958.

Threadfin Shad - - A large shipment of threadfin shad, transported from California in a specially-designed tank developed by Dr. Kenneth Norris of the Marineland of the Pacific, was received during August, 1959. These fish, first acclimatized to fresh water, were planted in various rivers and reservoirs on the islands of Maui, Kauai, and Oahu. In addition about 1,000 shad were established in laboratory tanks for use in studies comparable to those described above for tilapia.

1960 - FUTURE

Termination (June, 1960) of the exploratory phases of the Laboratory's research and recognition of the need to produce the more fundamental knowledge necessary for the solution of immediate practical problems, as well as those of the future, have resulted in a regrouping of the HBL research efforts.

One problem that has been and will continue to receive attention is that of increasing the efficiency of capture. HBL behavior studies will be augmented through the use of additional underwater observation facilities in order to increase our knowledge of the reactions of the tuna and other marine organisms to various specific stimuli and to their environment in general. Such knowledge may result in the development of more efficient fishing gear and in reducing scouting time.

Inadequate supplies of naturally occurring live bait often limit efficiency of capture. Potential supplemental bait species, such as those discussed in the previous two sections of this report and other species, will be evaluated. Studies are planned of their biology, the economics of rearing these fishes and of selective breeding experiments in order to combine several qualities, each of which have been proven to be of particular value to their use as a live bait.

Efficiency of capture may be increased through the use of reliable prediction techniques. Such predictions will be of optimum value, both to the producers and to the processors, when they provide information as to when, where, and how many fish will be available to the fleet. A prediction presently of value primarily in affording an estimate of "how many" skipjack has been developed by the HBL. Its ultimate reliability must await the test of time and increased knowledge of the biology of the fish and the relationship of the fish to their environment. Studies of general oceanography of the Hawaiian area will be continued along with more specific studies to reveal the mechanisms (wind-water-fish) involved. Although these investigations deal primarily with situations in Hawaiian waters, the basic knowledge gained will be applicable to similar fishery problems in other areas.

This ability to predict is a by-product or application of results from a study that was not concerned with a practical problem. Similarly, considerable effort is planned on the study of the biology of the tunas in order to contribute to the fund of knowledge available for application in the solution of practical problems of the future. Major effort in the immediate future will be placed on studies of spawning, growth, size distribution, spawning and year-class size of skipjack in Hawaiian waters and on the location of North Pacific albacore spawning grounds and the identification of albacore eggs, larvae and juveniles.

As the efficiency of capture is increased and as the exploitation of the tuna resources of the Pacific expands, the identity of stocks becomes increasingly important. That is, to know if the tuna fished in separate areas represent distinct stocks or if they are all part of an ocean-wide population. If there is a single population, a fishery in one area may affect other widely separated fisheries. If there are localized subpopulations, individual fisheries will have only localized effects.

Identification of the stocks may be determined by a study of body proportions, by tagging and through the study of genetic characteristics. Body proportion studies have given inconclusive results. Tagging experiments have been instructive, but are expensive and generally limited only to areas where there are fisheries to recapture the tagged fish. Determination of genetic characteristics, through the study of blood groups, are less expensive than tagging, are applicable to any area where samples can be obtained and the characteristics are known to be heritable. The occurrence of these characteristics in fish from different areas indicates whether or not inter-breeding occurs and, thus, whether or not there are one or more distinct subpopulations involved.

Blood group studies will be started at the HBL in 1960. It is planned, through a sampling program conducted aboard the HBL vessel and through the cooperation of other laboratories and commercial fishery activities, to study the genetic characteristics of the Pacific tunas. Initially, effort will be directed toward identification of blood group systems in tunas and, subsequently, determination of the occurrence of these groups in tunas of different areas.

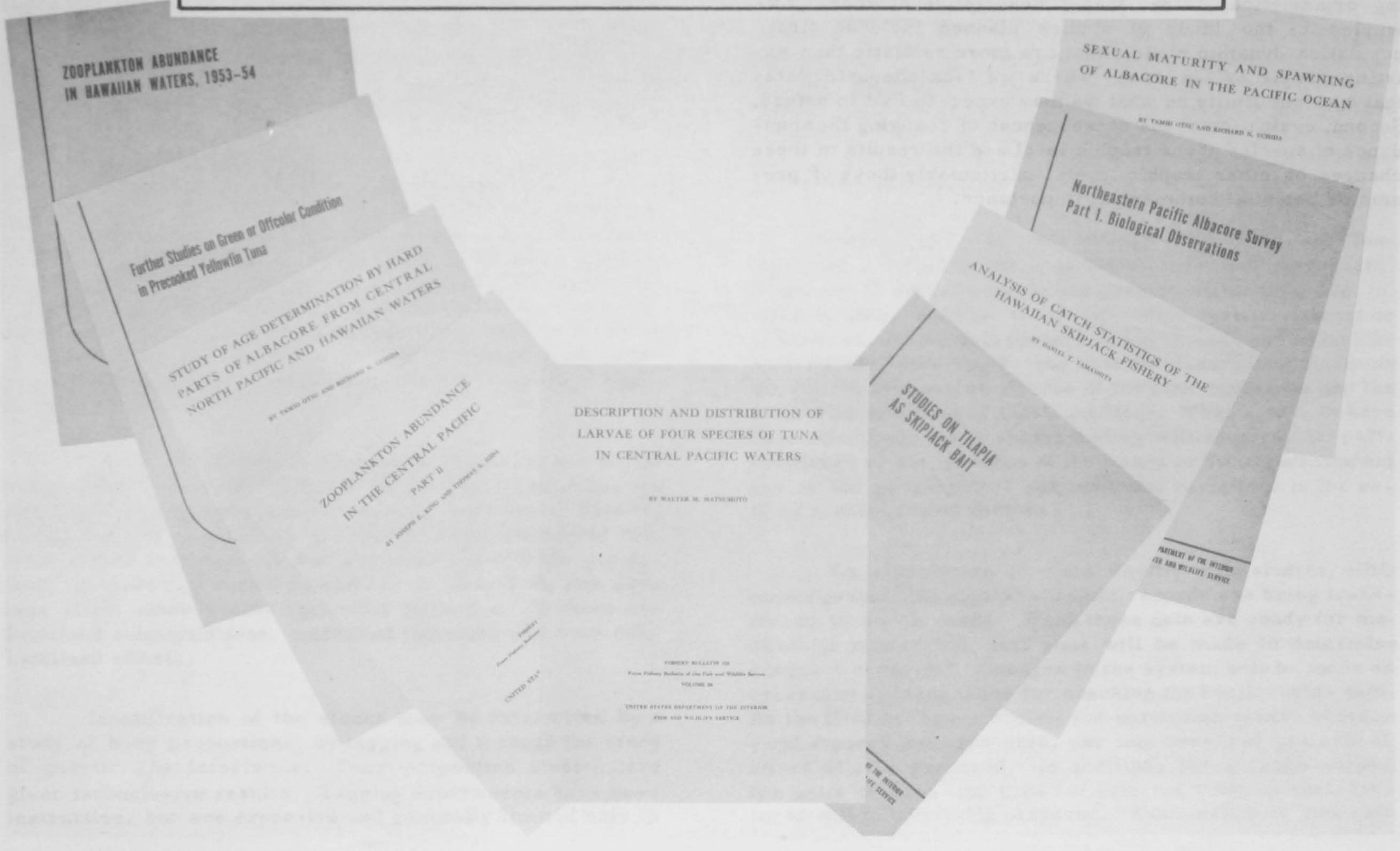
Efficiency of capture, biology of the tunas, and identification of stocks are meaningful on a localized basis. However, in order to obtain the greatest value from the results of these studies, the Pacific-wide resources must be considered. Thus, it is planned to accumulate and organize, on a Pacific-wide basis, the data necessary to determine the distribution and abundance of the tuna resources and the variations with time of these qualities. When such data have been compiled, their understanding will require, in part, knowledge of the relation of the fishes to their environment and of the geographical and temporal variations in the related oceanographic factors.

As a beginning of these Pacific-wide studies, HBL oceanographic, biological and catch records are being transferred to punch cards. When these data are ready for mechanical processing, test runs will be made to determine adequacy of format. Changes in the system will be made as necessary in preparation for punching the Pacific-wide data. As the files become complete for particular areas, average yield figures per unit area, per unit time and per unit of effort will be prepared. In addition, the average values for units of area and time for selected oceanographic features will be similarly prepared. Examination of both sets of data may be expected to lead to identification of problems or apparent relationships requiring more intensive study.

On the basis of existing knowledge, various exploratory theoretical studies are planned. Through attempts to generalize and synthesize existing knowledge, it is hoped to push understanding beyond present levels, perhaps by identifying critical observations or experiments to be made in the laboratory or at sea. It is only by such attempts that fishery biology will eventually be advanced to an understanding or analytical rather than a descriptive science. Examples of the kinds of studies planned include, first, population dynamic models that are more realistic than existing models or, in areas where we lack adequate data, that can set limits on what we may expect to find in nature. Second, evaluation of the consequences of changing the abundance of species at one trophic level and the results of these changes on other trophic levels, particularly those of present or potential commercial importance.

PUBLICATIONS 1949-1958

A major product of research studies is the publications which serve to make available the basic data and the descriptive and analytical results. In addition to these publications describing the research undertaken by members of the HBL staff, translations of oceanographic and fishery research articles from foreign languages, particularly Japanese, to English were also published. A list of the HBL publications for the ten-year period, 1949-1958, follows:



PUBLICATIONS 1949-1958

1949

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Methods of biological research on pelagic fisheries resources. Indo-Pacific Fisheries Council Proceedings, 1st Meeting: 132-138.

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AIKAWA, H. and M. KATO
Age determination of fish (preliminary report). U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries 21, 22 p. (Translated from the Japanese by W. G. Van Campen)

BATES, D. H., JR.
Tuna trolling in the Line Islands in the late spring of 1950. U. S. Fish and Wildlife Service, Fishery Leaflet 351, 32 p.

CLEAVER, F. C. and B. M. SHIMADA
Japanese skipjack (Katsuwonus pelamis) fishing methods. Commercial Fisheries Review 12(11): 1-27. Separate No. 260.

HIYAMA, Y.
Poisonous fishes of the South Seas. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries 25, 221 p. (Translated from the Japanese by W. G. Van Campen)

JUNE, F. C.
Preliminary fisheries survey of the Hawaiian-Line Islands area. Part 1 - The Hawaiian longline fishery. Commercial Fisheries Review 12(1): 1-23. Separate No. 244.

The tuna industry in Hawaii. Pan-American Fisherman 4(10): 11, 19.

KISHINOUYE, K.
Larval and juvenile tunas and skipjacks. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries 19, 14 p. (Translated from the Japanese by W. G. Van Campen)

A study of the mackerels, cybiids, and tunas. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries 24, 14 p. (Translated from the Japanese by W. G. Van Campen)

MATSUI, K.
The gonads of skipjack from Palao waters. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries 20, 6 p. (Translated from the Japanese by W. G. Van Campen)

MOORE, H. L.
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