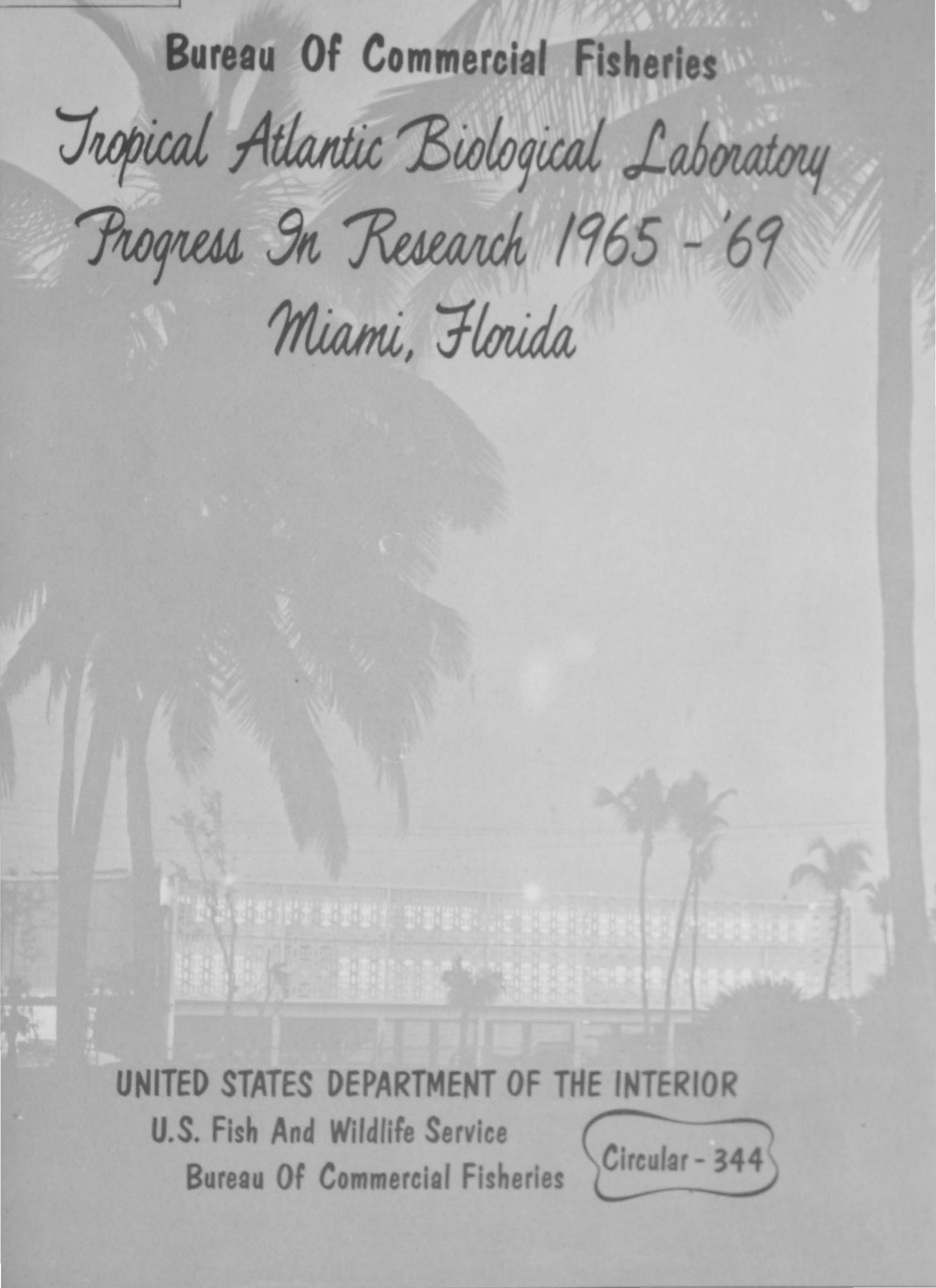
Bureau Of Commercial Fisheries

Tropical Atlantic Biological Laboratory

Progress In Research 1965 - '69

Miami, Florida



UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. Fish And Wildlife Service

Bureau Of Commercial Fisheries

Circular - 344

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Bureau Of Commercial Fisheries

Tropical Atlantic Biological Laboratory Progress In Research 1965 - '69 Miami, Florida

Carl J. Sindermann, Director
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Contribution No. 147 Bureau of Commercial Fisheries Tropical Atlantic Biological Laboratory, Miami, Fla. 33149.

by
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FOREWORD

Research on fishery resources of the tropical Atlantic was significantly augmented by the establishment in Miami in 1965 of TABL (Tropical Atlantic Biological Laboratory). Programs of the laboratory--oceanographic and biological--have concentrated on understanding the tropical Atlantic Ocean as a productive system, with emphasis on the commercial species of tuna.

TABL, during the critical developmental years 1965-67, was under the direction of Thomas S. Austin (now director of the National Oceanographic Data Center), to whom this circular is dedicated. He was instrumental in planning and shaping the course of Bureau research in the tropical Atlantic during this important period and was largely responsible for the early successes of the laboratory in cooperative international oceanographic studies.

Carl J. Sindermann
Director, Tropical Atlantic
Biological Laboratory

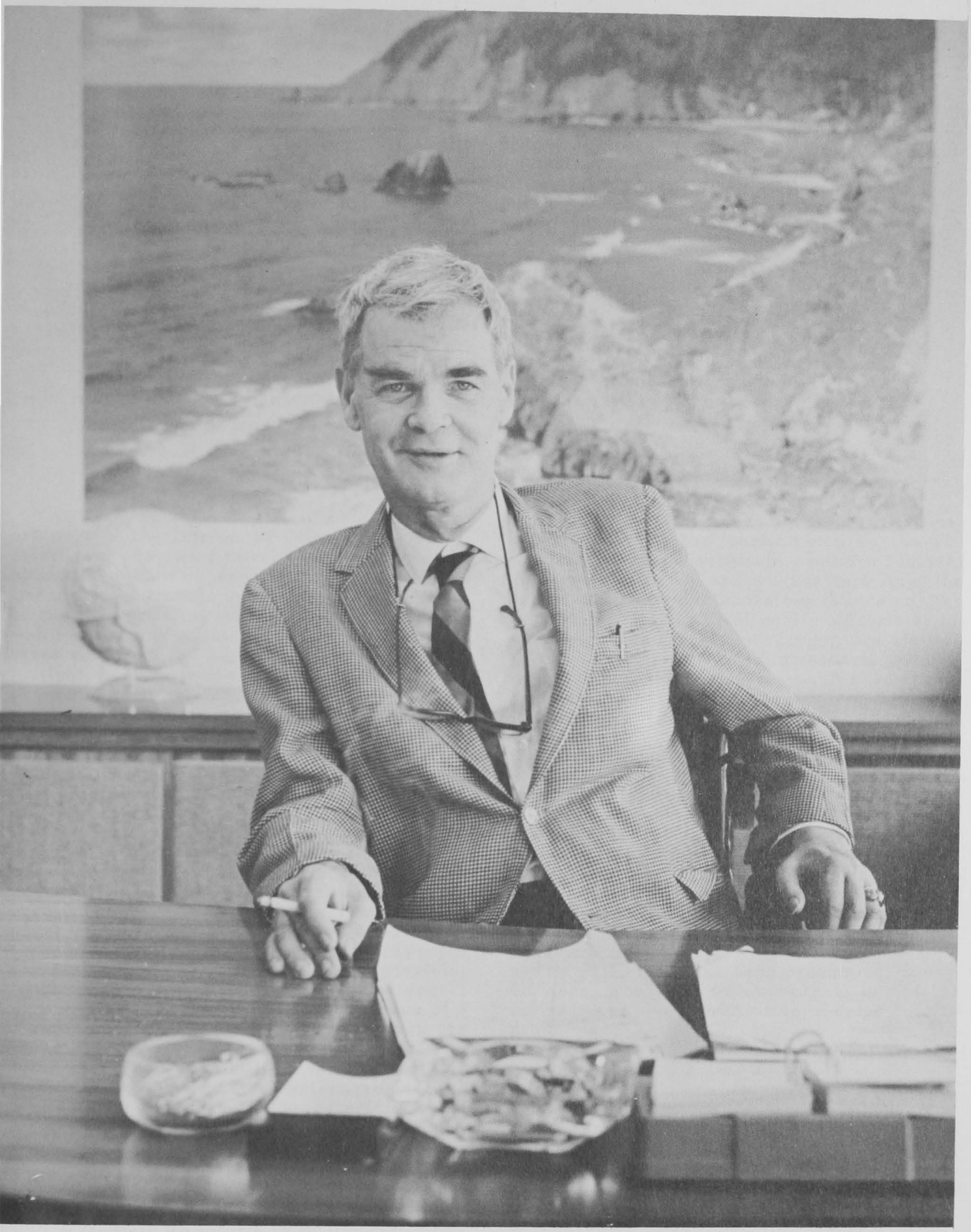

Figure 1.--Thomas S. Austin, former director of TABL, Bureau of Commercial Fisheries. He became director of the National Oceanographic Data Center in June 1967.

Bureau of Commercial Fisheries
Tropical Atlantic Biological Laboratory
Progress in Research, 1965-69
Miami, Florida

ABSTRACT

The history, facilities, and programs of the laboratory are described. The development of the tuna fishery in the tropical Atlantic Ocean, mid-1950's to mid-1960's, is discussed. Condensed cruise reports of the research vessels Geronimo and Undaunted are included.

INTRODUCTION

TABL (Tropical Atlantic Biological Laboratory) of the Bureau of Commercial Fisheries is approaching the end of its 4th year of operation in Miami and its 10th year of existence as a Bureau research unit. A number of the programs initiated while the laboratory was located in Washington (1959-65) have matured and produced significant scientific information; other, newer programs are rapidly approaching this status. It seems useful and relevant, therefore, to document and summarize the history and scientific results of a decade of Bureau research in the tropical Atlantic Ocean.

From the outset, major research emphasis of TABL has been on Atlantic tunas and related oceanography. Understanding has been materially advanced in both these research areas by the laboratory's programs and by cooperative international programs in oceanography of the tropical Atlantic. The following pages summarize some of our important findings, presented against a background of people and facilities that made the research possible.

We have seen during the past few years, and particularly in 1969, the emergence of a significant new U.S. purse seine fishery for tunas in the eastern tropical Atlantic. We think there are possibilities for further tuna fishery development in the western tropical Atlantic. Such fisheries can be materially aided by the existence of knowledge about stocks, population size, distribution, migrations, etc.--all of which are the concern of TABL.

This year (1969) is significant also in that the International Commission for Conservation of Atlantic Tunas has come into existence, through ratification of the Atlantic Tuna Convention by the required number of fishing nations. The obvious continuing role of TABL in these major developments can be an exciting and challenging one.

In addition to its own research activities, this laboratory has participated in the expanding ocean activities in southern Florida. A large tract of land on Virginia Key, the island on which the laboratory is located, has been designated by local public officials as an oceanographic park, with occupancy limited to organizations involved in research, education, and development in marine sciences. Designation of the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences (located adjacent to TABL) as a Sea Grant Institution offers opportunities to strengthen the Bureau's already close ties with that center of excellence in ocean sciences. Anticipated construction of ESSA's (Environmental Science Services Administration) new Atlantic Oceanographic and Meteorological Laboratories adjacent to TABL, beginning in 1970, should provide additional opportunities for cooperative research, and will significantly increase the number of ocean-oriented scientists on Virginia Key.

The past, then, has been productive, as can be seen from the following pages, and the future gives every indication of being equally productive.

THE GENESIS

At the beginning of the sixties, a number of events and circumstances combined to lay the groundwork for TABL. Philosophically the mood of Government, the scientific community, and much of the public favored the advancement of scientific research, especially that directed toward outer space and the oceans. Consternation was widespread over the twin specters of a world population explosion and a dwindling food supply, and demographers repeated

Malthus' theory, first expressed in 1798--that populations, when unchecked, increase in a geometrical ratio while the means of subsistence increase in only an arithmetical ratio. A number of nations began to direct their attention to the problem of how to gage and meet the nutritional needs of their future populations. The Department of the Interior, dedicated to the development and conservation of natural resources, was in the forefront of the worldwide effort to discover, augment, and use food resources. It devolved upon BCF (Bureau of Commercial Fisheries) to aid in the design of new programs to assist and improve commercial fisheries of the United States. TABL was to form a segment of the broad mosaic of scientific investigation of the oceans.

Realistically, nutritionists the world over had already recognized the urgent need for a stepped-up production of food, particularly animal protein, as a deterrent to starvation in many of the developing countries. One of the sources of protein that naturally came under close scrutiny was fish, including tuna. Coincidentally, fishery experts had concluded that the yellowfin tuna stocks in the Pacific Ocean might be in precarious balance and the Inter-American Tropical Tuna Commission was ready to set catch quotas. Also coincidentally, tuna fisheries in the tropical Atlantic Ocean had begun to record impressive catches, particularly of the valuable yellowfin tuna.

Plans for an investigation of the living resources and the oceanography of the tropical Atlantic were set in motion as the result of a 1960 "Symposium on Thunnidae" held in Dakar, Senegal. In 1961, BCF Director Donald L. McKernan proposed a synoptic survey of pelagic fisheries in the eastern tropical Atlantic. The same year, the BCF began to recruit the scientific staff for the tropical Atlantic program. Vernon H. Brock was appointed director of the BCF Biological Laboratory in Washington, D.C. (the forerunner of TABL), which grew out of the Atlantic Fishery Oceanographic Center, established in January 1958 under the leadership of Lionel A. Walford. Plans for a cooperative international investigation were expanded as a result of an exploratory meeting of oceanographers in Washington, D.C. in early 1962, and a formal program was settled upon by an International Working

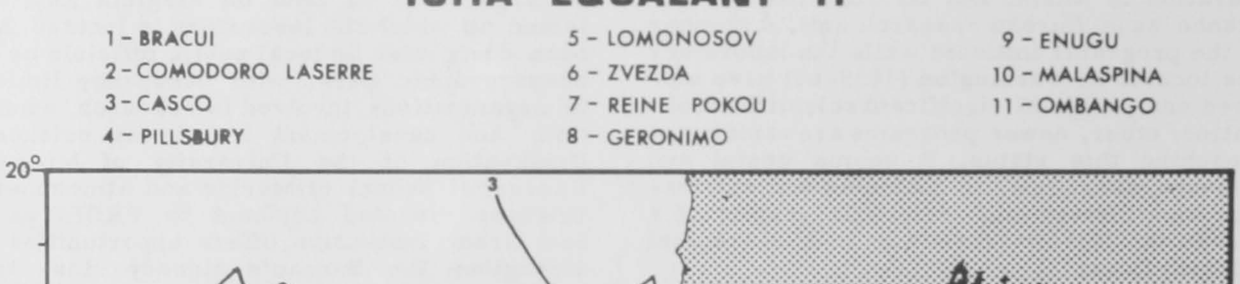

Figure 2.--Cruise tracks of 11 research vessels that took part in Equalant II voyages, August, September, and October 1963, in the tropical Atlantic Ocean. The Bracui is from Brazil; the Comodoro Laserre from Argentina; the Casco, Geronimo, and John Elliott Pillsbury from the United States; the Mikhail Lomonosov and Zvezda from the U.S.S.R.; the Reine Pokou from Ivory Coast; the Enugu from Nigeria; the Malaspina from Spain; and the Ombango from Republic of the Congo (Brazzaville).

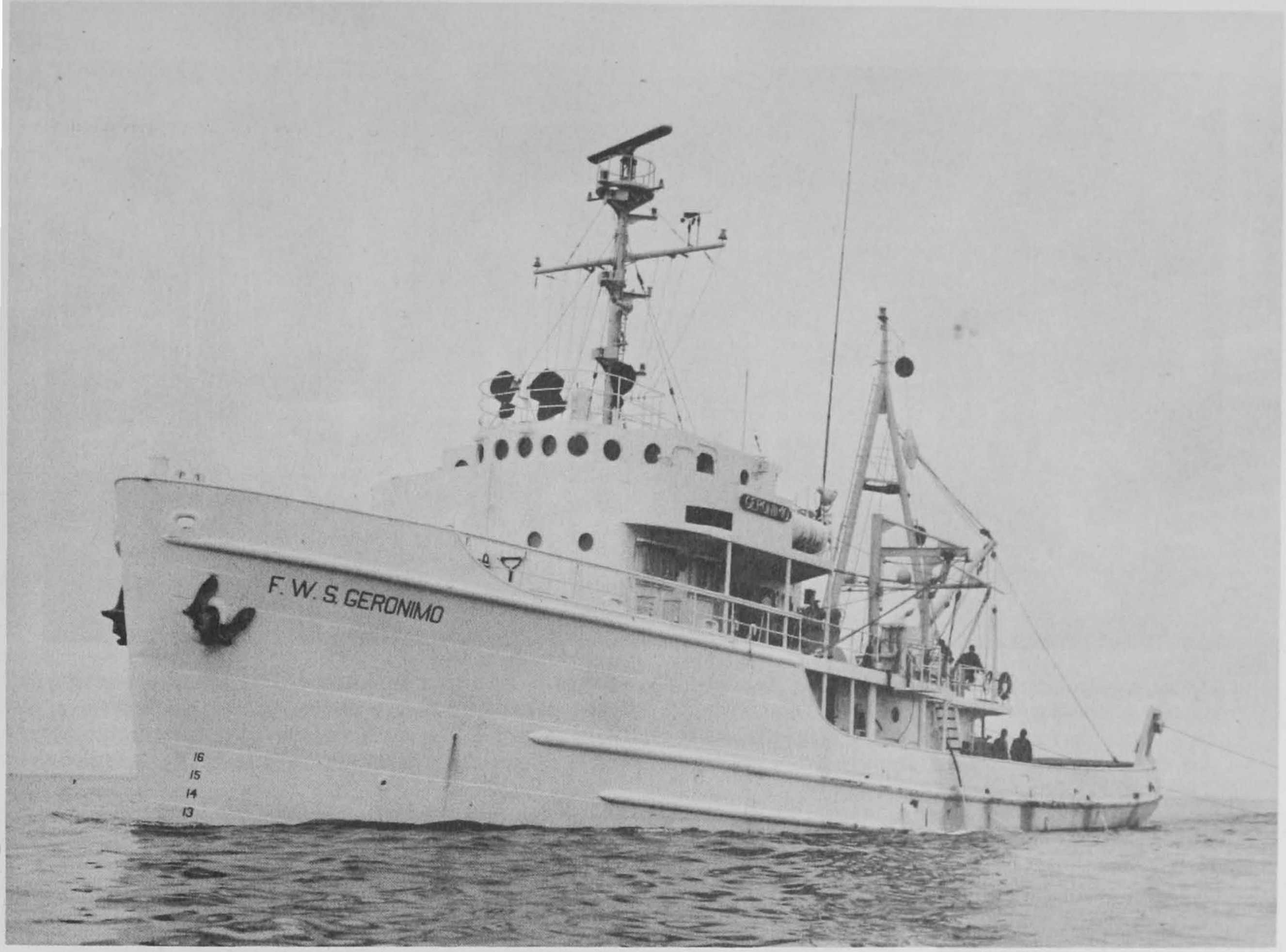

Figure 3.--The R/V Geronimo, originally commissioned as an ATA-class (seagoing) Navy tug in 1944, and converted into a BCF research ship in 1963. The Geronimo participated in eight major cruises for TABL.

Group sponsored by the IOC (Intergovernmental Oceanographic Commission) of UNESCO in mid-1962. The program was subsequently adopted at an IOC meeting in September, and Vernon Brock was chosen as International Coordinator of ICITA (International Cooperative Investigations of the Tropical Atlantic). In 1963 Brock resigned from the BCF to become Director of Marine Biology at the University of Hawaii and was replaced--as both director of the biological laboratory and international coordinator of ICITA--by Thomas S. Austin, who had been a member of the planning group from 1961.

The boldly imaginative ICITA represented the most ambitious attempt ever made to understand the biology and oceanography of the tropical Atlantic Ocean. Seven nations committed 14 research vessels to the ensuing investigation, whose program was divided into three correlative expeditions--Equalants I, II, and III (fig. 2)--which were carried out in 1963 and 1964. The Bureau's R/V Geronimo (fig. 3) was a participant in two of the Equalant surveys. (The Geronimo worked under the direction of TABL until her transfer elsewhere in 1966.) Several of the scientists and technicians who worked on the vessel at that time are still with TABL at this writing, in 1969. The results of the Equalant Expeditions provided the equivalent of two seasonal "photographs" of the horizontal and vertical distribution of the physical, chemical, and biological properties of tropical Atlantic waters from the Tropic of Cancer south to the Tropic of Capricorn.

THE EVOLUTION

Motivated by the preliminary findings of the Equalant surveys, BCF expanded its concept of scientific coverage of the tropical Atlantic and began to consider sites more appropriate than Washington, D.C., for the activity. The idea of a tropical Atlantic biological laboratory became reality in late 1963, when the director of BCF Region 2 (St. Petersburg, Fla.) formally requested that Florida's Dade County allocate 5 acres of land on Virginia Key (Miami) to the Federal Government, for use as an oceanographic research center. The Congress had already appropriated $125,000 for an architectural outline of the planned BCF laboratory, pending selection of the site. County officials agreed to transfer the land to the Department of the Interior a month after the request was made, and arrangements for the building of TABL began without delay. A year later, in

Figure 4.--At dedication ceremonies that marked the opening of TABL on Virginia Key, Miami, Fla., -- Nov. 20, 1965 -- Oceanographer of the Navy O. D. Waters, addresses the audience. Seated on either side of Waters, (left to right) are: Miami Metro Mayor Chuck Hall, TABL Director Thomas S. Austin, Assistant Secretary of the Interior Stanley A. Cain, President of the University of Miami Henry King Stanford, and U.S.N.R. Chaplain W. Ivan Hoy.
(Courtesy of the Miami Herald, Miami, Fla.)

Figure 5.--Carl J. Sindermann (left), present director of TABL, Albert C. Jones (right), assistant Director since 1965.

November 1965, the new laboratory was dedicated (fig. 4).

TABL remained under the direction of Thomas S. Austin until 1967 when he left to become director of the National Oceanographic Data Center. Albert C. Jones was acting director for more than a year until Carl J. Sindermann assumed the directorship in 1968 (fig. 5).

For those readers who have never visited TABL, a brief description of the locality seems in order. TABL is situated on Virginia Key, a county-owned island just offshore of Miami, joined to the city by the Rickenbacker Causeway (see fig. 35 in centerspread). The Straits of Florida lie along the eastern shore of the island; Biscayne Bay is on the west.

Adjacent to the laboratory is Bear Cut Bridge, which leads south to Key Biscayne. Just across the road from TABL is RSMAS (Rosentiel School of Marine and Atmospheric Sciences)[2] of the University of Miami; the Miami Seaquarium is next door to RSMAS. Within a short distance is the site for ESSA's Atlantic Oceanographic and Meteorological Laboratories (Department of Commerce). Construction of a marine science and technology center for Miami-Dade Junior College is scheduled for 1970 on the island. The TABL research vessel, Undaunted, docks a few miles away at a municipal pier in Miami but will be berthed at a new oceanographic vessel facility--to be shared by ESSA, TABL, and RSMAS--at the nearby county port, Dodge Island, when construction of the port is completed.

Miami's geographical and climatic environment--essentially tropical though 150 miles north of the Tropic of Cancer--makes it a logical base for the study of marine science objectives in the tropical Atlantic. The Gulf Stream, with its boundless opportunities for marine research, passes within sight of shore, and small craft and research vessels can easily reach the scientifically interesting Florida Straits, the Bahama Banks, the Gulf of Mexico, and many Caribbean areas. The location is ideal for the launching of deep-sea studies in the waters between it and Bermuda, South America, and West Africa; and Florida's waters provide easy access to a wide variety and rich quantity of marine life.

The setting offers another benefit, intangible but highly important--the opportunity to be part of an almost unique fishery-oceanography community. Virginia Key, though only minutes from downtown Miami, has few of the complexities and distractions of an urban area. The island retains much of its natural flora, and the clean, sandy beaches that surround it offer opportunities for swimming, fishing, and the collecting of marine specimens. (Laboratory personnel catch fish only yards from the back door; plankton tows are made almost daily at locations mere minutes away.) Except for a marine stadium and a few service buildings, construction on the key consists entirely of fishery-oceanography establishments, all built near each other. The special ambience of the island--at once unspoiled and sophisticated--is ideally suited to the work of marine research scientists (fig. 6).

At his farewell address to the Miami oceanographic community in June 1967, former

[2] Formerly IMS (the Institute of Marine Sciences).

Figure 6.--A TABL research supervisor helps a participant in the NSF-sponsored summer research program (for college teachers) to collect a water sample to be used for a study of diurnal variation of carbon-14 uptake by phytoplankton. The boat is in a cove a short distance from the rear entrance of the laboratory.

TABL director Austin made a proposal that bore fruit in early 1969 when civic authorities set aside 162 acres of county- and city-owned land on Virginia Key as an oceanographic park. According to the charter, users of land within the oceanographic park "... must be engaged in an activity for the benefit of the public welfare ... directly related to and actively involved in marine science or marine technology through education, training, research, or development ... The activity of the applicant must be compatible with the activities of the other members of the marine science complex and contribute to the advancement of the complex through mutually beneficial relationships."

TABL is a three-story, air-conditioned structure made of precast, prestressed concrete, containing 46,300 square feet of covered work space. Within its two wings are offices, research laboratories, a library, two room-sized refrigerators, a 100-seat seminar room with motion picture facilities, X-ray and darkrooms, a fireproof records vault, a data-processing center, two controlled environment rooms, and a large aquarium room with five big fish tanks. Staff and visiting scientists generally work in separate two-room suites containing an office and a laboratory. The laboratories have outlets for compressed air, gas, and hot and cold running fresh water and sea water. Sea water is pumped through a dual-pipe system into the laboratory (500 gallons per minute) from an intake crib submerged in the ocean near Bear Cut. A 2,500-square-foot building adjoining the laboratory contains a large collection of preserved subtropical and tropical fishes, and offices and work space for visiting ichthyologists.

The physical design of TABL was predicated upon the accomplishment of all its assigned duties, with space, facilities, and equipment for expansion and adaptation of future programs as needed. This dual philosophy may be illustrated by features contained in the aquarium room--so far the room has been used for the study of small- and medium-sized specimens, but its electrically driven hoist and overhead monorail can handle fish of large size readily when the need arises. Many other innovative features were constructed with similar concepts in mind.

THE STRUCTURE OF THE RESEARCH PROGRAM

From the beginning, the BCF's mandate to TABL was broad and many-faceted: an assessment of the biology and ecology of the pelagic marine food resources of the tropical Atlantic, particularly the tunas; the design of programs that would increase the total yield of seafood products, at the lowest possible cost to U.S. commercial fisheries; the extension of assistance, through cooperative efforts, to the developing nations bordering the tropical Atlantic in their search for more and better supplies of protein food in nearby waters; and the acquisition of the knowledge necessary for the development and application of sound conservation policies for international as well as domestic control of marine resources.

Initially (in 1965), the scientific work was divided into six dovetailing programs, defined as follows:

1. Climax Predators. Study of the biology and ecology of fish populations and effects of fishing on these stocks. The program concentrated on marine fish at the top of the food chain in the tropical Atlantic, with emphasis on the tunas.

2. Nekton Ecology. Study of the swimming sea life that occupies an intermediate position in the food chain, with special attention to those species that serve as food for tunas.

3. Zooplankton Ecology. Study of the small floating marine life that feeds on phytoplankton or other zooplankton.

4. Primary Productivity. Investigation of the first link in the food chain--the conversion of solar energy and nutrients into living matter (photosynthesis).

5. Systematics of Fishes. Identification and study of taxonomy of fishes, particularly those native to the western and tropical Atlantic. The preparation of field guides to different groups of fishes was part of the program's assignment.

6. Physical Oceanography. Study of the total environment in which all the links of the food chain operate, and how that environment affects the separate elements in the chain.

A reorganization took place in 1967--after TABL had gone through its "shakedown" phase--and the scientific operations were rearranged into four programs: Tuna Fishery Biology, Developmental Biology of Fishes, Fishery Oceanography, and Systematics of Fishes. This structure remained in effect until late 1968, when the scope of the Systematics of Fishes program was reduced, to accommodate a new program devoted to the study of calico scallops that had been discovered in commercial quantities off northern

Figure 7.--A general view of scientific and support activities carried on at TABL. Photo of laboratory off center of montage was taken in 1965, just before completion.

Florida. Thus the operating pattern in mid-1969 is:

1. Tuna Fishery Biology.

Strives to reach an understanding of the ecology and relation to the environment of the tropical Atlantic tuna stocks. Inherent in this understanding is the determination of optimum equilibrium yield for efficient fishing. Assessment of tuna population dynamics is an important facet of the program.

2. Developmental Biology of Tunas.

Investigates the biology of eggs, larvae, and juvenile tunas, with particular attention to distribution, growth, and mortality.

3. Fishery Oceanography.

Studies the physical, chemical, and biological environment in which all links in the oceanic food chain operate, and how this environment affects the separate elements in the chain.

4. Calico Scallop Biology.

Studies and determines significant biological characteristics of scallop stocks, mainly off the east coast of Florida near Cape Kennedy, to estimate sustainable levels of harvesting.

5. Taxonomy of Clupeoid Fishes.

Studies the systematics of clupeoid fishes (herrings, sardines, and anchovies). Maintains the TABL reference collection of marine fishes.

All five programs are discussed in greater detail elsewhere in this report.

Support for the scientific program rests with three units--Marine Services, Technical Services, and Administrative Services. The Marine Service unit (Gerald L. Hood, marine superintendent) is in charge of the operation of the research vessel, and its maintenance, staff, equipment, and supplies; the unit is also responsible for the operation of TABL's radio station KAG (fig. 8), which maintains daily

Figure 8.--TABL's single sideband radio station, KAG, has been operative since March 1968. The 1,000-watt, 4-frequency coastal station allows contact between TABL and research vessels many miles away. Theoretically the station can reach ships by voice anywhere in the world. KAG serves other oceanographic institutions in the Florida area.

voice contact with the ship. The Technical Services unit, which the assistant director supervises, provides a variety of support services for the scientific program. It includes the data processing section, which works closely with the staff of the computer center at the University of Miami, on the conversion of data gathered at sea into forms suitable for scientific analysis (fig. 9). Unit personnel also consists of scientific technicians, a librarian, an artist, a technical editor-public information officer, a photographer, secretaries, and typists. Willis S. Siferd III is in charge of the Administrative Services unit, which is responsible for the management of personnel, finances, supplies for the laboratory and the ship, bookkeeping, clerical work, and maintenance.

TABL employs about 30 scientists, 40 other laboratory workers, and 17 crew members of the Undaunted. During summer the staff is increased by about a dozen visiting scientists and student workers.

THE ATLANTIC TUNA FISHERY

The primary assignment of TABL is the thorough investigation of the biology and ecology of pelagic fishes of the tropical Atlantic Ocean, with major emphasis on the tunas. The ultimate goal of TABL is to learn enough about the biology and ecology of the Atlantic tunas to enable commercial fishermen to catch profitable quantities of fish under the most economical conditions possible, yet not deplete the tuna stocks.

Many BCF laboratories came into being in the wake of a fishery, but TABL is an exception. It was created, in 1965, in anticipation of a successful U.S. tuna fishery in the tropical

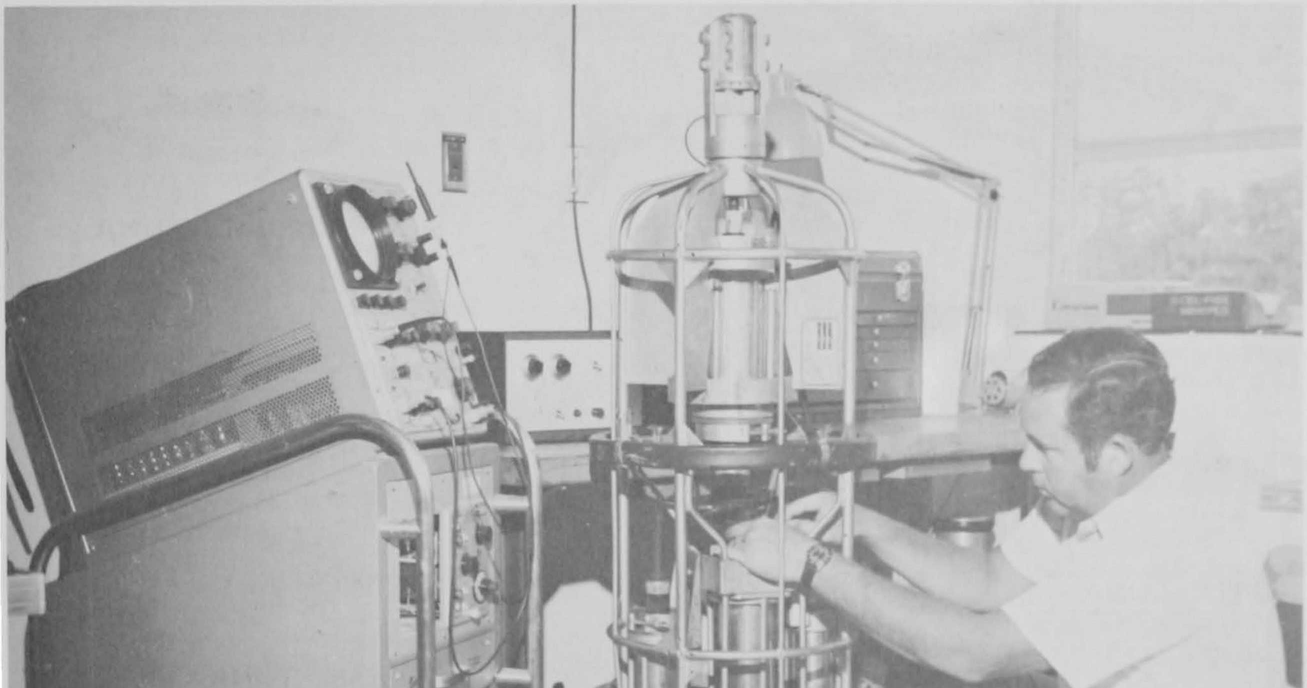

Figure 9.--A portion of the TABL electronic laboratory. A technician is shown at work on the STD (salinity-temperature-depth) "fish," used regularly aboard the research vessel. The device at left of picture is an oscilloscope, used for tracing and testing electronic pulses.

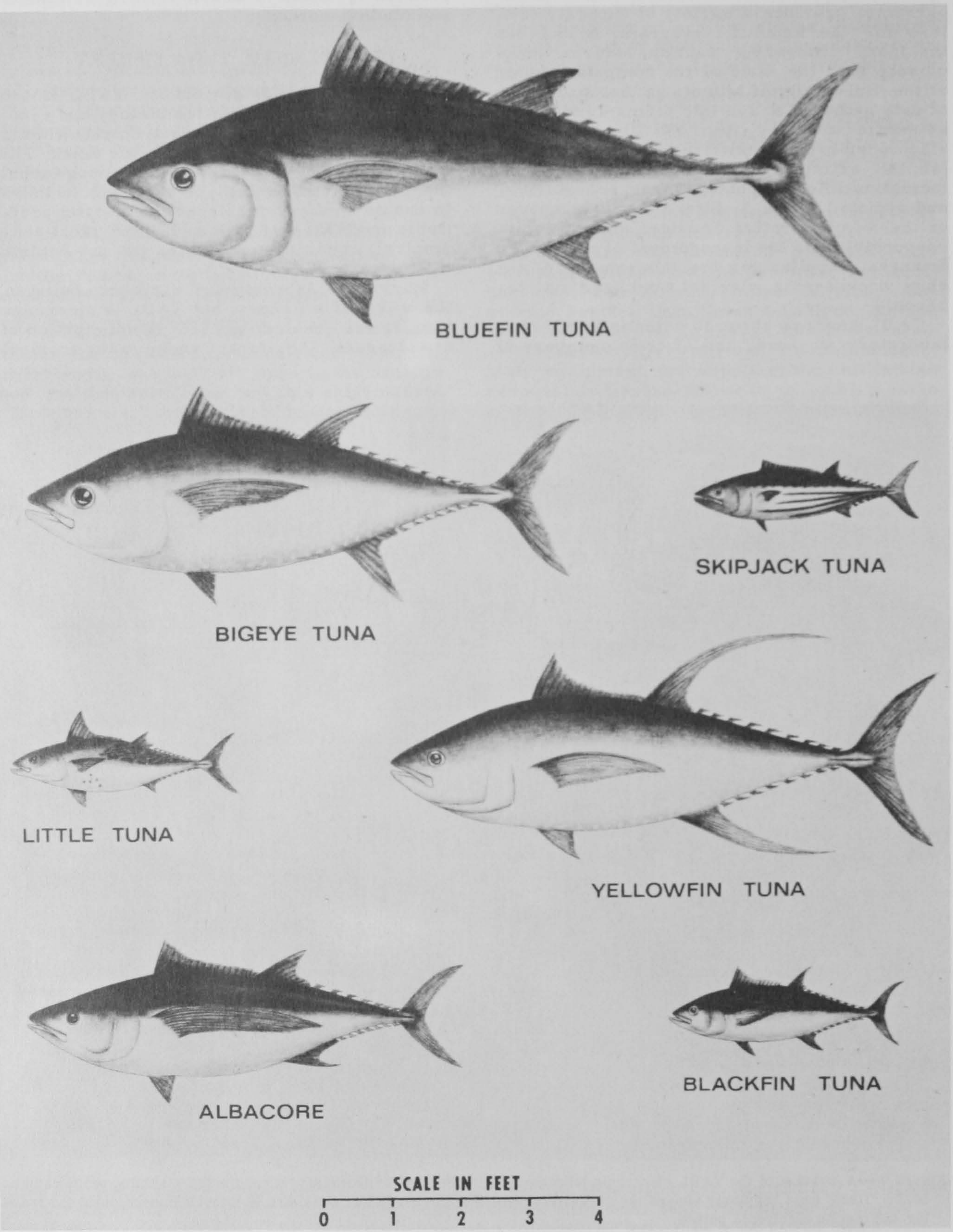

Figure 10.--The Atlantic tunas under study at TABL, drawn to scale to show approximate maximum size.

Atlantic. Until the early 1960's, U.S. fishermen did not actively seek Atlantic tunas except for bluefin tuna (Thunnus thynnus)[3] and relatively minor amounts of skipjack tuna (Katsuwonus pelamis). This restricted production did not mean, of course, that other Atlantic tuna fisheries did not exist. Albacore (Thunnus alalunga) and bluefin tuna have been caught for many years on the European side of the Atlantic; yellowfin (Thunnus albacares), skipjack, and bigeye (Thunnus obesus) tunas, and albacore have been caught intermittently off Africa for a long time; blackfin tuna (Thunnus atlanticus) has long been known to South American and Caribbean fishermen (fig. 10). From time to time in the past, U.S. tuna fishermen have taken a moderate interest in these fisheries.

In the mid-fifties, a dramatic change began with the appearance of, first, a surface fishery--by trolling and live bait--for yellowfin and skipjack tunas off western Africa mostly by French and Spanish fishermen. Soon after, the Japanese began an extensive longline fishery that eventually covered much of the tropical and subtropical Atlantic Ocean and landed great quantities of the deep-swimming yellowfin tuna, albacore, and bigeye tuna. U.S. tuna fishermen, however, took little part in the new fishing activity because most of their efforts traditionally were centered in the Pacific.

The rapid expansion of the fishery may be illustrated briefly by these statistics: Tuna production from the entire Atlantic was only 180,000 metric tons in 1955 but had climbed to 330,000 metric tons by 1964, according to figures published in 1966 by FAO (Food and Agriculture Organization of the United Nations); one exploratory longliner fished in tropical Atlantic waters in 1955 compared with 150 in 1965 (Jones, 1966[4]); U.S. tuna seiners recorded no landings of tunas from the tropical Atlantic in 1955 but caught more than 9,400 metric tons of yellowfin and skipjack tunas off western Africa in 1968.

When TABL's investigation of the tunas of the tropical Atlantic began, a near-vacuum existed in terms of availability of a genuine body of sound scientific data on the subject. Many of our scientists had to start from scratch to accomplish the tasks assigned them. Records of catches in the vast region under study were virtually nonexistent, for instance, until the early sixties. The French, Spanish, and Portuguese were able to provide only sketchy figures on surface fishery catches before 1960; few of the early catch records kept by the Japanese longliners that traversed broad areas of the Atlantic were available in the forms needed for BCF's broad-scale survey of stocks. Those records that were available were not translated from the Japanese--much less analyzed--until a few years ago. A great part of what is now an analysis of considerable scope and substance began with the Equalant Expeditions and continued on a foundation of painstaking "detective" work by TABL scientists in cooperation with others. Year by year, bit by bit, information was fitted together from other BCF laboratories, from FAO, from foreign fishery agencies and scientists (figs. 11 and 12), from research cruises, and from commercial tuna vessels. Now--in 1969--even though much work remains, a relatively well-defined picture has emerged of the past, present, and possible future of the tuna fishery in the tropical Atlantic.

The tropical and subtropical tunas of the Atlantic are essentially the same as those of the Pacific, with a few exceptions. As in the Pacific, the yellowfin tuna is caught in great numbers--by longline, purse seine, trolling, and live bait fishing. The omnipresent skipjack tuna also forms a significant portion of the Atlantic catch by surface fisheries off western Africa. Substantial catches of bigeye tuna are made by longline. The albacore, though more an inhabitant of temperate waters, is highly important to the longline tuna boats that move in and out of the tropical Atlantic. The bluefin tuna travels seasonally through the subtropical waters of the Atlantic in huge schools. (Generally bluefin tuna caught in the Atlantic are considerably larger than those caught in the Pacific. Record weight (rod-caught) for the Atlantic bluefin tuna is 977 pounds, and the species is thought to reach well over 1,000 pounds.) One species of little tuna, Euthynnus alletteratus, is plentiful in tropical Atlantic waters. The blackfin tuna, found only in the western Atlantic (from Cape Cod to Brazil), forms the basis for a commercial fishery in Cuba.

Latest available figures indicate that tuna production in the Atlantic Ocean accounts for about 15 percent of the world catch. In the tropical Atlantic, the tuna catches are divided between the longline (fig. 13) and surface fisheries. The Japanese have done most of the longline fishing in the decade 1955-65, but their 150-boat fleet (with more than 97 million hooks) of 1965 decreased to about 75 longliners in 1968, evidently because of diminished returns of yellowfin tuna (Wise and Fox, 1969). Japanese data revealed that the 1955-67 longline catch in the Atlantic consisted of:

	Albacore	Yellowfin tuna	Bigeye	Others
Percent	42	38	11	9
Numbers (thousand fish)	9,783	8,697	2,441	2,176

Total annual landings of tunas from the Caribbean are estimated at 28,800 metric tons,

[3] Called "horse mackerel" in the northeastern United States.

[4] See "List of TABL Publications" for detailed information on scientific papers by TABL personnel.

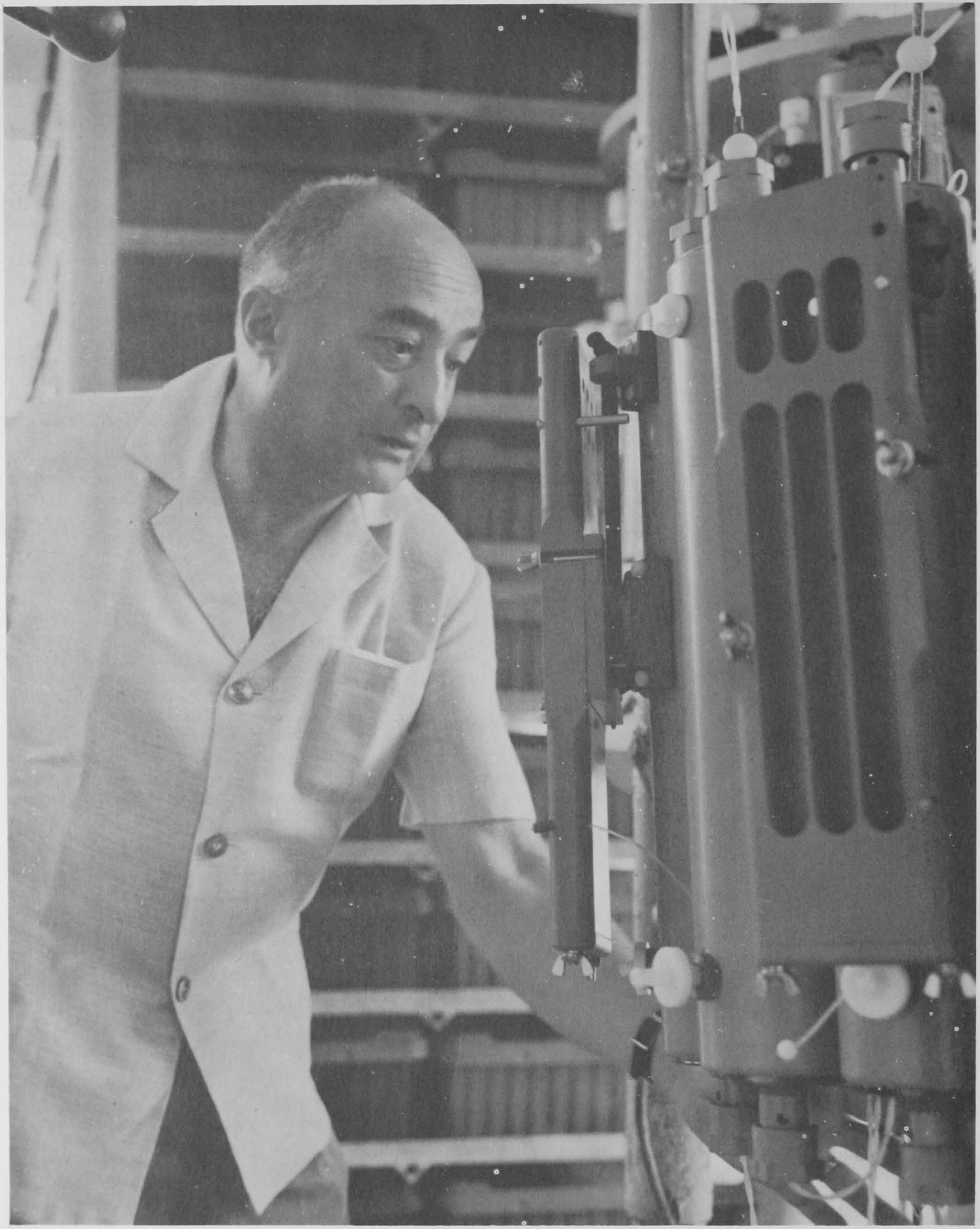

Figure 11.--G. R. Berrit, director of the ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer) laboratory at Abidjan, Ivory Coast, examines "rosette" water sampler aboard the R/V Undaunted in late 1968, on a research cruise in west African waters.

Figure 12.--F. Poinsard, director of ORSTOM at Pointe Noire, Congo (Brazzaville), discusses oceanic features of the Gulf of Guinea with Albert C. Jones (right) asst. director of TABL, aboard the Undaunted in late 1968.

according to Wise and Jones. Longliners from Japan, Venezuela, and Cuba land significant quantities of tuna from the Caribbean region. Japanese statistics showed averages for their longliners of about 10,000 metric tons of yellowfin tuna per year, 1958 through 1965. Over the entire 10-year period, 1956 through 1965, totals for all longline catches (as published by FAO in 1967) were: 101,160 metric tons of yellowfin tuna; 21,474 of bluefin tuna; 19,869 of bigeye tuna; 12,176 of albacore; and 14,648 of other species.

The considerable body of evidence now on hand concerning longline catches seems to indicate that deepwater yellowfin tuna in the tropical Atlantic were subjected to unusually heavy fishing pressure for several years (1961-65). As stated earlier, a substantial number of Japanese longliners have departed from tropical Atlantic fishing grounds, and other nations--South Korea, China (Taiwan), Cuba, and Venezuela--have counterbalanced that reduction only partially by adding some 70 longliners to the fishery. Longline fishing also has decreased in recent years in the Gulf of Mexico and the Caribbean region. These reductions in the total effort by longliners have been accompanied by an apparent increase in the abundance of yellowfin tuna, according to recent analyses.

Surface fisheries in the tropical Atlantic land smaller tunas than the longline fishery, but quantities caught have been increasing steadily over the last decade. France and Spain reported a total catch of about 30,000 metric tons of yellowfin tuna in 1966. The major increase by these nations came in the late 1950's when fishing from French and Spanish live-bait vessels began in waters off western Africa. Yellowfin tuna forms the largest percentage of the catch by far, and is followed by skipjack tuna and small amounts of bigeye tuna. In 1965 the landings of yellowfin tuna from the surface fishery in west African waters

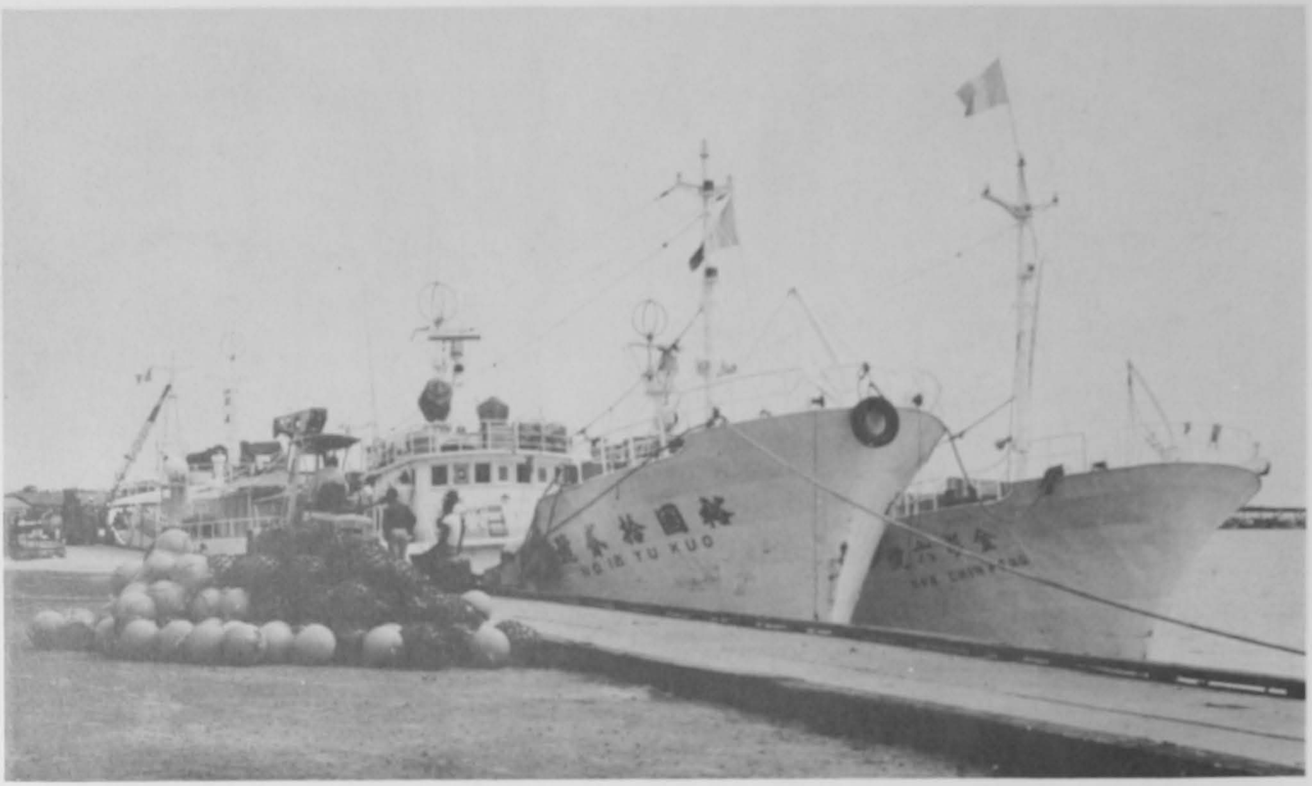

Figure 13.--Chinese (Taiwan) longline fishing vessels at anchor, Abidjan, Ivory Coast, in the fall of 1968.

were 23,700 metric tons; in 1966, landings had increased to 28,000 metric tons and exceeded the 22,500 metric tons caught by longline. Most of the early fishing for surface-schooling tunas was by pole-and-line, but in the mid-1960's the fishery began to use seiners. By 1967, seiners made up nearly half the 39-boat surface fishery fleet, which by then had assumed a more international character. French, Spanish, and Portuguese fishermen had been joined by others from Senegal, Japan, Yugoslavia, and the United States. Three U.S. seiners entered the fishery in late 1967 after quotas set for yellowfin tuna catches in the Pacific had been reached; the vessels returned after a 65-day voyage with about 1,500 metric tons of tuna, composed of 60 percent yellowfin tuna and 40 percent skipjack tuna. In late 1968, eight U.S. purse-seiners caught just under 10,000 metric tons of yellowfin and skipjack tunas (fig. 14) in about the same percentages as in 1967 (fig. 15). Canadian vessels also joined the fishery in 1968. In July and August of this year (1969), 23 U.S. tuna boats were scheduled to steam toward the fishing grounds in the eastern tropical Atlantic.

The best months for surface fishing for tuna off west Africa appear to be from June through November. According to data obtained from the Pointe Noire fishing fleet, the peak periods for seining for yellowfin tuna fall in September and October. Abundance of pole-caught yellowfin tuna in the area increases steadily from February until August, then declines again until February. The most productive area over the period is apparently along the west African coast, at or south of the equator (fig. 16).

Surface fisheries in the Caribbean, primarily carried out by Cubans, use live-bait methods mostly to catch about 1,000 metric tons per year of blackfin tuna (60 percent), skipjack tuna (30 percent), and other scombrid species. TABL's Undaunted located great schools of yellowfin and skipjack tunas on five research cruises in and near the Caribbean in 1967 and 1968, but fishing results, though encouraging, did not quite live up to expectations.

PROGRESS IN RESEARCH

To achieve a truly unified analysis of a subject as broad as the ecology of pelagic marine populations, equal emphasis must be given to studies of biology and studies of oceanography. The two subjects are inextricably interwoven--students in each discipline originate and advance hypotheses and philosophies that affect, directly and indirectly, the theories and contemplations of the other. TABL's arrangement of scientific programs was conceived on the basis of just such an interaction. Research cruises follow the same pattern of divided but complementary procedures.

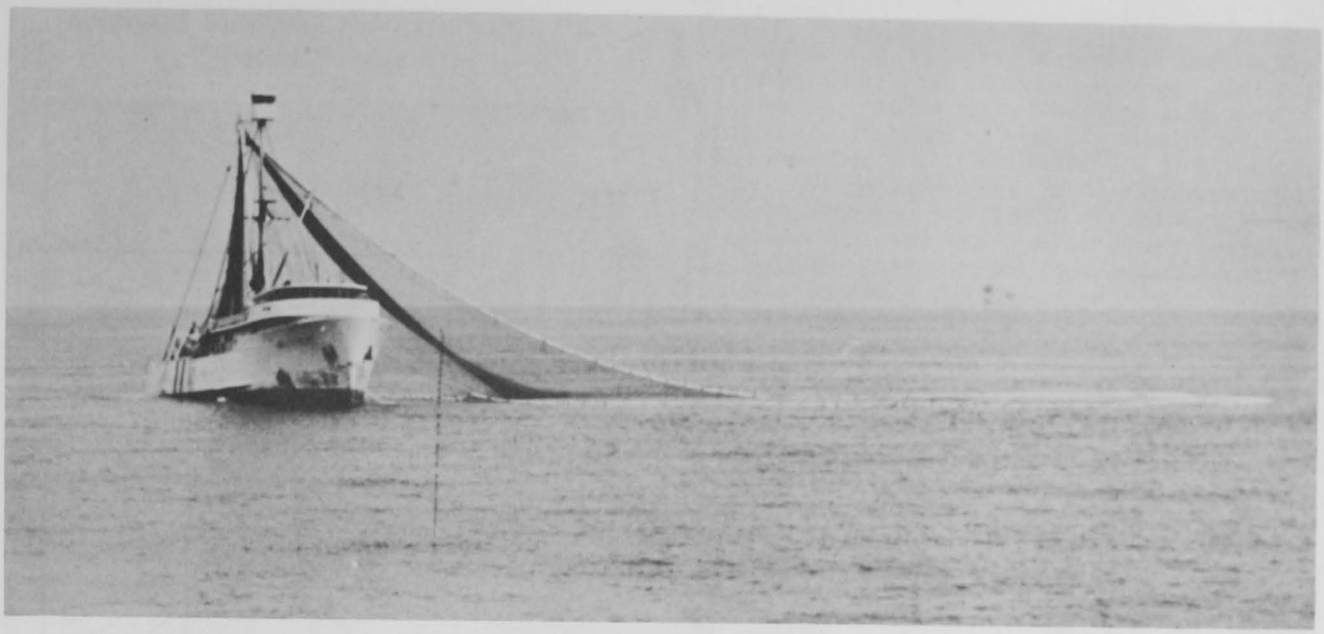

Figure 14.--The Bold Venture, a U.S. tuna boat, fishing by purse seine in the Gulf of Guinea in the fall of 1968. Eight U.S. vessels caught just under 10,000 metric tons of yellowfin and skipjack tunas off west Africa in 1968. Photo was taken from the R/V Undaunted.

Tuna Fishery Biology

The mission of the Tuna Fishery Biology program is to reach a clear understanding of the characteristics of the six Atlantic tunas of commercial value and their relations to their environment. To reach the goals set for the program, a host of factors must be considered over a long period and an enormous area. Approaches to those factors involve: collection and analysis of biological information from the tropical Atlantic fisheries and from research vessels; study of stock identification and migration; study of tuna forage organisms; and consideration of measures designed to determine the potential optimum commercial yield of the tuna resources. Work carried on by the Tuna Fishery Biology program stresses the synthesis of the mass of information gathered in past years by scientists, fishermen, and other qualified observers.

Program leader John P. Wise directs the activities of six interacting projects: Yellowfin Tuna Biology, Albacore Biology, Skip-Jack Tuna Biology, Bigeye and Blackfin Tuna Biology, Bluefin Tuna Biology, and Tuna Forage Biology.

Important information has been gained from analyses of the detailed information published by the Japanese about the fishing effort and catches of their longline fleet (fig. 17). To date, program personnel have had published six papers that synthesize the Japanese statistics (from 1956 through 1965) into working tools to link fishing effort to fishing success. An analysis of Japanese data covering longline fishing in the Atlantic for 1966 and 1967 is now in progress. The 1956-65 data show that the yellowfin tuna catch per unit effort declined gradually to a 10th of the high reached in the early sixties (fig. 18). Albacore, the second most valuable species to the longliners, more than doubled in importance in the same period, but by 1965 albacore catches, too, had begun to decrease. The Japanese reduced the longline fishing in 1966 and again in 1967 to a point where the 1967 total effort was similar to the 1961-62 average and less than a third of the 1965 level. The abundance (catch per unit effort) of yellowfin tuna increased markedly in the past 2 years in most areas of the Atlantic. The aforementioned declines, as well as the subsequent signs of recovery, were predicted in several reports by the program staff.

Another important source for the Tuna Fishery Biology program is the information obtained from foreign fishery scientists working in the tropical Atlantic, particularly those attached to ORSTOM. Marine biologist Jean-Claude Le Guen (fig. 19), from the ORSTOM station at Pointe Noire, Congo (Brazzaville), has supplied large quantities of working data to program personnel right from the start of the TABL operation; he spent several months at TABL in 1967, working on cooperative studies. Data contributed by such overseas contacts have been of incalculable value to studies of the surface fisheries (live bait and purse seines) for yellowfin and skipjack tunas in the tropical Atlantic.

Program personnel have prepared nearly 20 publications, consisting of original scientific

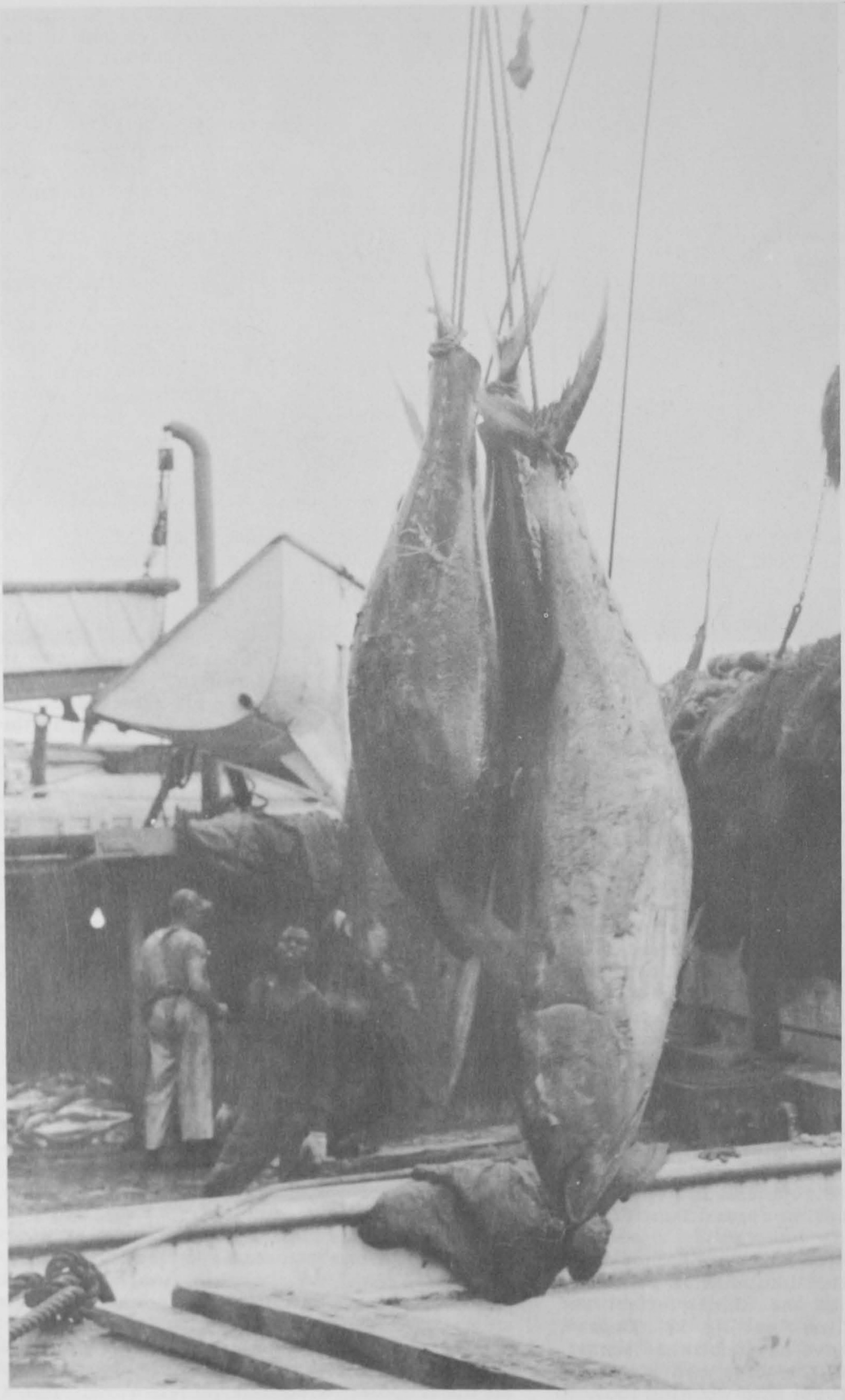

Figure 15.--Yellowfin tunas (about 130 lbs. each) caught by the U.S. purse seiner, San Juan, being unloaded from the vessel at Abidjan, Ivory Coast, in September 1968--for transshipment to Puerto Rico.

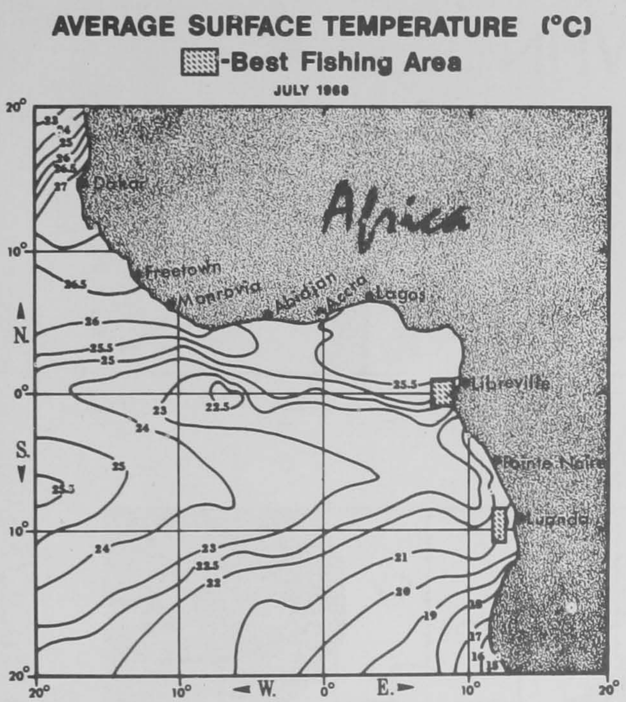

Figure 16.--Average surface water temperature and best fishing areas (July 1968) off the west coast of Africa.

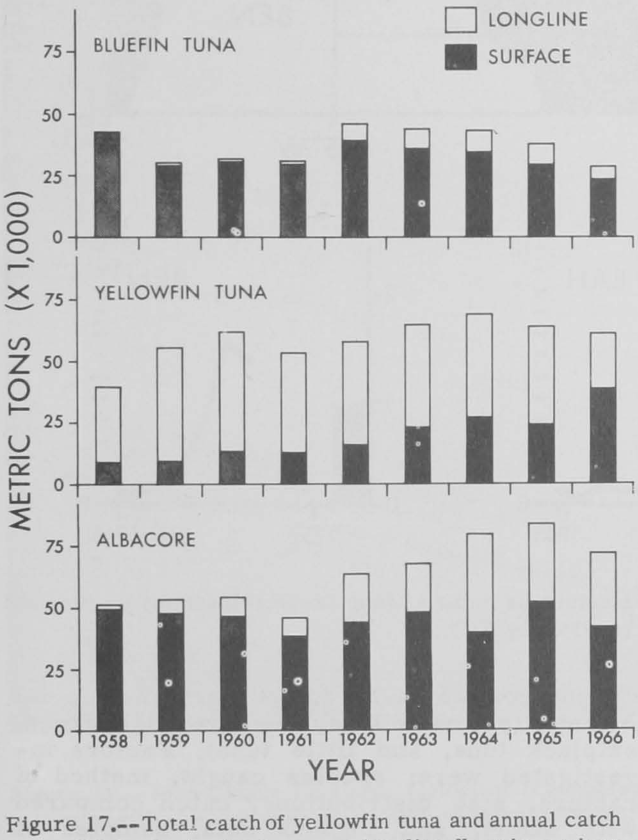

Figure 17.--Total catch of yellowfin tuna and annual catch per 100 hooks by the Japanese longline fleet in various regions of the Atlantic Ocean, 1956-1965.

papers and translations, related to methods used and species of tuna caught in the surface fisheries. Three special informal documents, which gave detailed information about tuna fishing in tropical Atlantic waters, were written and distributed (in 1967, 1968, and 1969) to members of the commercial fishery community. The three reports were prepared to answer queries from fishermen on species and sizes of tuna available, catch figures, the best fishing areas by months, and the most favorable surface temperatures and depths for tuna catches; numerous illustrative figures were included.

In keeping with the importance of catches of yellowfin tuna to the tropical Atlantic fleet, major emphasis has been placed on investigation of the species over the past few years, but other Atlantic tunas have also come under close and continual scrutiny by program personnel. The highly valued albacore (the only truly "white" meat tuna), though more commonly found in temperate or subtropical waters than in the tropical regions covered by TABL research, is an important species to Atlantic fishermen. The large and deep-swimming albacore are caught mostly by longline, but French and Spanish fishermen also have a surface fishery for smaller albacore in the Bay of Biscay and adjacent Atlantic. A major shift in fishing emphasis by the Japanese longliners began in 1964, according to Wise (1968)--from good yellowfin tuna grounds to good albacore grounds--because of declines in the catch rates of yellowfin tuna. Albacore landings by the Japanese in the Atlantic rose from about 600 metric tons in 1957 to more than 39,000 metric tons in 1964. The Albacore Biology project collected and analyzed data on length-frequency and migration for Atlantic albacore. On the basis of Japanese data covering longline catch and effort in the Atlantic, 1957 through 1965, G. L. Beardsley has suggested a broad migratory pattern for the species.

Project personnel have now completed an analysis of the distribution and relative abundance of white and blue marlins in the Atlantic, also based on Japanese records of longline catches.

As a possible means of identifying separate stocks of Atlantic tunas, skipjack tuna samples collected on Undaunted cruises have been surveyed for liver esterase variations, under a contract with the University of Miami. The project, which is based on the hypothesis that the biochemical system in skipjack tuna livers is inherited by each fish from its parents, may shed considerable light on the composition of skipjack tuna populations.

Frank J. Mather III, a scientist on the staff of the Woods Hole Oceanographic Institution, and recognized expert on bluefin tuna, spent the spring of 1968 at TABL where he undertook a comprehensive examination of data on

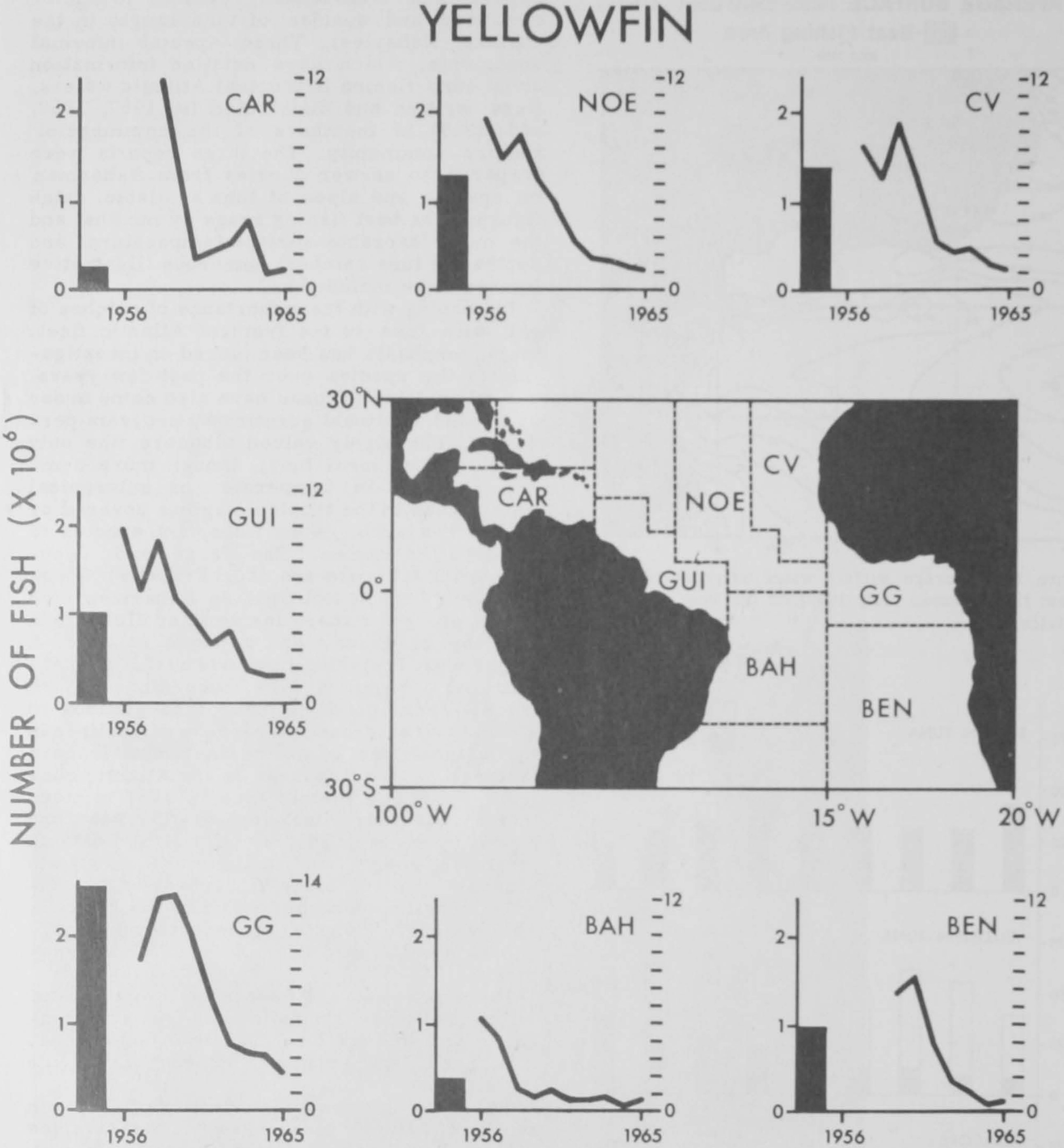

Figure 18.--Estimated catch of yellowfin tuna, albacore, and bluefin tuna in the Atlantic Ocean 1958-66, by longline and surface fisheries. Data provided by FAO.

the distribution and migration of bluefin tuna in the Atlantic.

Under a contract between the BCF and IMS, a TABL technician spent 10 months in west Africa and collected data and samples from tunas at several fishing ports from Dakar, Senegal, south to Moçamedes, Angola. The sampling program was undertaken to provide the basis for an extensive report on the tunas caught commercially in the eastern tropical Atlantic (yellowfin tuna, albacore, bigeye tuna, skipjack tuna, and little tuna). Factors investigated were: species caught, method of capture, size distributions, catch compared with effort, and logbook data. Samples of various organs were removed from tunas, preserved, and returned to either TABL or IMS for study.

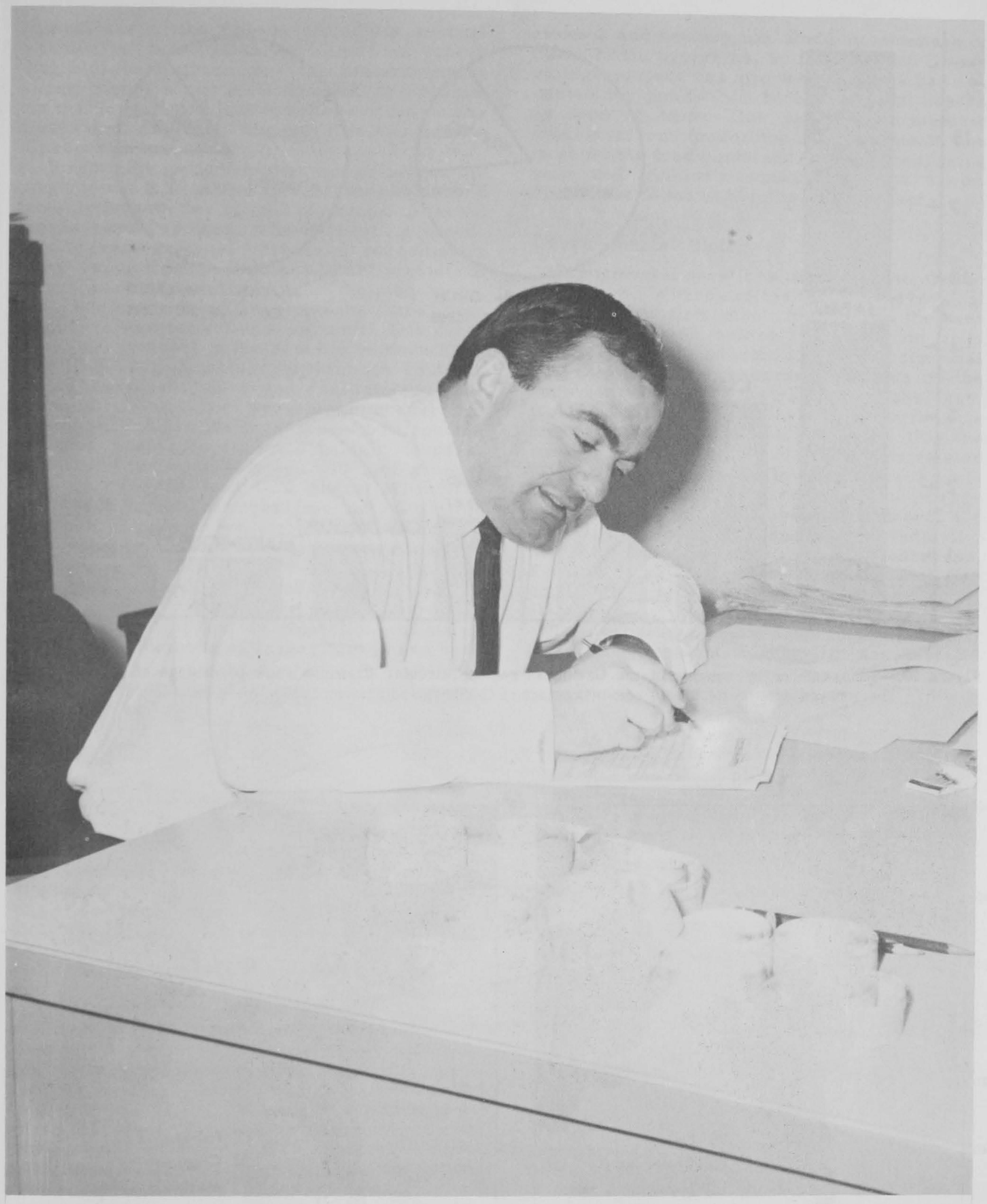

Figure 19.--Jean-Claude Le Guen, biological oceanographer stationed at ORSTOM, Pointe Noire, Republic of the Congo (Brazzaville), spent several months working at TABL in 1966. Much of his study was centered on tuna population dynamics of the eastern tropical Atlantic Ocean.

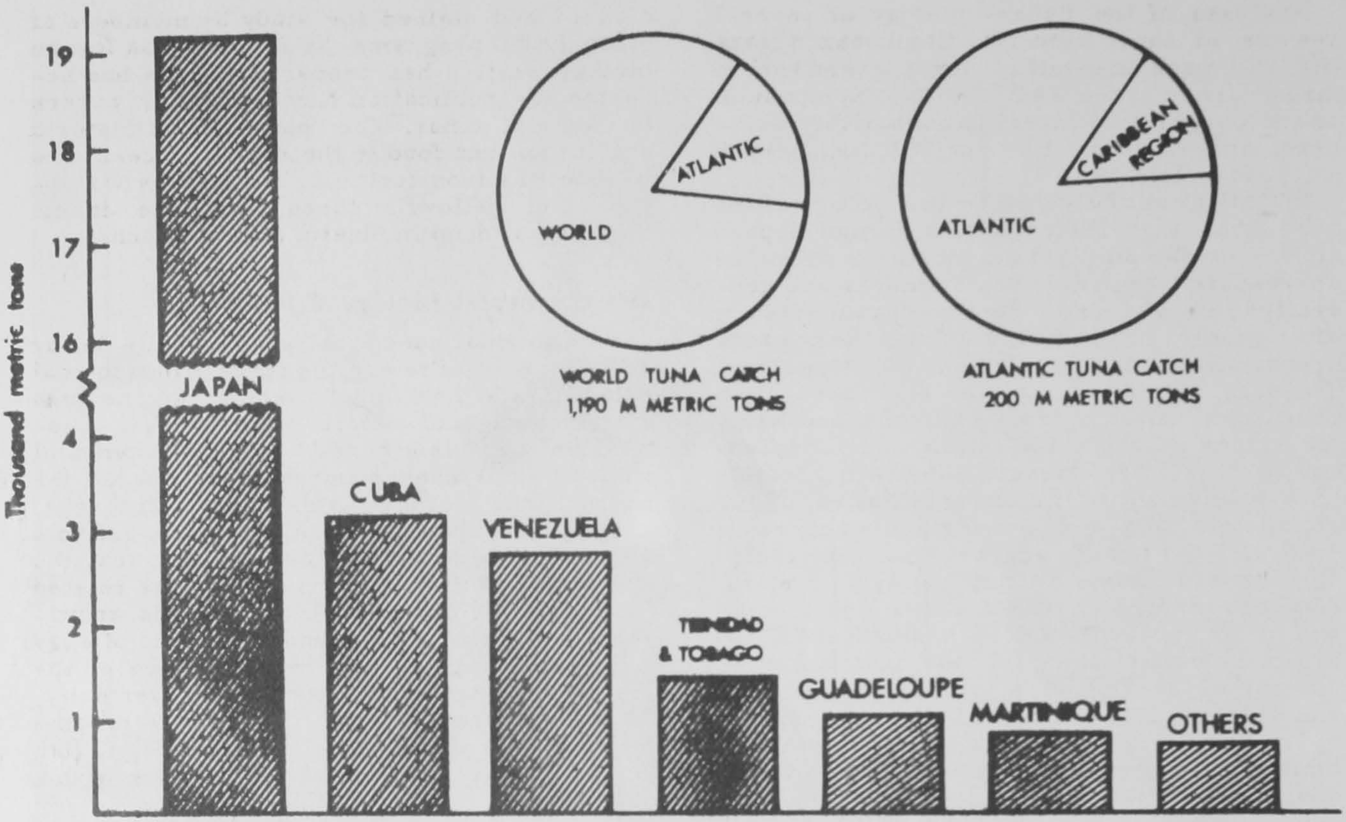

Figure 20.--Tuna catches by country in the Caribbean region; circular drawings show percentage of Atlantic catch compared with world catch, and percentage of Caribbean catch compared with Atlantic catch.

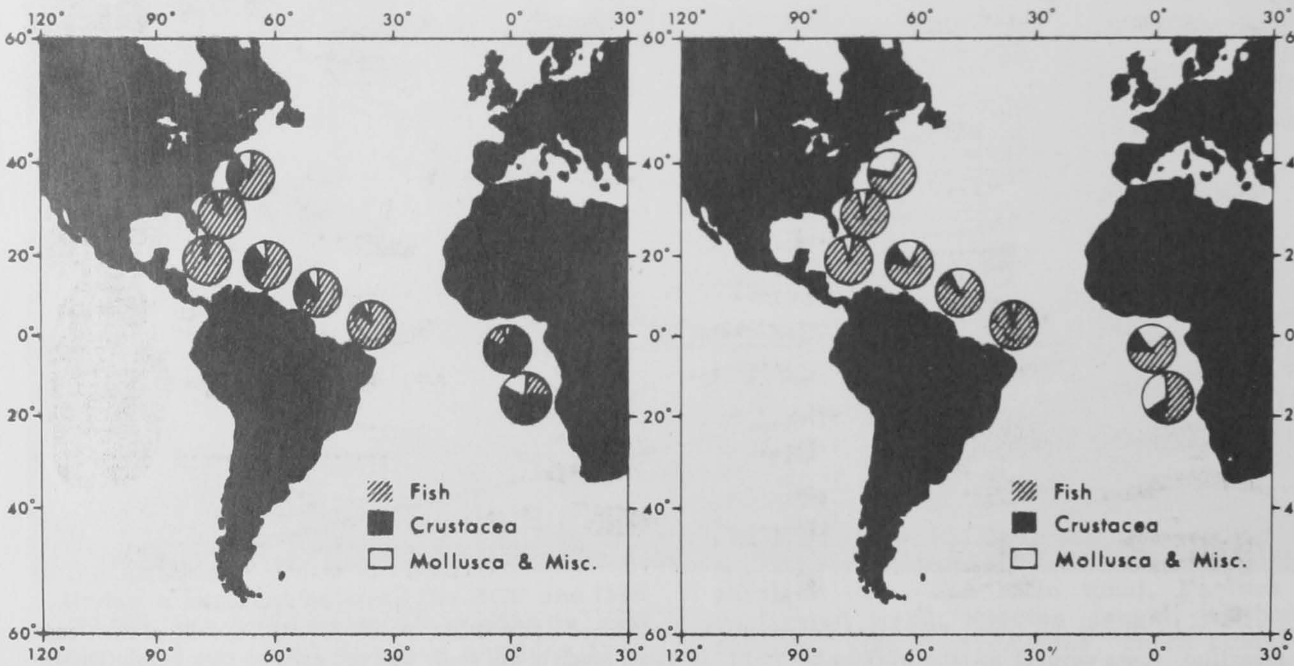

Figure 21.--Percentage frequency of occurrence (A) and volume (B), forage species found in stomachs of yellowfin and skipjack tunas collected in different areas on various TABL research cruises in 1965 and 1966.

Analyses of the fishery biology of several species of tuna found in Caribbean waters (fig. 20) were assembled for presentation in three papers at the FAO/UNESCO Symposium on the Cooperative Investigations of the Caribbean and Adjacent Regions (CICAR), held in Curaçao in late 1968.

Investigations centered on the biology of the organisms that make up tuna forage depend heavily on samples of tuna stomachs collected on research cruises. The stomachs are generally removed and preserved immediately after capture of the fish, and later the contents are separated and analyzed at the laboratory. To date, about 3,000 stomachs have been processed--mostly from yellowfin and skipjack tunas caught in the Atlantic surface fishery (fig. 21). Analyses of stomach contents have been quantitative and qualitative, by the volumetric and the percentage occurrence methods, and results suggest that both species of tuna are indiscriminate pelagic feeders. Although the food of skipjack tuna (168 groups) and of yellowfin tuna (176 groups) consisted of a wide variety of organisms, only a limited number of species were prominent in number and volume. Examination of stomach contents of tunas (fig. 22) has also revealed that the tunas often can serve as collectors of juvenile specimens of their own species: 500 juvenile scombrids identified in collections of material from stomachs of larger tunas have been cleared and stained for study by members of other TABL programs. So far, the tuna forage biology project has prepared and has had accepted for publication three technical papers on food of tunas. One paper is on historic studies of tuna food in the Atlantic Ocean, one is about the food contained in stomachs of skipjack and yellowfin tunas, and one is on organisms found in bluefin tuna stomachs.

Developmental Biology of Fishes

Fundamental questions being investigated by TABL are: Where are the tunas in the tropical Atlantic, and how much fishing can the tuna stocks withstand before the maximum sustainable yield is affected? The Developmental Biology of Fishes program proceeds on the suppositions that the distribution of the eggs, larvae, and juveniles of a population reflects the distribution of the adults, and that the number of animals in each category is related to the number of adults. In other words, knowledge of the distribution and abundance of eggs and young stages is indirect evidence of the presence of the adults and should eventually, therefore, lead to the required solutions. Furthermore, the natural mortalities of fish populations are greatest during the young stages.

The program received its impetus mainly from the Equalant surveys in the tropical

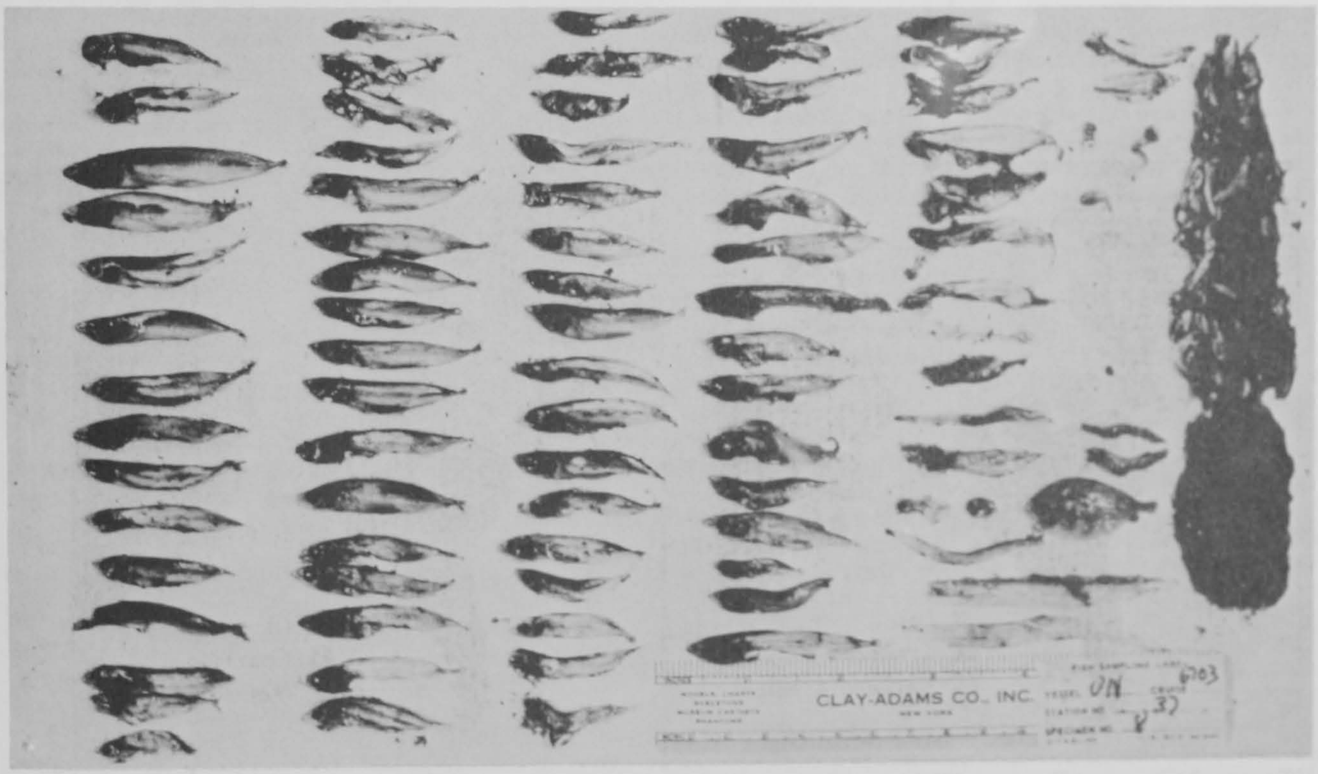

Figure 22.--Contents of the stomach of an 11-lb. skipjack tuna, consisting primarily of juvenile scombrids, and including other fish and a few cephalopods and crustaceans. The mass at right of picture is food in an advanced stage of digestion.

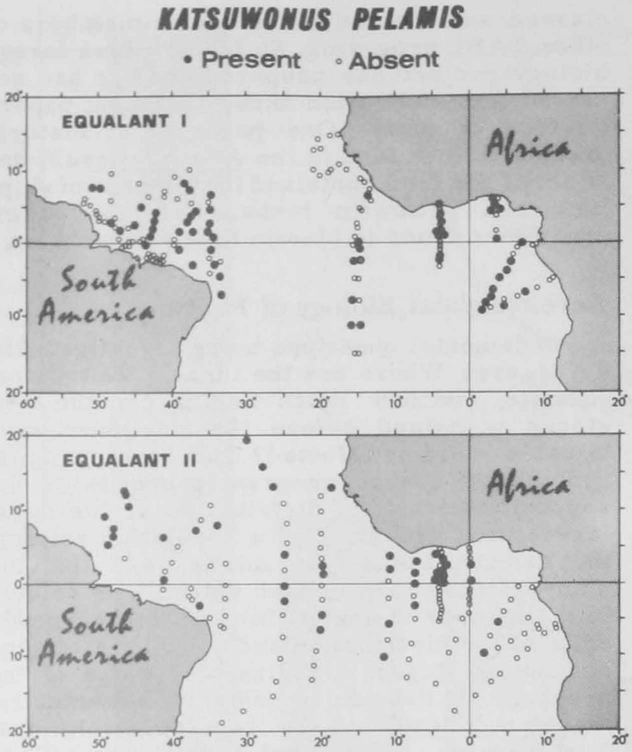

Figure 23.--Distribution and relative abundance of larval skipjack tuna, Equalant I and Equalant II.

Atlantic Ocean in 1963 (fig. 23). The analysis of distribution and abundance of tuna larvae collected on the surveys was the first step in the investigation of Atlantic tuna eggs, larvae, and juveniles. Results were better than expected, good enough to confirm the belief that the tropical Atlantic was rich in the commercially important yellowfin, skipjack, and bigeye tunas. In intervening years, TABL research vessels made smaller, more detailed surveys designed to answer questions posed by the Equalant results and collected mounting quantities of fish samples for study.

The goal of the program is to investigate the biology of a tuna population before it is subjected to commercial fishing. Within that goal, attempts are made to (1) determine the environmental requirements and tolerances of the eggs and the larval and juvenile stages, (2) estimate spawning in a population by studying adult gonads and numbers of eggs and larvae in the environment, and (3) support estimates with detailed information on growth and mortality rates of eggs, larvae, and juveniles.

Program leader William J. Richards supervises the activities of three projects: Distribution and Abundance of Tropical Atlantic Tunas (on the basis of collections of eggs, larvae, and juveniles), Identification of Tropical Atlantic Tuna Eggs and Larvae by Hatching and Rearing Studies, and Reproduction and Fecundity of Tunas. The program is also charged with the design and scientific maintenance of TABL's aquarium rooms, which are used for rearing fish larvae.

The first project involves the study of fish eggs, larvae, and juveniles in plankton collected by research vessels that work over broad areas of the tropical Atlantic and by scientists who sample local waters (fig. 24) and examine stomachs of fishes and sea birds. The organisms in these materials are identified, and subsequent analyses are prepared on the distribution of the animals collected, particularly the tunas. Taxonomic studies are a necessary part of all such identifications, which must be species specific.

It is interesting to consider that sea birds--one of man's most ancient fish-finding aids--also have proved helpful to the TABL tuna developmental program. The stomachs of terns collected near the Straits of Florida contained considerable numbers of juvenile tunas, most of which were readily identifiable to species. A study of these stomach contents showed that terns collected in 1967 in the Dry Tortugas, Fla., consumed a large quantity of juvenile bluefin tuna, evidently from nearby areas.

Two basic approaches are used to solve identification problems. The first is the classical approach in which identification proceeds backwards from the adult, and study is concentrated on characters common to adults and larvae or juveniles. In the second approach, identification proceeds forward--from fertilized eggs obtained from known parents, to adult stages. The first, or classical, approach has been used almost exclusively on tuna identifications (fig. 25). The identification of tuna eggs, larvae, and juveniles has been particularly difficult because the young stages of tunas and tunalike fishes (the scombrids) are morphologically similar and hard to collect. Until it is possible to distinguish the seven kinds of tuna larvae, investigation of tuna populations in the western Atlantic cannot be complete. Recent studies of internal morphology, however, have revealed important differences among genera of tuna larvae.

A study has been completed and published (Simmons, 1969) on the reproduction and fecundity of skipjack tunas collected in the eastern and western Atlantic Ocean, 1964-67. The work was based on examinations of ovaries from 537 fish. Similar studies are either in progress or planned for other species of Atlantic tunas.

A member of the Developmental Biology of Tunas program visited Puerto Rico in late

Figure 24.--A biologist in the Developmental Biology of Fishes program retrieves a plankton net from the ocean. Nets are suspended from a long dock at the rear of the laboratory.

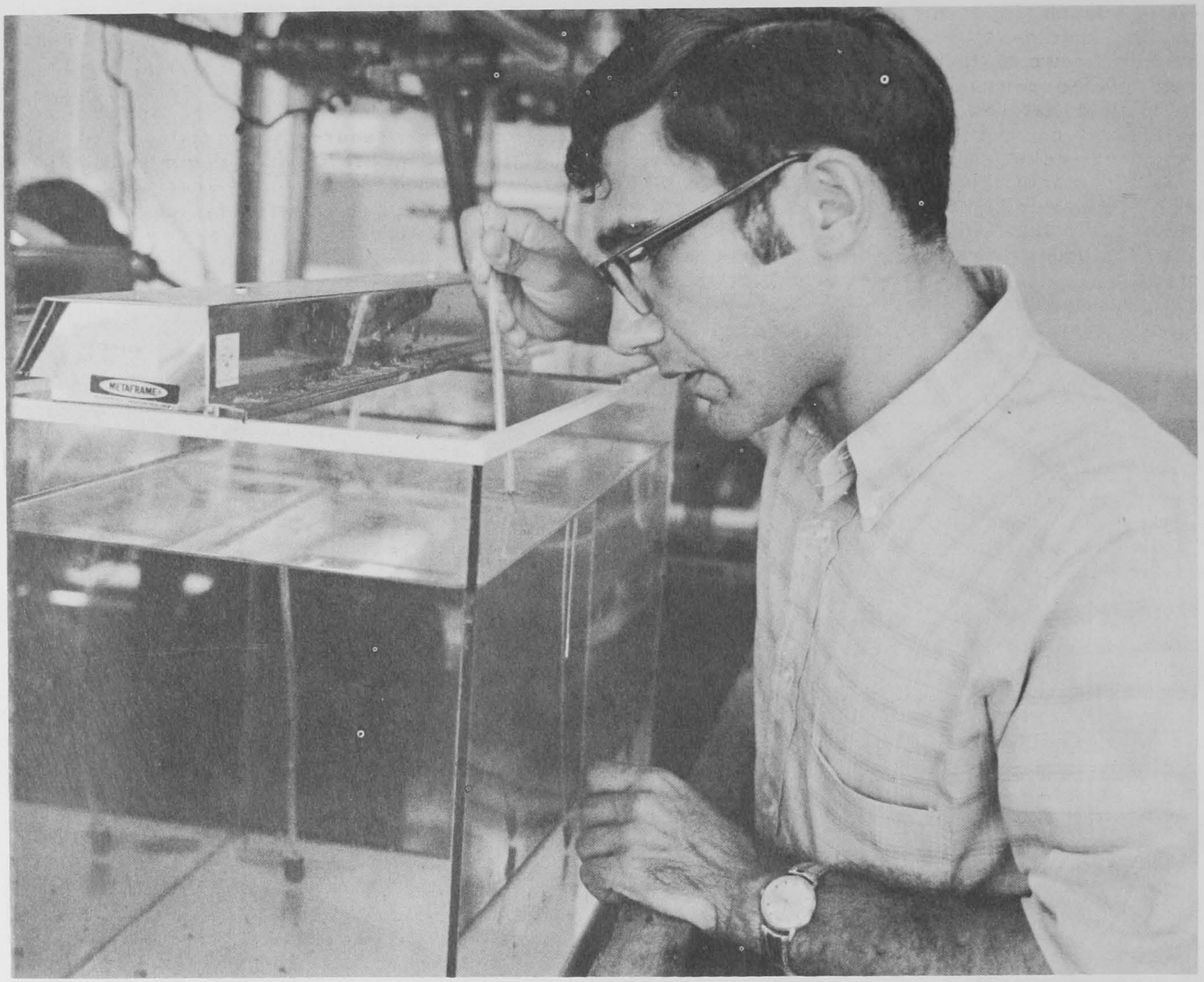

Figure 25.--A BCF biologist retrieving larval fish from a glass aquarium in the hatching and rearing laboratory of the Developmental Biology of Fishes program. (The larvae are not visible in the photograph.)

1968 to sample tunas from eastern tropical Atlantic landings. Samplings included 1,000 lengths of yellowfin, skipjack, and bigeye tunas, and the preservation of 100 gonads and 10 stomachs from tunas. Earlier in the year, the same biologist visited Bimini, the Bahamas, during the annual Bluefin Tuna Tournament and sampled bluefin tunas caught by sport-fishermen.

Studies of the distribution and relative abundance of larval tunas collected in the tropical Atlantic during Equalants I and II have been completed and published; information has been presented on the biology of tunas at several international and national symposia; a hypothesis on yellowfin tuna migrations in the eastern Gulf of Guinea will soon be published in the ORSTOM series; and three data reports have been published by program personnel, covering distributions of tuna larvae collected on three TABL research cruises.

Hatching and rearing studies figure prominently in the developmental research program and appear to offer the most promising method yet evolved at TABL for determining characteristics of growth stages. Project personnel have successfully reared--from egg to juvenile stages--about 30 species of fish including, in 1968, the commercially important thread herring, Opisthonema oglinum. Two rearing efforts were capped by outstanding success last June when ocean-caught tuna eggs were hatched and the larvae reared beyond the yolk-sac stage and kept alive for as long as 20 days--for the first time in the history of marine biology, as far as is known. Several hundred fertile tuna eggs were collected off

Miami Beach in a mixed catch of plankton, but the species to which the eggs belonged was not known at the time. After the eggs had been placed overnight in laboratory tanks, 200 of them hatched into larvae later identified as little tuna. Most of the larvae lived for almost 2 weeks (or about 10 days beyond the yolk-sac stage), and six survived beyond 14 days. In a similar experiment several days later, 1,000 tuna eggs hatched but most survived for only a few days; one of the fish lived for 20 days. At the end of the two experiments, project scientists not only were able to distinguish tuna eggs from others--the eggs were of a specific size, the oil globule was light amber, and the distribution of pigment on the embryo was distinctive--but they had preserved samples of growth stages from egg to juvenile tuna (fig. 26).

Such rearing studies also contribute greatly to knowledge of the factors that affect the survival of larvae, important because most fishery biologists believe that the year-class strength of any population depends on larval survival. The TABL rearing experiments indicated that survival rates improved when the larvae were supplied with carefully selected and sized food organisms. Early in larval life, the fish fed on small organisms measuring less than 100 microns; in midlarval life, the appetite changed abruptly to organisms of 500 microns; and on the basis of research now in progress, another abrupt change may take place at the end of the midlarval life and the fish may eat even larger organisms, including other fish larvae.

Part of the Developmental Biology program is devoted to the evaluation of equipment and methods used in field sampling of fish populations and the preservation of samples. The staff has developed various material for the assistance of field investigators including: instructions on how to identify species of marine life; procedures to be followed in the collecting and preserving of various organs, samples of tissue, and whole specimens; and containers of special design for the delivery of living specimens to the laboratory.

Fishery Oceanography

The principal goal of the Fishery Oceanography program is to supply a description of the physical, chemical, and biological environment (in the lower trophic levels) of the fishes under investigation by TABL. The description is meant to form the basis for (1) a model in space and time of the distribution of the fishes in terms of the changing environmental conditions in oceanic waters, (2) an ecological study of the fishes, and (3) a study of the trophic-level dynamics for the primary and secondary levels.

In the eastern tropical Atlantic, studies of fishery oceanography have been concentrated off the west African coast from Dakar in the north to Angola in the south, with major effort in the Gulf of Guinea and south to Angola. Study in the western tropical Atlantic has extended as far south as Rio de Janiero, Brazil, with emphasis on the Caribbean and the region surrounding the southern Lesser Antilles.

Most of the investigations undertaken by the program have been centered on the ecology

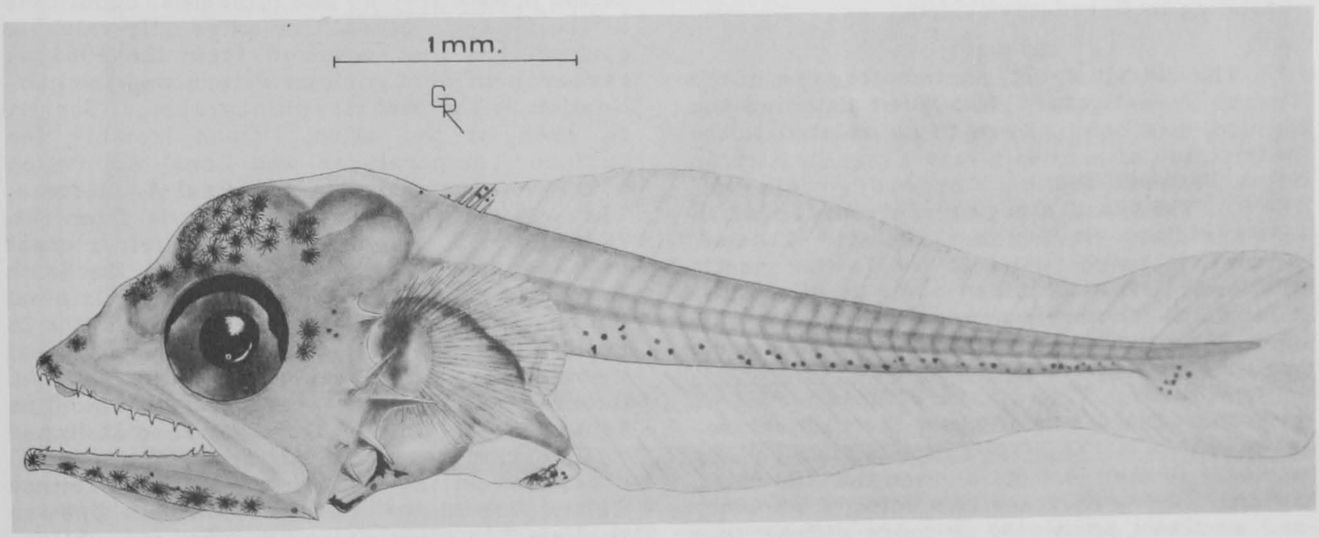

Figure 26.--The drawing is of an 11-day old larval little tuna, Euthynnus alletteratus, which was reared from the egg under artificial conditions at TABL. The eggs were collected in the Straits of Florida off Miami Beach on June 19, 1969. The specimen used by the artist was killed for study on July 1. Of interest are the red pigment cells, which appear as gray dots along spine and lower jaw.

of tunas of the tropical Atlantic Ocean and the Caribbean Sea, but the same studies can be applied to any species of fish in any part of the world ocean. The construction of a distributional model for commercially important fishes is most useful if the determinations are of ecological significance as well as statistical significance. Accordingly, it is necessary--when dealing with such highly mobile species as the tunas--to relate their distribution to the broad and varied conditions found over wide stretches of the ocean, rather than to the necessarily circumscribed data obtained at individual oceanographic stations.

The interrelated but varied support projects that fall under the direction of Acting Program Leader J. Frank Hebard (Merton C. Ingham was in charge until June 1969) are: Interaction of Marine Nutrient Complexes, Sea Surface Surveillance, Primary Productivity, Zooplankton Distribution in the Tropical Atlantic, and Chemical Methodology.

On the basis of data from research in the eastern tropical Atlantic, four oceanic features that have been studied closely are:

1) The Angola Dome, which was described in detail by Mazeika (1967) as a cold-water, subsurface dome that occurs off Angola during the southern hemisphere summer. The doming action causes deep, nutrient-rich water to rise near the surface and results in increased productivity in the waters around the dome. The possible effects of the productivity apparently correlate closely with high catches of tuna "downstream" from the Angola Dome, according to Beardsley (1969).

2) The Berrit Front, named after one of the French investigators who first detected the feature, has been shown to be related to the distribution of yellowfin tuna along the African coast between the equator and Angola (lat. 15° S.). The front, a region of strong temperature gradient (it includes the 24° C. sea-surface isotherm used to locate the frontal position), is established near the equator during the southern hemisphere winter and near Lobito, Angola, during the summer (fig. 27).

Preliminary analysis of data collected on two 1968 cruises confirmed the general relation between the distribution of tuna and the position of the front but showed that the front, at least during its transition between northern and southern positions, is more diffuse than anticipated. It was apparent, though, that the tunas were on the warm side of the thermal gradient (yellowfin tuna at greater than 24° C.; skipjack tuna at greater than 20° C.).

3) The Mauritanian-Sierra Leone Front, which may also affect tuna distribution, is found along the northwest coast of Africa between Cap Blanc and Cap Roxo (fig. 28). The front, as represented by the 24° C. surface isotherm, is at about lat. 10° to 11° N. during January-April, and between lat. 19° and 21° N. during July-September. It is in relatively rapid motion between the two extremes in other months, according to G. R. Berrit, 1961 (Cah. ORSTOM (Office Rech. Sci. Tech. Outre-Mer), Ser. Oceanogr. 13: 715-727) and Mazeika (1968). Preliminary studies at TABL have suggested a close relation between the mean monthly percentage frequency of upwelling winds above 10 knots, and the latitudinal position of the 24° C. sea-surface isotherm. Additional cruises will be necessary to establish whether a connection exists between the front and tuna populations.

4) Seasonal upwelling (a wind-induced offshore transport of deeper water) was evident to observers on three TABL cruises in 1964 and 1965 along the coasts of Ivory Coast and Ghana. Wind data collected during the cruises were used at TABL to test the hypothesis that wind-driven upwelling was responsible for the oceanic conditions observed in the northwestern Gulf of Guinea. Results indicated that the phenomenon is a seasonal manifestation that takes place in July-October and is supplemental to the year-round upwelling induced by currents.

Program personnel have produced eight published documents--atlases and papers--that define oceanographic and biological conditions in the Gulf of Guinea. One extremely valuable contribution that resulted from the 1964-65 research in west African waters was the publication by the American Geographical Society in 1968 of the atlas, "Mean Monthly Sea Surface Temperatures and Zonal Anomalies of the Tropical Atlantic," by Paul A. Mazeika. The area covered by the atlas is from lat. 20° N. to 20° S., and from the African coast in the east to long. 60° W. and the South American coast in the west (fig. 29). Original temperature data were contained on 2.25 million punch cards stored at the National Weather Records Center, Asheville, N.C. An informal atlas that described thermocline depths in the Gulf of Guinea was distributed to fishermen in 1968. An atlas of biological conditions in the northwestern Gulf of Guinea (from Geronimo cruises 3, 4, and 5) was published in 1968. Being prepared for publication is a monthly wind atlas for the eastern tropical Atlantic, in which more than 600,000 observations were used to determine the percentage winds by direction and velocity for 5° rectangles of latitude and longitude.

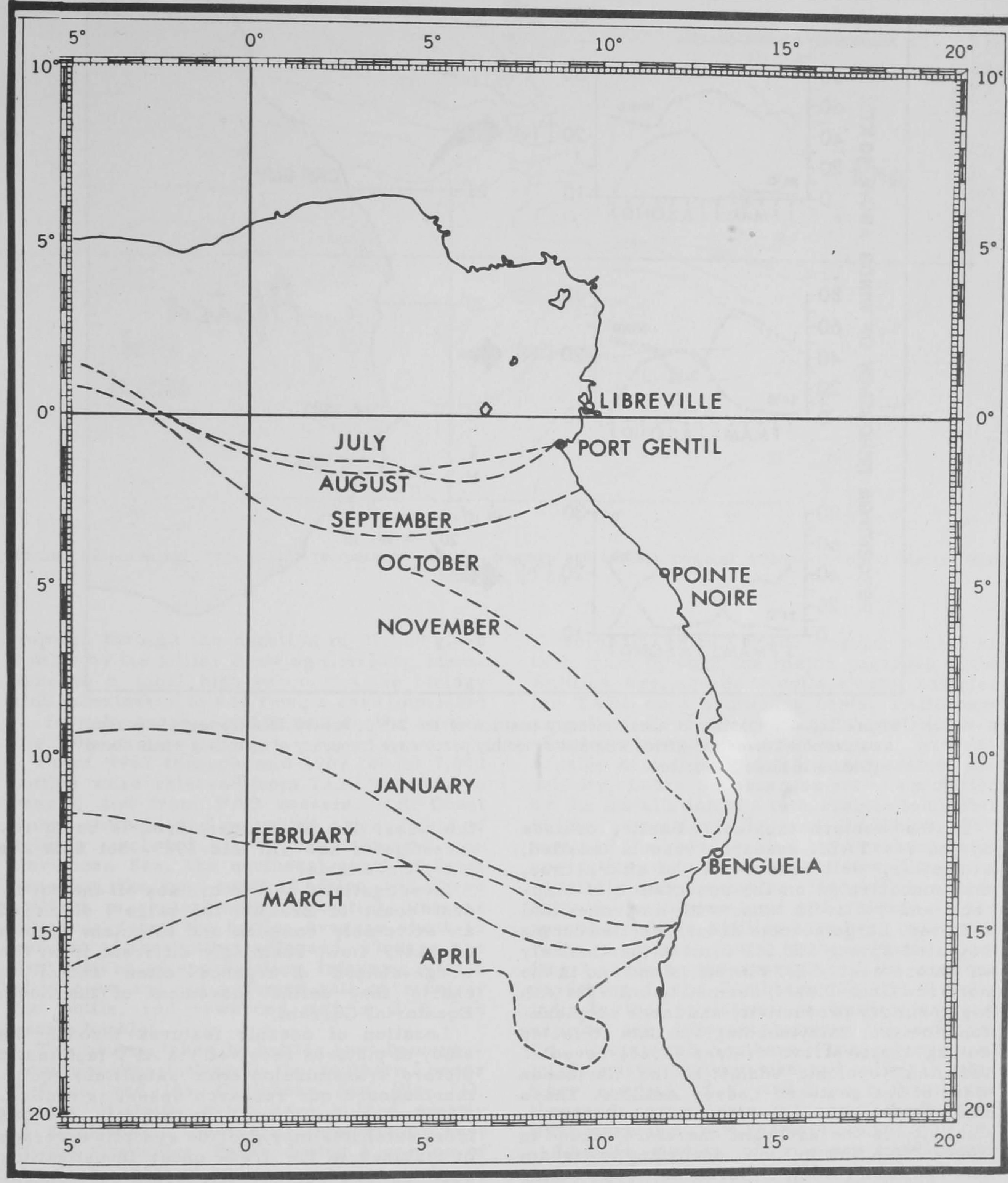

Figure 27.--Monthly position of the oceanic front (24^{o} C. sea-surface isotherm) in the Gulf of Guinea (from Le Guen, Poinsard, and Troadec, 1965, U.S. Fish Wildl. Serv. Commer. Fish. Rev. 27(8): 7-18).

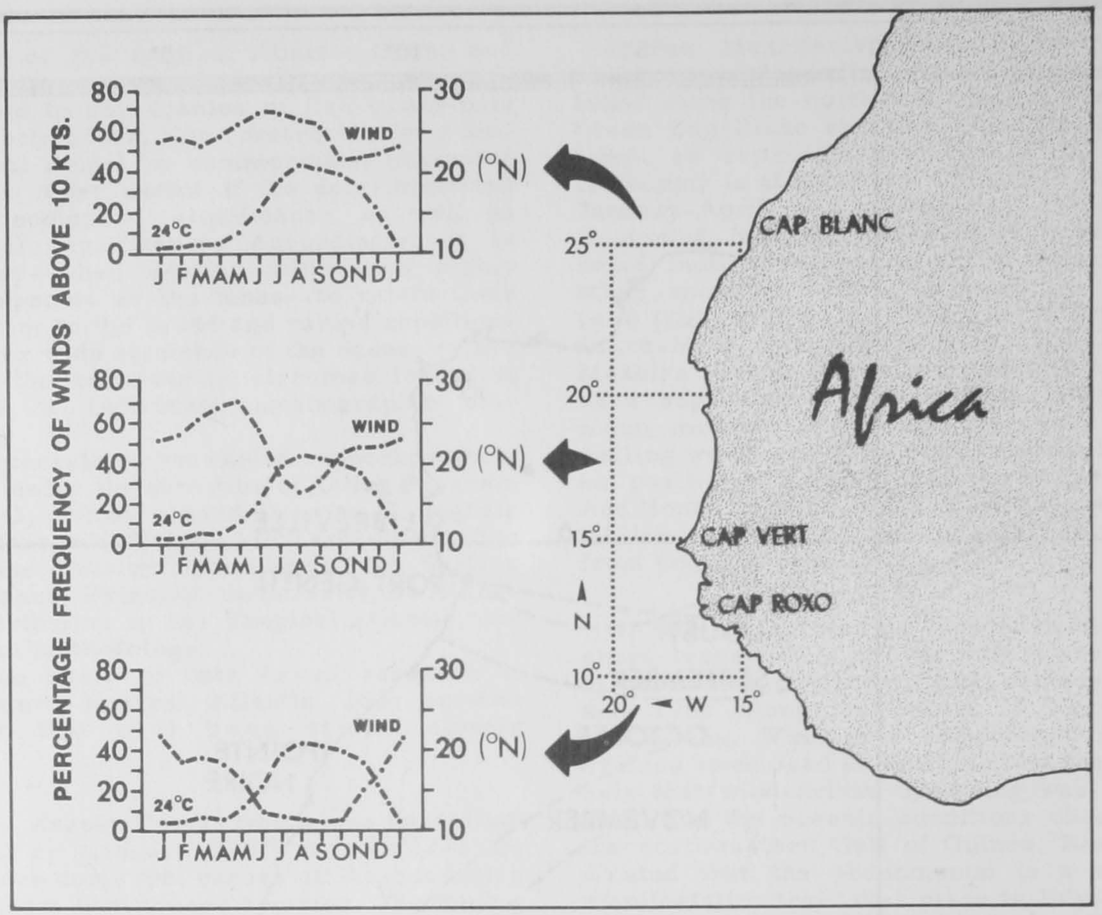

Figure 28.--Comparison of mean monthly position of the 24° C. sea-surface isotherm in coastal waters of northwestern Africa with mean monthly percentage frequency of upwelling winds above 10 knots in three 5° squares.

In the western tropical Atlantic, cruises by the two TABL research vessels entailed, altogether, well over a year of ship's time, and concentrated on the association of skipjack and yellowfin tunas with environmental features. Large schools of tuna, spotted during repeated spring and fall cruises (particularly in waters west of St. Vincent Island and in the northern Grenadines), seemed to coincide with high primary productivity and large zooplankton biomass. Bathythermograph data collected during the first two cruises (1966) revealed turbulent cyclonic eddies in the Caribbean west of the southern Lesser Antilles. These eddies may have caused an increase in productivity in the area and therefore tended to concentrate tuna schools, according to Ingham and Mahnken (1966). Differences were striking between the waters to the east and those to the west of the archipelago, in their patterns of current and color, and the transparency of the water. A third survey of the same region in the fall of 1966 found large tuna schools again, but the downstream eddy system was not as pronounced as it was earlier in the year. The St. Vincent area is being reinvestigated now--in mid-1969--but data are not yet available.

Investigations on two cruises off the northeast coast of Brazil ("the bulge") disclosed an extremely complex and turbulent system of water flow, seemingly different from the wedge-shaped divergence often shown on charts that define movement of the South Equatorial Current.

Location of oceanic features through the study of pictures received via APT (automatic picture transmission from satellites) equipment aboard our research vessel is routine. TABL oceanographers hope that data received from satellites may provide synoptic coverage of features in the areas under investigation, such as sea-surface temperatures, concentrations of phytoplankton and zooplankton, and even the distribution of tuna schools.

One of the projects of the Physical Oceanography program (begun in 1967) is the study of surface currents of the Caribbean through the use of drift bottles and "ships of opportunity." The project was given unexpected

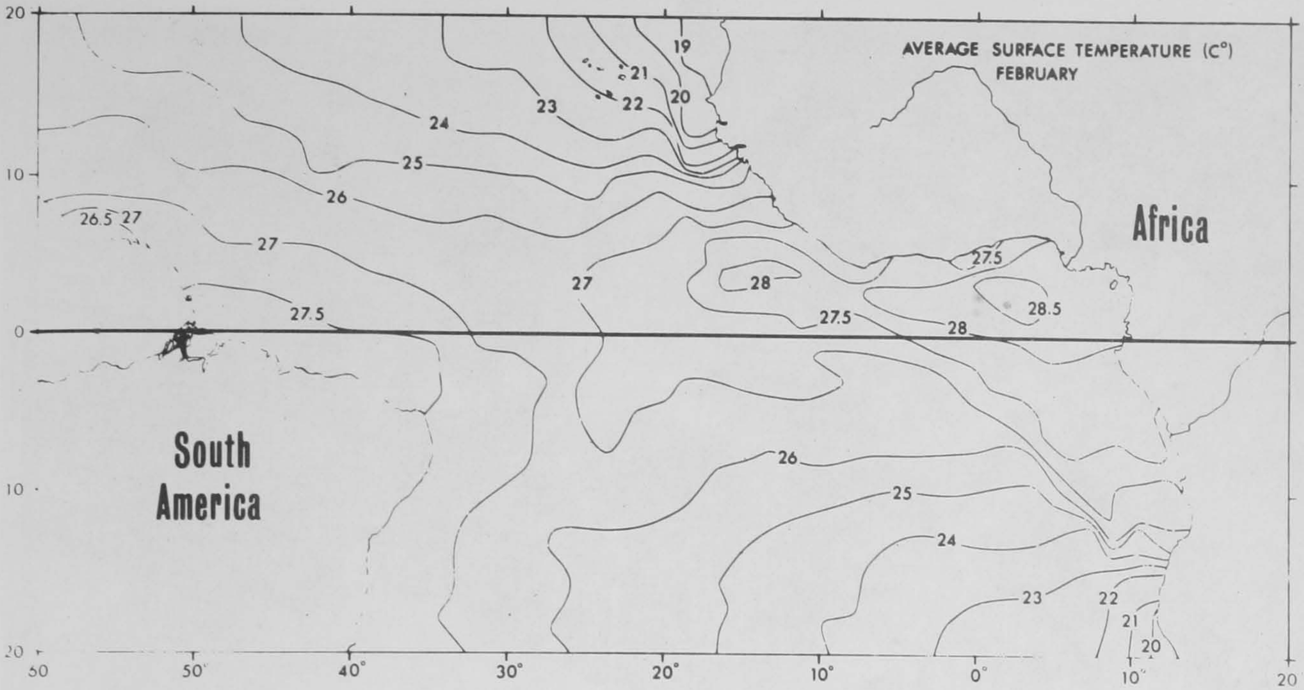

Figure 29.--Average sea-surface temperature in the western and eastern tropical Atlantic Ocean in March (from Mazeika, 1968).

impetus through the donation of 20,000 glass bottles by the Miller Brewing Company. Members of a local high-school marine biology club volunteered to add sand, a card imprinted in four languages, and a seal to the bottles (fig. 30).

From 1967 through mid-1969, about 7,000 bottles were released from TABL's research vessel, and from FAO vessels, U.S. Coast Guard cutters, and merchant ships. Areas of release included the Florida Straits, the Caribbean Sea, the northeast coast of South America, the west coast of Africa, and (three bottles) in regions near Antarctica. Returns of cards from the bottles average about 15 percent of the bottles released. Finders are sent letters of appreciation, informed of date of release and the assumed path of travel by the bottle, and rewarded with a BCF fish recipe booklet.

The routes taken by bottles have been particularly illuminating in the southern Lesser Antilles and the Caribbean Sea (fig. 31). Routes of drift, which have helped greatly in studies of a divergence immediately east of the Grenadine Banks during a portion of the year, seem to indicate that the southern extension of the divergence enters the Caribbean through a passage between Grenada and Trinidad, and that--contrary to existing literature on the subject--the northern extension flows north on the Atlantic side of the Antilles Arc. In the western Caribbean, drift routes have helped to define eddies in the Gulf of Honduras and along the north coast of Panama.

Merchant ships, whose regular schedules take them through the major passages of the Antilles Arc, agreed to collect water samples for TABL on a continuing basis. TABL personnel at first designed and constructed a simple, inexpensive sea-surface sampler capable of obtaining data on temperature and salinity. Later the arrangement was modified by the installation of a temperature telemeter in the sea-water intake of the ships. Now most of the data donated by merchant ships are gathered in this fashion rather than from "over the side" samples. Since 1967, observations on temperature and salinity in the passages of the Antilles have been made on a twice a month basis, with additional help from various oceanographic field stations nearshore in the Caribbean (fig. 32). Results indicate that variations in temperature and salinity are different between the northern (St. Croix) and southern (Tobago) regions. In the north, temperature and salinity variations reached 3° C. and 1 p.p.t. (parts per thousand) respectively; in the south the fluctuations were 1° C. and nearly 4 p.p.t.

TABL's studies of primary productivity are directed at consideration of the various mechanisms that produce the primary organic matter of the sea and how numerous environmental factors affect such mechanisms. The ultimate aim of the project is to predict times and places of abundant production of phytoplankton (plant life), which marks the beginning of the formation of commercially important food from the sea. The process,

Figure 30.--Members of the Coral Gables High School (Florida) Marine Biology Club helped fill 10,000 drift bottles when the drift project began in 1966.

generally referred to as the marine "food chain" or "food pyramid," begins with phytoplankton, the pastureland of zooplankton (minute animal life); zooplankton, in turn, forms the food supply of small fish; small fish become forage for larger ones; and so on, to the top of the chain, which includes species of commercial value to man. Originally TABL's approach involved measurement of the uptake of radioactive carbon by phytoplankton (nearly 1,000 samples in the Atlantic Ocean and the Caribbean Sea) collected at various depths and then incubated on the deck of the research vessel (fig. 33). Later the collection of data on plant pigmentation and phytoplankton cell counts was added to sampling routines. Still more recently, measurements of biochemical and physiological elements became part of the primary productivity project. Examples of current experiments are: comparison of the rate of production and excretion of organic compounds by marine phytoplankton; determination of the rate of increase of protein, nucleic acid, carbohydrates, fats, and various enzymes in natural populations of marine phytoplankton; use of autoradiographic techniques for measuring the standing crop of marine phytoplankton; study of the significance of the uptake of radioactive carbon in darkness by marine phytoplankton; and selection of phytoplankton species within the food chain that are significant to marine organisms of commercial importance.

The study of the distribution of zooplankton follows two paths: estimates of biomass and the distribution by species. Biomass estimates are made from the displacement volume of each sample and reported in milliliters per 1,000 cubic meters. Such estimates provide details on the standing crop of zooplankton at time of sampling but none on the dynamics or turnover rates. Biomass volumes have shown a positive relation to upwelling, particularly along the northwest coast of Africa (near Sierra Leone), along the coast of the Gulf of Guinea (Ivory Coast and Ghana), along the coasts of Venezuela and northern Honduras, and in the Caribbean Sea west of the southern Lesser Antilles. Although biomass data do yield valuable information about total amounts of food in a given area, the information is regarded as extrinsic to a degree--since TABL's main interest is in tuna--unless and until more is known about a relation between the biomass and the selectivity (or "preferences") of larval tunas. (Put in a highly simplistic context: If, for instance, a researcher should find quantities of vigorous

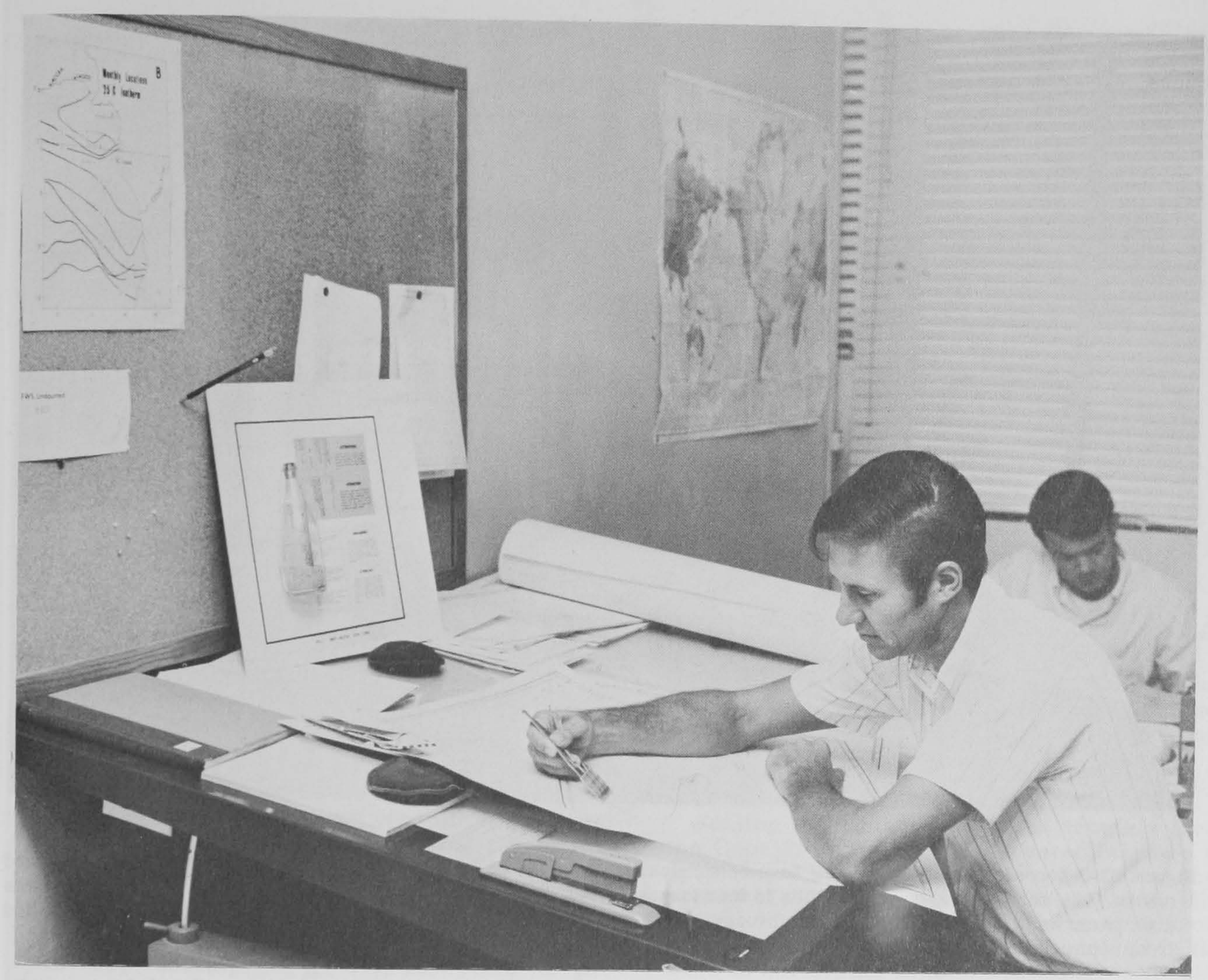

Figure 31.--A BCF oceanographer calculating speeds of drift bottles. Typical drift bottle and enclosed card are shown, propped against bulletin board.

larval tunas again and again living in a community heavily populated by other species minute enough to serve as prey for the larval tuna, he can assume--if he finds the other species in tuna stomachs--that the tunas thrive on a diet composed of their smaller neighbors.) Project personnel believe the best approach is to study those zooplankton species most frequently found in association with larval tunas, in the hope that gaps will become progressively narrower and exact associations can be confirmed between tuna larvae and their natural forage. On the basis of the large quantities of zooplankton collected on Equalants I and II, the association analyses so far completed--on tuna larvae, copepods, and chaetognaths--have defined five species associations that show distributions related to geographic areas in the tropical Atlantic. Those distributions are: cosmopolitan, southern-cold water, bathypelagic, central tropical, and coastal tropical. A former project leader in the Physical Oceanography program completed and published (in 1969) a study of primary organic production and zooplankton standing stock in the tropical Atlantic.

Another phase of the program is the testing and development of devices that can collect samples of plankton at peak efficiency. The necessity for quantitative measurements of the zooplankton community is well known, but data on volumes of water filtered by commonly used samplers have been at times difficult to calculate, and repeated evaluation has been necessary to solve attendant problems. Experimentation involving the hydrodynamics of collecting nets and the placement of flowmeters began early in TABL's history and has continued. Personnel involved in this series of experiments have discussed--in six published or ready-to-publish papers--designs, filtration efficiencies, speed of towing, flow patterns (inside and in front of the nets),

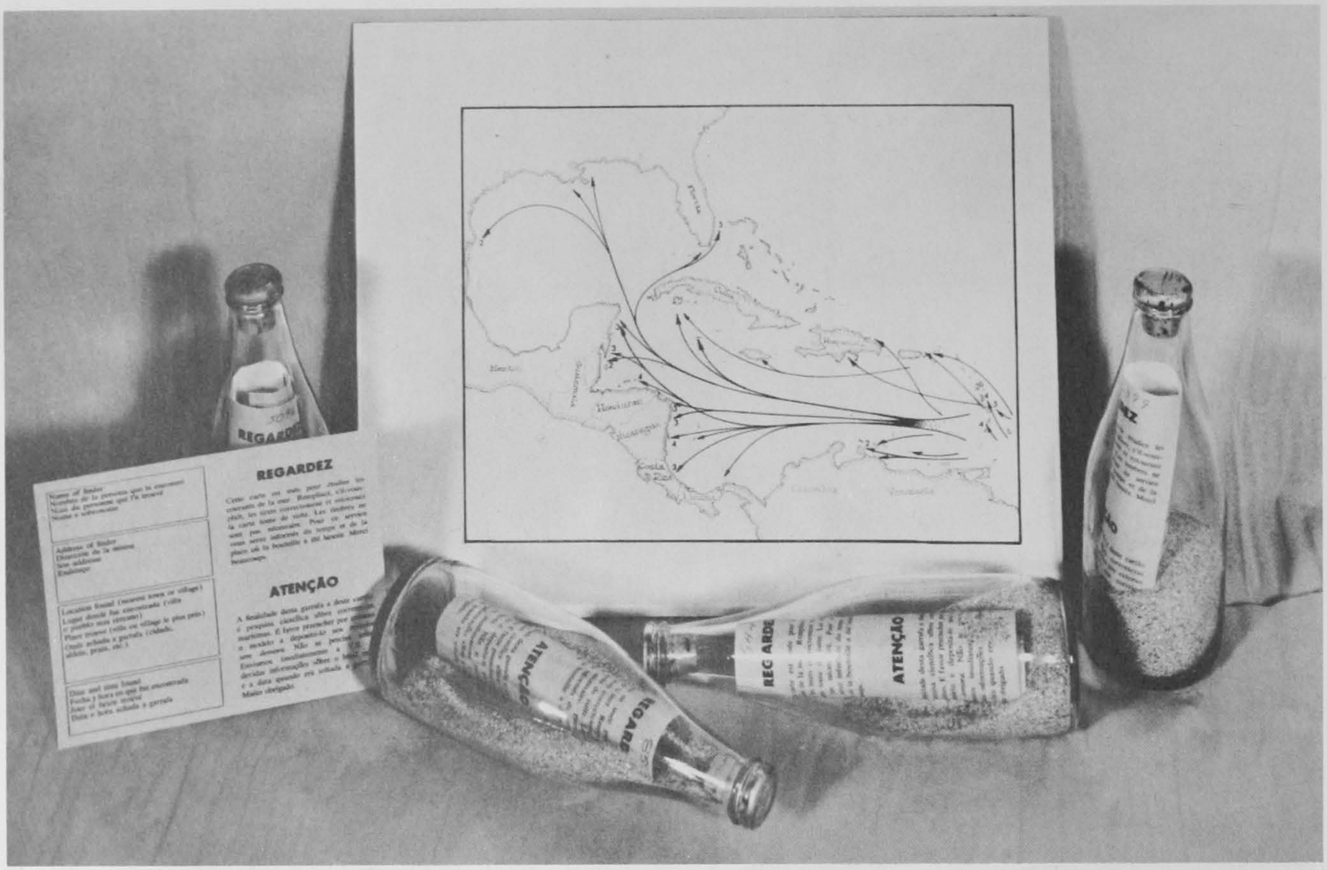

Figure 32.--Thousands of drift bottles have been released to waters of the tropical Atlantic Ocean by TABL vessels and others. The card inside the bottle tells in four languages how finders may return the card to TABL. The figure shows drift patterns of bottles released in February-March 1967 from Undaunted cruise 6701 (Caribbean region), as plotted from returned cards.

avoidance, sample condition and sample escapement, towing characteristics, and stretching of net material during tows. In addition, an annotated bibliography of zooplankton sampling devices developed since the cruises of H.M.S. Challenger in 1873 is well underway. Two members of the program have developed a modification of the plankton volume gage for use aboard ship, a description of which has been published (Tashiro and Hebard, 1969).

The chemical methodology project furnishes the analytical data on chemical properties of sea water--mostly salinity, oxygen, and phosphate. Part of the project's responsibility is the development of new and improved techniques for determining chemical concentrations in sea water. Such techniques contribute to the most precise possible description of the physical and biological environment. The project ranges over a broad spectrum of chemical experimentation that has resulted in: significant improvements in the estimation of phosphate in sea water; increased knowledge on the source of errors in inductive salinometry (fig. 34), which led to a new technique for reducing bubble formation; a simple, inexpensive method (for laboratory use) for determining salinity by differential weighing; and the development of a technique for determining the "salinity equivalent" in fresh well-water. The project is now devoting major attention to the nitrate cycle of the sea. Work continues on the histochemical aspects of a biological preservative developed to meet the problem of color loss in specimens fixed in formaldehyde and alcohol; application has been made for a patent covering the process; and a description of the process is being prepared for publication.

The Calico Scallop Biology Program

The newest of the TABL programs springs from investigations begun in earlier years by the BCF Exploratory Fishing bases at Pascagoula, Miss., and St. Simons Island, Ga. In January 1960, the BCF-chartered research vessel, Silver Bay, discovered a large population of calico scallops on grounds covering about 1,200 square miles near Cape Kennedy, Fla. The beds lie at depths between 15 and 30 fathoms, and extend along more than 200 miles of the Florida coast, roughly from St. Augustine south to below Fort Pierce (fig. 36).

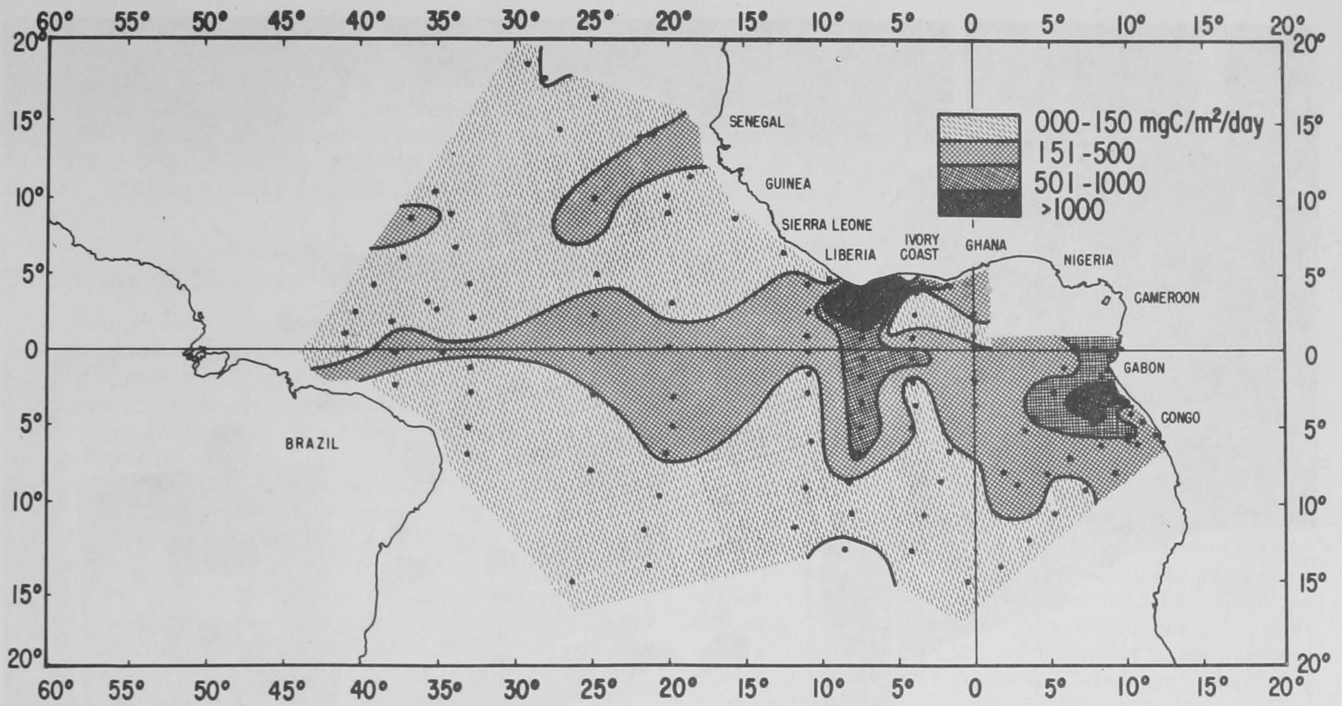

Figure 33.--Correlation between uptake of carbon-14 and physical oceanographic features, on the basis of data collected during Equalant II (August, September, early October 1963). Areas of high uptake off Gabon and Senegal are associated with seasonally migrating thermal fronts. Carbon-14 uptake is high along Liberia and Ivory Coast, also an area of upwelling. A thermal anticline exists along the equator during the season indicated.

The calico scallop, an inhabitant of warm temperate waters, is found along the southeastern coast of the United States, in the Gulf of Mexico, and as far south as Brazil. Calico scallops, so called because of the mottled appearance of their shells, are closely related to bay scallops (fig. 37), but yield larger quantities of edible meat owing to an unusually large adductor muscle. The discovery of plentiful stocks of calico scallops may be of great significance once full production is achieved, particularly in view of the reduced U.S. landings of scallops in recent years. If the potential yield from the Cape Kennedy source--which some BCF personnel have estimated at more than 300 million pounds of meats per year--is realized, the fishery could become one of the most valuable in the United States. Five vessels equipped with newly developed devices for mechanical shucking began dragging on the calico scallop grounds in 1969, but results were only fragmentary at the time of writing.

A study of the life history of calico scallops began in late 1968 at TABL, under the leadership of Thomas J. Costello. The purposes of the program are to (1) determine time of spawning, (2) study larval development, (3) determine time and space variations in spat setting, (4) establish methods for age determination, (5) determine growth rates, and (6) study mortality.

Scallop specimens are taken monthly from the Cape Kennedy grounds to establish time of spawning. Preliminary work indicates that color of the fresh gonads varies with the degree of sexual maturity, as determined from histological sections, and may be used in the field to determine time of spawning.

Adult scallops were induced to spawn in aquariums; the larvae, which were fed cultured phytoplankton, survived to the veliger stage (in which the shell and foot are developed). Observations were made of the characteristics and the development times of eggs and larvae during the 5 days of survival. Descriptions of larvae from this and future rearing experiments will be useful in identification of larvae in plankton collections.

To determine age and growth, live calico scallops were captured, marked, placed in cages, and returned to their natural enviroment in 12 fathoms, off Cape Kennedy. The object of the experiment was to establish whether scallops form growth rings on their shells at regular time intervals. Results obtained were similar to those reported for certain other mollusks, i.e., clear sculptured ridges formed on the shell as size increased. The results of the study, though not conclusive, suggest that not more than one growth ring is added per day (fig. 38).

Preliminary observations suggest that predators and parasites cause substantial

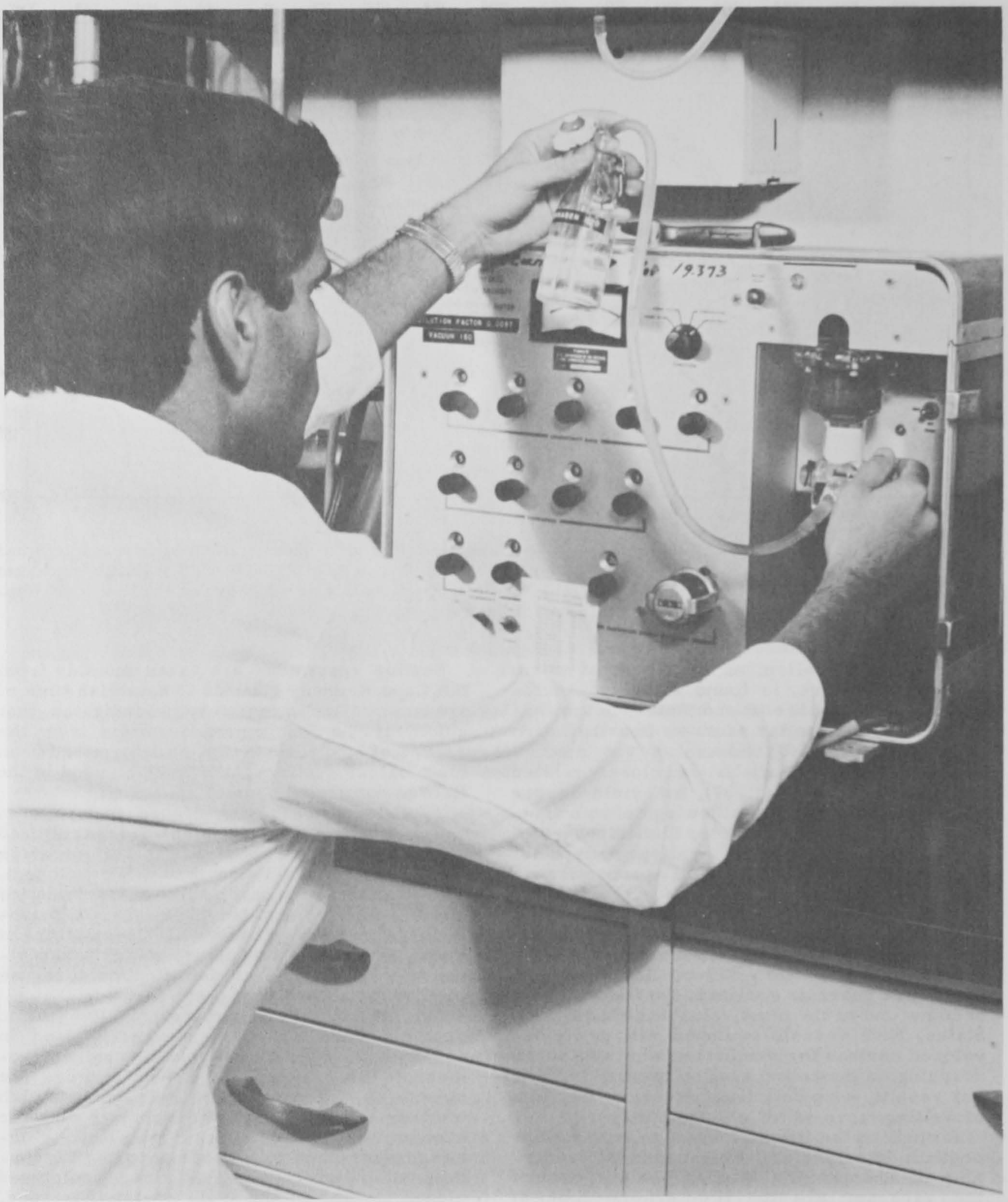

Figure 34.--A TABL chemist runs salinity analyses on the portable inductive salinometer at the laboratory. The salinometer is also used aboard the Undaunted.

mortalities. Scallops held in cages were drilled by gastropods and attacked by starfish. Fouling of scallops by many marine organisms often prevents complete shell closure and may facilitate predation. In addition, parasites that infest scallops may affect the reproductive organs.

Taxonomy of Clupeoid Fishes

A few months ago, the more broadly based Systematics of Fishes program was revised, to become the Taxomony of Clupeoid Fishes program. As such, the program concentrates its investigations on the commercially important clupeoid fishes of the western Atlantic area -- herrings, sardines, anchovies, and the like. Program Leader Frederick H. Berry has devoted his efforts to augmenting the program's already impressive collection of clupeoid fishes. He has received hundreds of new specimens collected from other systematists and biologists stationed throughout the tropical Atlantic region (fig. 39). The program will attempt to resolve a number of questions concerning the exact identities of certain clupeoid fishes found in the western Atlantic, the Gulf of Mexico, and the Caribbean Sea. The program has been working for some time on a field guide to some 40 species of clupeoids from those areas.

The Systematics of Fishes program was originally established at the BCF Biological Laboratory at Brunswick, Ga., but became part of the TABL research complex in 1965. The program's fundamental aim was to study, comprehend, and clarify the taxonomy and relationships of marine fishes. Strong emphasis was placed, naturally, on those species with actual or potential commercial importance in the western Atlantic. Knowledge was lacking or inadequate for many of the several thousand species of marine fishes of the tropical and subtropical Atlantic Ocean. The program's main concerns, therefore, were to improve the knowledge of the taxonomy of those species, to uncover principles of morphology and ontogeny that would assist in studies of early development and life history, and to provide means for ready identification of various fishes.

Two fish families came under close scrutiny on a worldwide basis: the clupeoids and the carangids (jacks, scads, pompanos, ...) (fig. 40). The clupeoid studies included description of a new species of bait fish (the Marquesan sardine); rediscovery of the striped herring off Venezuela; reanalysis of the western Atlantic thread herrings, scaled herrings, and Spanish sardines; and a revision of the American "bloodless clupeoids" (pristigasterids). The carangid investigations dealt with the description of a new species of mackerel scad and comparative analysis of the other three Atlantic species of the genus; the morphology and ontogeny of the rainbow runner; reanalysis of the four species of the moonfishes from the eastern Pacific, the western Atlantic, and eastern Atlantic; a diagnosis of the nine species of jack crevalles of the world; an analysis of the 23 species of pompanos of the world; and study of cottonmouth jacks.

Soon after Systematics personnel were transferred from Brunswick, a major part of the accumulation of the Atlantic marine fishes that had been collected over a long period was also transferred to Miami.

Since 1965, the TABL fish collection has been expanded by about 25 percent through the addition of specimens collected by TABL researchers and donated by other marine science establishments. The collection now is very possibly the largest and most varied assortment of clupeoids and carangids in existence. Members of the program have collected many specimens on research voyages to the Gulf of Guinea, Honduras, the Caribbean region, and in waters between Florida and the Bahamas. Additionally, the program leader acquired hundreds of specimens from the Indian Ocean on a trip to India in 1966. The collection is of value not only to TABL researchers but to other ichthyologists and biologists throughout the world; an exchange of specimens on a reciprocal basis has existed for some time between TABL and other establishments and workers.

Two additional field guides--one on the carangid fishes of the western Atlantic, and one on the clupeoids of the Indian Ocean--are being prepared.

The array of subjects investigated by the program over the years is too diversified to discuss at length, but in addition to studies of the clupeoids and carangids, research has included: a review of the eastern Pacific hakes; study of the macrourid rattails, with a revision of eastern Atlantic forms; study of the taxonomy and ontogeny of the deepsea Giganturiformes; and study of species of searobins, needlefishes, filefishes, triggerfishes, croakers, boarfishes, and others (fig. 41).

For part of 1968, the program leader investigated the culture of Florida pompano, in cooperation with IMS and the Miami Seaquarium. Juvenile pompano were successfully reared in specially constructed pompano ponds near TABL, and results of the experiment were highly encouraging.

A new zoogeographical concept was advanced by Systematics personnel, based on studies of the distribution of armored searobins and other fishes, to wit, that the Antillean region acts as a barrier to the northward dispersal of many South American marine fish species. The barrier consists of water temperatures, currents, bottom types and habitats, and bottom topography combined with extreme depths. The transition zone between the South American and

Figure 35.--An aerial view of Virginia Key, Miami, Fla. Miami Beach can be seen at top left of picture; the Atlantic indicate: (1) site for the Marine Science Technology Center, Miami-Dade Junior College; (2) the Miami Seaquarium; Atmospheric Sciences (formerly the Institute of Marine Sciences), University of Miami; (5) TABL. The collection of

Ocean is at top of photo, Biscayne Bay is at bottom. Bridge at right spans Bear Cut and leads to Key Biscayne. Numerals (3) site for the ESSA Atlantic Oceanographic and Meteorological Laboratories; (4) the Rosenstiel School of Marine and scientific establishments is called "The Virginia Key Marine Science Complex."

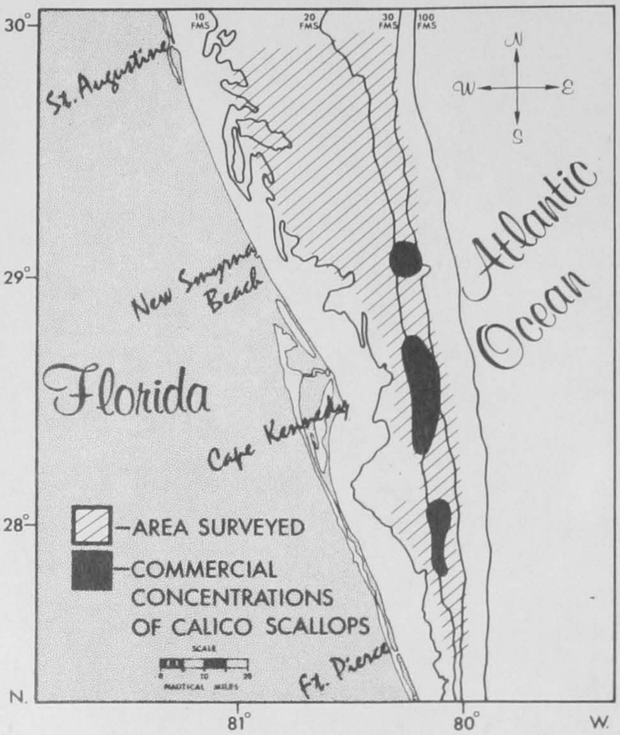

Figure 36.--The calico scallop beds along the east coast of Florida. TABL, in Miami, is about 125 miles south of Fort Pierce.

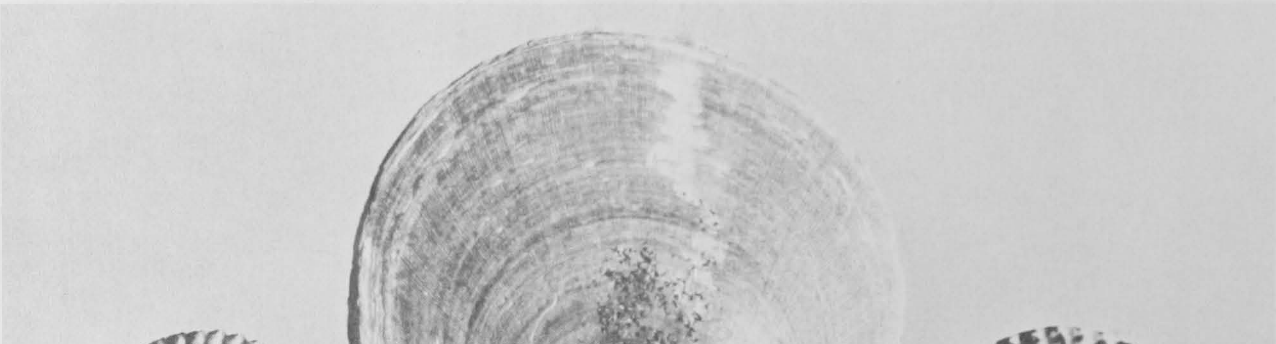

Figure 37.--Comparative sizes of shells of commercially valuable scallops. Left, the bay scallop, Argopecten irradians; middle, the sea scallop, Placopecten magellanicus; right, the calico scallop, Argopecten gibbus.

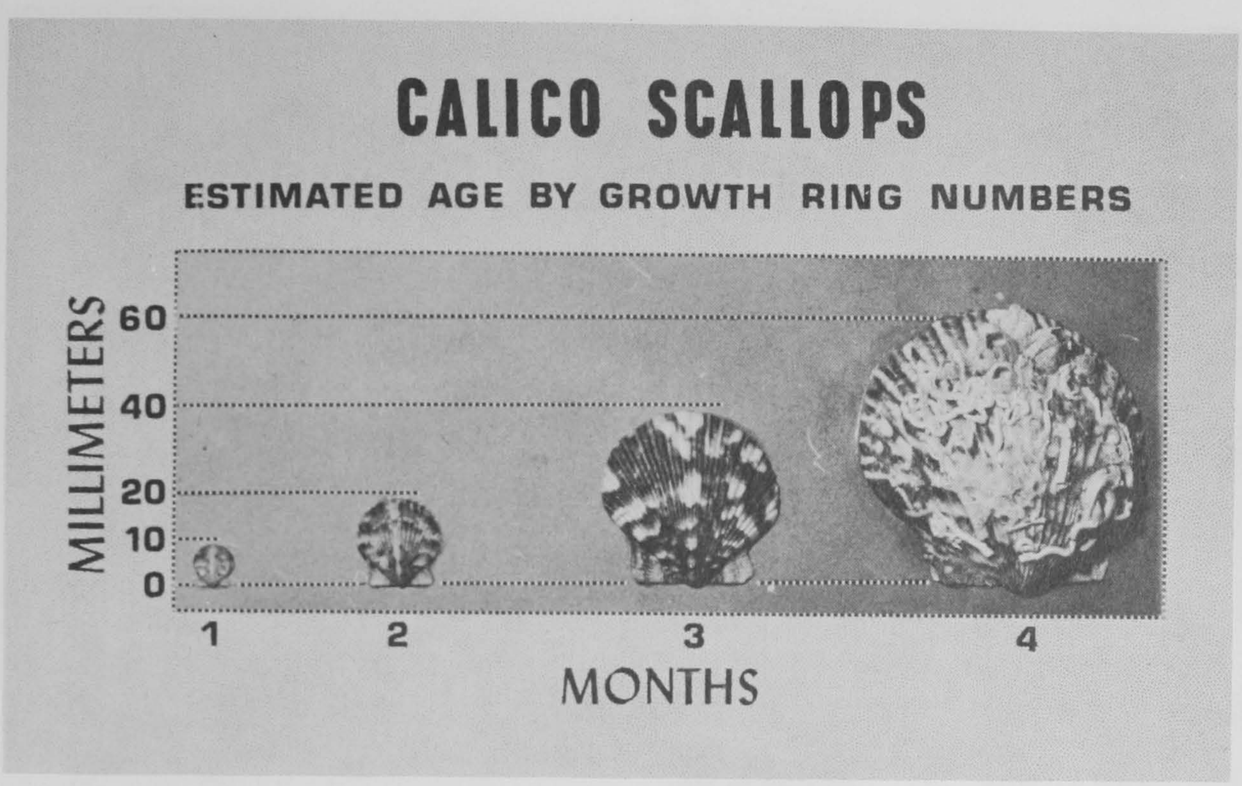

Figure 38.--Calico scallop shells, with growth measurements indicated.

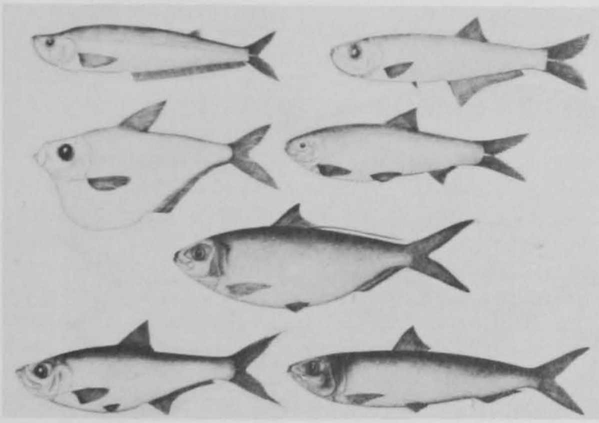

Figure 39.--Various species of clupeoid fishes studied by TABL systematists, including herrings, sardines, and anchovies.

the Antillean faunas is believed to be on the slopes of the submerged banks extending from Jamaica to northern Honduras. The new concept differs from the previous belief that the current-aided northward movement of fishes from the Caribbean into the Gulf of Mexico and the Straits of Florida is unrestricted. Evidence in support of the concept was on the basis of intensive study of the pelagic, shallow-water, and deep-water bottom organisms that inhabit these regions.

The program also has been concerned with guidance of the research of 10 students during the past 3 years. This instructional work has helped the students' progress and has produced data of value to the program.

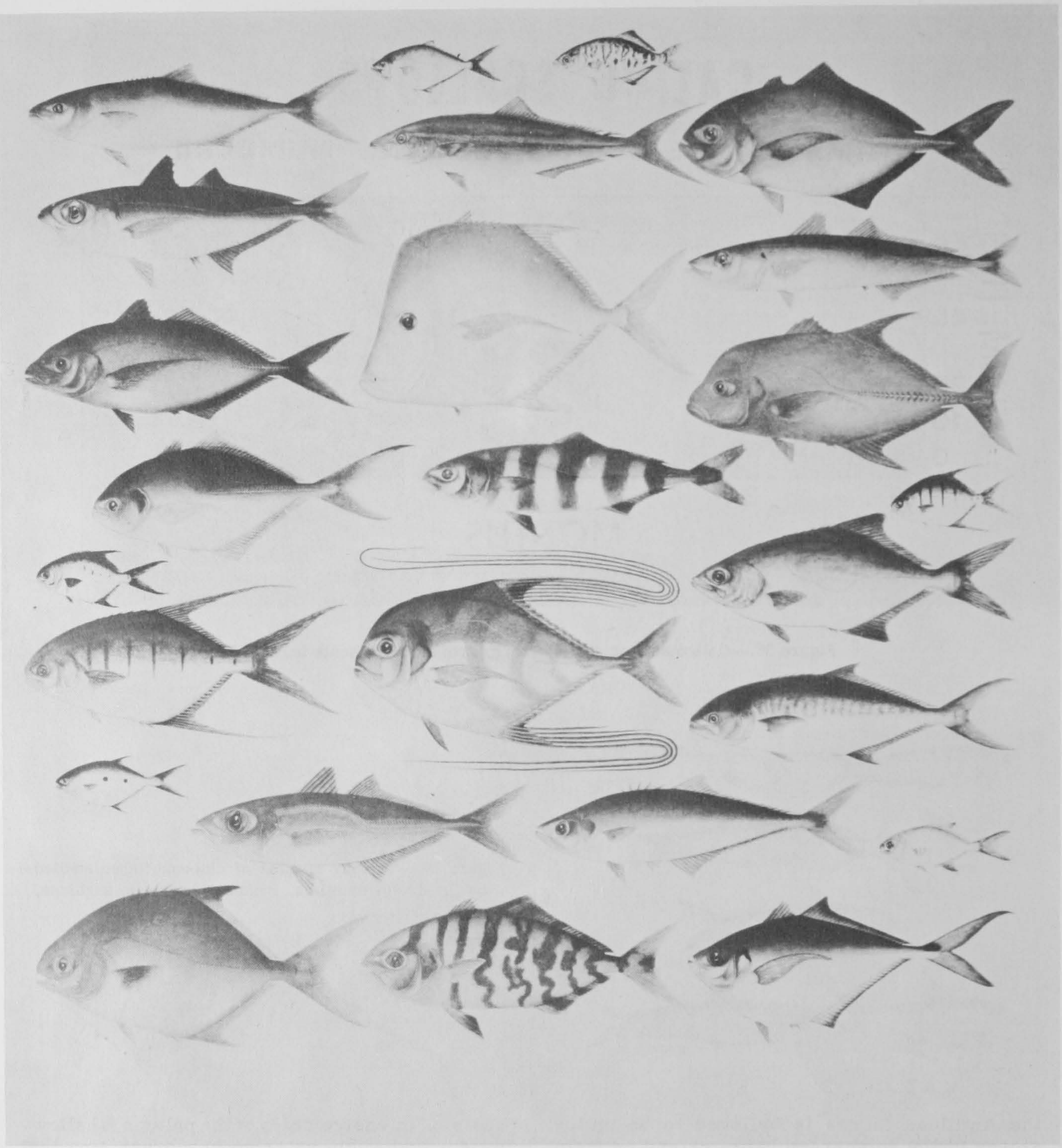

Figure 40.--Various species of carangid fishes studied by TABL systematists including jacks, scads, and pompanos.

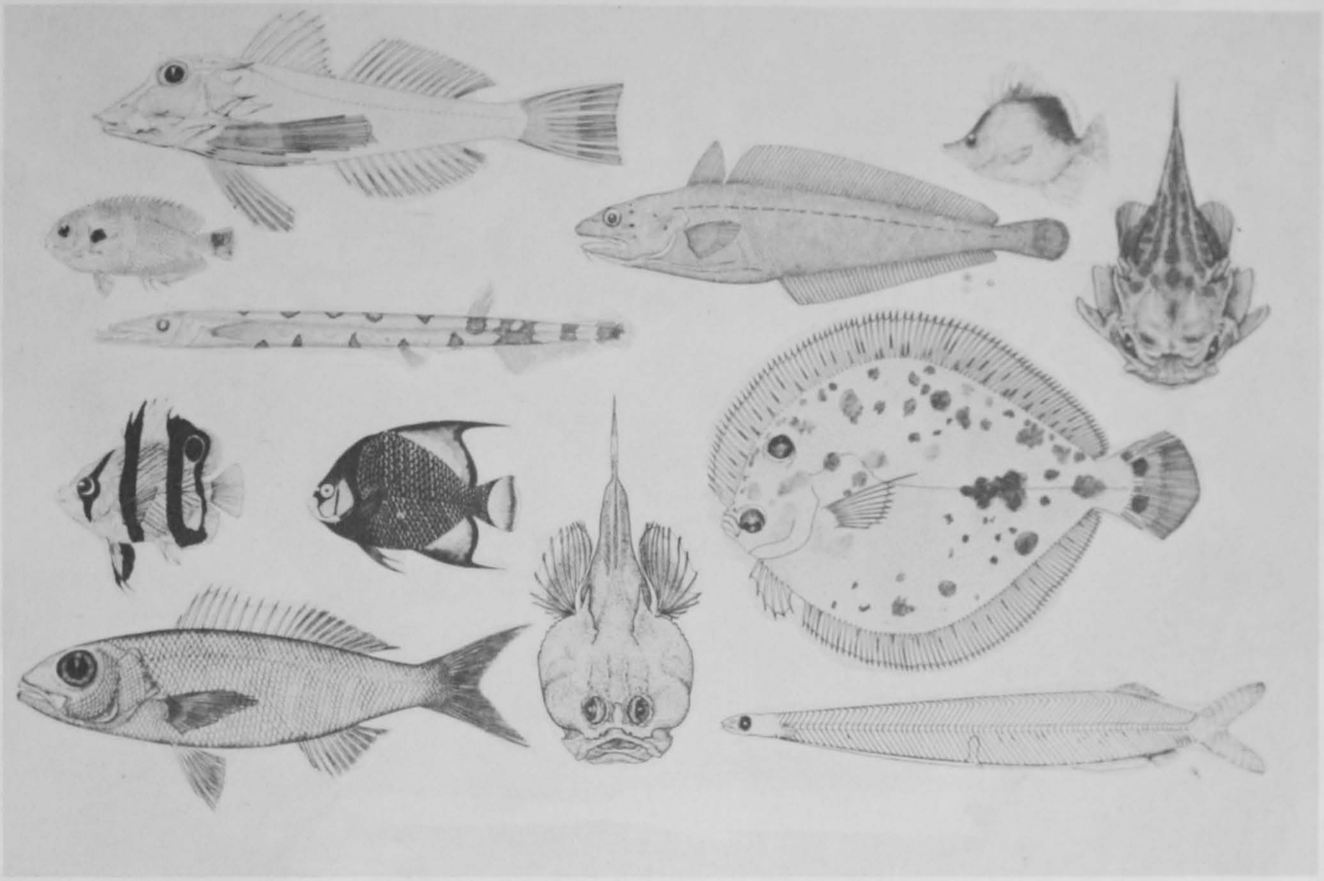

Figure 41.--Various species of fishes studied by TABL systematists, including snappers, flatfish, stargazers, searobins, butterflyfish, and angelfish.

RESEARCH VESSELS AND CRUISES

It is axiomatic that the progress of research in a fishery-oceanographic laboratory leans heavily on data collected by research vessels. The two BCF vessels assigned to investigations of the tropical Atlantic Ocean--the Undaunted and the Geronimo--have logged, in total time and distance, 1,557 days and about 200,000 miles on 27 research cruises. Both ships and their crews helped immeasurably to gather the prodigious amounts of data needed for TABL's research program.

Originally commissioned in 1944 as an ATA-class (seagoing) Navy tug, the Undaunted was converted into a BCF research vessel in 1965. The Undaunted is 143 feet long, with a 34-foot beam and a 12-foot draft; speed is 10 to 12 knots, and cruising range is about 5,000 miles (fig. 43). The ship is equiped for live-bait fishing and for bottom and upper-level trawling, as well as for oceanographic observations at varying depths. She carries an STD (salinity-temperature-depth) system (2,187-fathom capability) for measuring characteristics of sea water, a 25-channel data acquisition system, and an automatic picture-transmission receiver for use with space satellites on broad-scale oceanography. Aboard the vessel are: laboratories for chemical analysis, general biology, and electronic equipment; a live-bait tank capable of holding 2,000 pounds of fish; and two single sideband radio transmitters for contact with the home laboratory's radio station and for rapid transmission of data from ship to shore. Quarters include six staterooms for scientists and nine cabins for crewmembers --total accommodations for 25 people.

By mid-1969, the Undaunted had spent almost 900 days at sea and traveled 115,000 miles on 19 research cruises for TABL and 4 for other laboratories. She has touched ports in Bermuda and the Bahamas, in many Caribbean areas, in South America, Africa, and in the Pacific. Almost all of 1968 was spent in waters off west Africa on two cruises; in spring of 1969 the Undaunted joined the BOMEX (Barbados Oceanographic and Meteorological Expedition) flotilla in the West Indies to participate in the 2-month environmental study of air-sea interaction in cooperation with a number of other Government agencies. Theodore M. Sorensen is the captain of the Undaunted.

The Geronimo (fig. 44), sister ship to the Undaunted, was commissioned as a BCF research vessel in 1963 and worked for the tropical Atlantic program out of Washington, D.C., then Miami, from that year until mid-1966, when she was transferred to the BCF Biological Laboratory at Galveston, Tex. The vessel

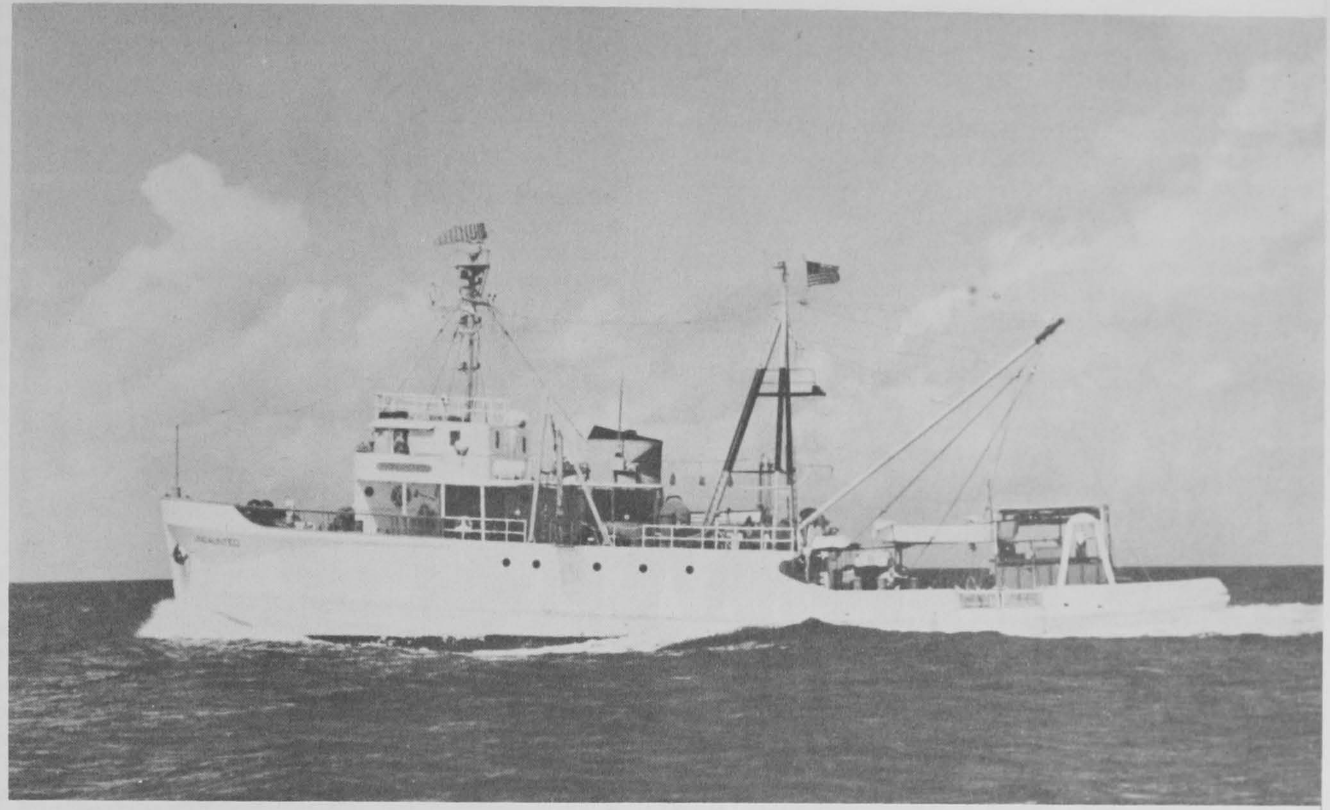

Figure 43.--The TABL research vessel, Undaunted. The ship has traveled 115,000 miles on 19 research cruises for the laboratory.

spent 657 days at sea and traveled about 85,000 miles on eight cruises in the tropical Atlantic.

The following condensed cruise reports portray the wide variety of data gathered on laboratory cruises. Minor shakedown or equipment testing cruises are not listed.

Cruises for BCF Biological Laboratory, Washington, D. C., 1963-65 (pre-TABL):

GE (Geronimo) Cruise 2, July-October 1963.--Participant in Equalant II expedition to the Gulf of Guinea, off western Africa. Oceanographic and biological stations were occupied offshore from Cape Three Points (Ghana) south to the mouth of the Congo River. In cooperation with the Guinean Trawling Survey, the ship trawled the bottom on the Continental Shelf between Cape Lopez and Pointe Noire. It searched for pelagic fish along the Continental Shelf between Cape Three Points, Ghana, and Cape Palmas, Liberia; scattered schools of small yellowfin tuna were seen but abundance was not great. A seamount was discovered at lat. 14° 38' S., long. 5° 13' E., and its height was 1,300 fathoms above the ocean floor and 1,000 fathoms beneath the surface. For the first time oceanographic data were transmitted via Syncom satellite to the NODC (National Oceanographic Data Center), Washington, D.C., as a means of measuring quality control, and corrections were received by the vessel within 45 minutes. Observers were aboard from the Virginia Institute of Marine Science; the U.S. Weather Bureau; NODC; the Fisheries Laboratory, Lowestoft, England; the ORSTOM Laboratory, Pointe-Noire, Republic of the Congo, Brazzaville; the Fisheries Department, Nigeria; and the University of Hamburg, West Germany.

GE Cruise 3, January-May 1964.--Participant in Equalant III to the Gulf of Guinea. Tuna schools found near Cape Palmas and Cape Three Points were judged to be associated with interaction between the easterly flowing Guinea Current and the configuration of the two cape areas. Physicochemical observations included 120 hydrographic casts to 547 fathoms; 73 observations of primary productivity and zooplankton biomass were made (fig. 48); a variety of methods was used to take 391 biological samplings; fish were caught and sampled

Figure 42.--A general view of the research activities carried on aboard TABL research vessels Undaunted and Geronimo.

Figure 44.--The BCF director presented to the captain and crew of the Geronimo an Interior Department unit citation "in recognition of exceptional performance in operating the vessel during three extended cruises in the Gulf of Guinea," in May 1965.

from 47 schools of surface-swimming yellowfin and skipjack tunas. Sea birds were collected for the U.S. National Museum. Records were kept of bathymetric and meteorological conditions. Visiting scientists were aboard from NODC and New York University, and from the Federal Fisheries Service, Nigeria, and the Institut für Meerskunde, West Germany.

GE Cruise 4, July-November 1964.--Gulf of Guinea. Two separate tuna surveys were undertaken but, because the "cold" season was underway in the Gulf, fish sightings (baitfish and tuna) were sparse. Only 51 schools of tuna were seen, from which 147 fish were sampled. Ocean current measurements were taken, including consistent observations of the Guinea Undercurrent flowing beneath the Guinea Current; 44 plankton tows were made--in one series, well over one thousand scombrid juveniles and larvae were taken per tow. Enroute to West Africa, personnel took productivity and bacteriological samples in the Sargasso Sea. Bathymetric and meteorological observations were made. Field training of technical personnel and testing of new equipment were accomplished during the cruise. Aboard were one observer from the U.S. National Museum and three from the Columbia University Lamont Geological Observatory (fig. 50).

GE Cruise 5, January-May 1965.--Gulf of Guinea. Two tuna surveys were made, the first off the coast of Sierra Leone and Liberia, the second south of Ghana and Togo. Skipjack and small yellowfin tunas were caught and sampled from 16 of 84 schools sighted on the first survey, and from 23 of 137 schools observed on the second survey (fig. 51). Direct current measurements and a survey of oscillations in the Atlantic equatorial undercurrent were undertaken in cooperation with the IMS research vessel, John Elliott Pillsbury. Environmental studies sought to determine the relation between concentrations of tuna and the Mauritanian to Sierra Leone oceanic front -- seemingly the boundary between cold, recently upwelled water to the north and warmer water to the south--previously detected off the coast from Senegal to Liberia. Bathymetric and meteorological records were kept. A special 1-day demonstration cruise was attended by scientists and fishery people from Abidjan, Republic of Ivory Coast; research procedures were demonstrated for university students at Sierra Leone and Liberia. Observers were aboard from the ORSTOM Laboratory, Pointe Noire, Republic of the Congo (Brazzaville), and from the University of Miami, Fla.

GE Cruise 6, July-November 1965.--Western Atlantic Ocean adjacent to Lesser Antilles and the Caribbean Sea. Stocks of surface tunas and other pelagic predators, and baitfish for tuna fishing were the objects of the research. Abundant quantities of herring, sardines, and anchovies were seen along the southeastern coast of the United States, around Puerto Rico south to Trinidad and Venezuela, and in other coastal regions of the Caribbean. The thread herring proved the hardiest of the baitfishes caught. Forty-four tuna schools were sighted, from which 48 fish--yellowfin, skipjack, blackfin, and little tuna--were caught. Though few surface schools of tuna in commercial quantity were sighted, two incidents were noteworthy: While running through the New Providence Channel in the Bahamas, the vessel passed through what appeared to be an enormous concentration of large fish (judged by sounds made as they leaped at the surface) for $2\frac{1}{2}$ hours; and at lat. 12° N., long. 65° W., big schools of good-sized yellowfin and skipjack tunas were seen in quantities estimated at 80 to 100 tons. Oceanographic observations also were made throughout the cruise. Representatives of several other BCF laboratories were aboard, as were observers from the Department of the Interior, the Commerce Department, New York University, Johns Hopkins University, and from Barbados, Jamaica, Netherland Antilles, and Trinidad (for the UN-FAO Special Fund for the Caribbean).

Cruises for TABL, Miami, Fla.:

GE Cruise 7, January-April 1966.--Northeast coast of South America and the eastern Caribbean Sea. Investigation of surface tunas, other pelagic predators, and baitfish formed the major part of the schedule, but an added aspect was the testing of procedures in which uncorrected oceanographic data were sent to shore stations in the United States, processed, and returned to the vessel. Fishing was poor around Trinidad and Brazil during the first leg of the cruise because of rough weather, but fair to good in the southern Caribbean on the second leg. Two- to three-ton schools of blackfin tuna were sighted near Caracas in late March; waters off Anguilla (the Leeward Islands) had plentiful schools of yellowfin and skipjack tunas. Numerous baleen whales were seen in the same area. To determine time-space changes in distribution of eddies, an intensive grid of bathythermographic, hydrographic, and biological stations was occupied in a 550-square-mile stretch on the western side of the Lesser Antilles. Preliminary analysis of the distribution of temperature suggested that the eddies might be permanent features that act as mechanisms for biological enrichment. Two new duties were added to the ordinary procedures used to collect oceanographic and biological samples -- blood samples were taken from 100 tunas for serological analysis at the BCF biological laboratory at Honolulu, and tissue samples were collected for study of psssible insecticide concentrations at the BCF biological laboratory at Gulf Breeze, Fla. The original cruise track was interrupted in April so the Geronimo could join the Undaunted in waters off St. Vincent Island (the Windward Islands), where extremely large schools of tunas had been located.

UN (Undaunted) Cruise 2, February-April 1966--Western Atlantic Ocean adjacent to the Lesser Antilles and the Caribbean Sea. Of 44 tuna schools observed, 18 were fished and 508 fish were brought aboard. The highest percentage of the catch was skipjack tuna, but yellowfin tuna and dolphin were also present. Most of the tuna schools were sighted between the islands of Martinique and Trinidad, and enormous schools of skipjack and yellowfin tunas were seen immediately west of St. Vincent Island. Observers were impressed with the generally large sizes of the fish (10-160 lbs.) and of the schools (some estimated at 200-300 tons each), the presence of the schools in a region not generally considered productive, and the fact that the tunas remained for more than a week in the one area. A spotter plane accompanied the Undaunted for a month (fig. 52). Dense schools of small seabasses (creole-fish) were seen near the tuna schools and also were found in tuna stomachs, and abundant quantities of sardines were sighted. Water properties on the eastern and on the western sides of the Lesser Antilles differed significantly. On the western side of St. Vincent Island, where tunas were schooling, turbulent eddies in the upper 164 fathoms apparently increased the supply of plankton in the upper mixed layer. Forage organisms were collected by net tows and night lights; oceanographic measurements were made to depths of 273 fathoms; and meteorological conditions were recorded. Fishery observers were aboard the vessel from Barbados, Jamaica, Puerto Rico, and St. Kitts.

UN Cruise 3, May 1966.--Between Bermuda and Miami. Adults and larvae of midwater fishes were collected, as were specimens of deepsea angler fish. Participating in the cruise were personnel from the University of Miami, and University of Rhode Island.

UN Cruise 4, June 1966.--The Florida Straits off Key West, Fla. Oceanographic investigation was concentrated on efforts to determine whether a turbidity layer 150-ft. thick

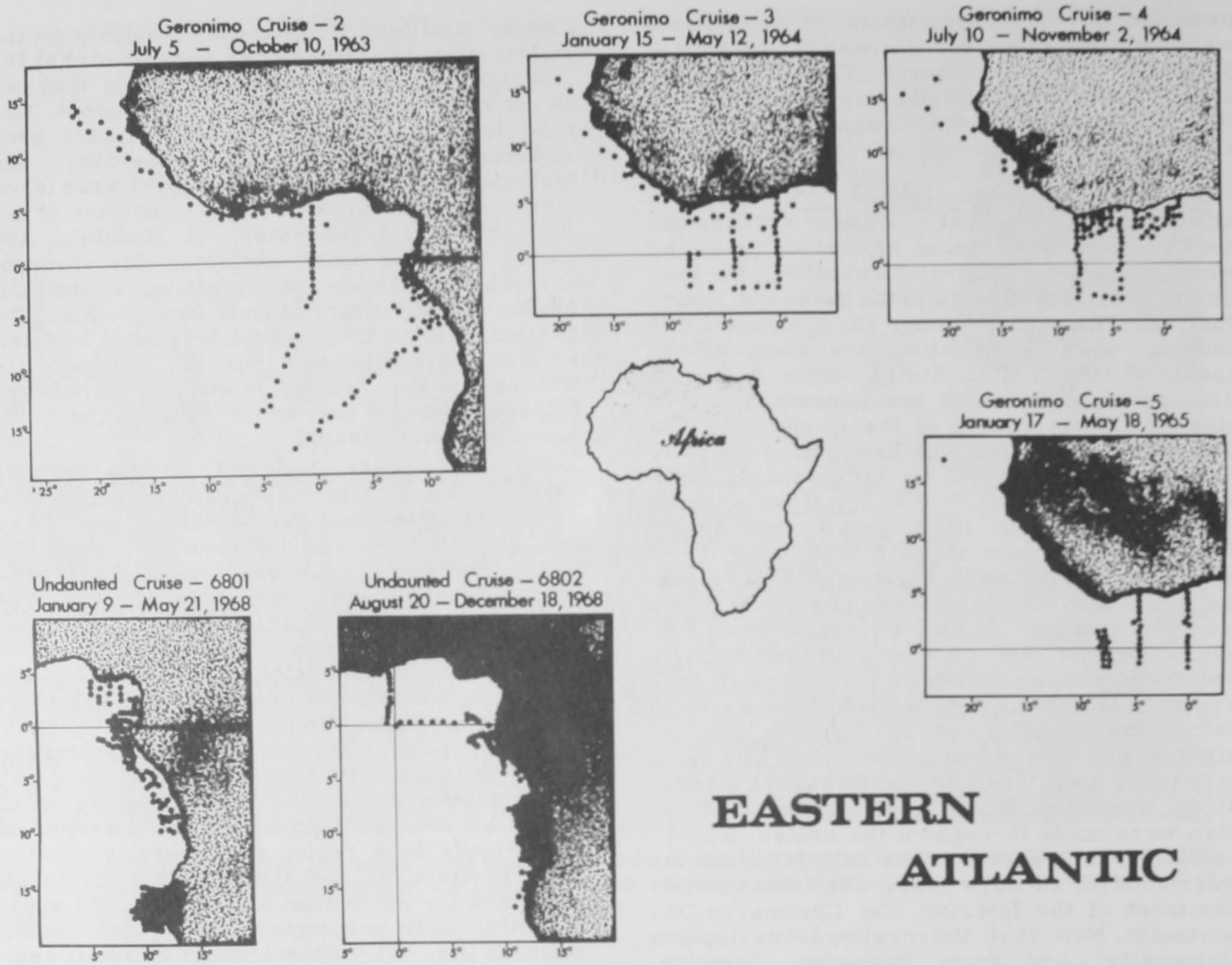

Figure 45.--Cruises in the Eastern Atlantic by TABL research vessels. Dots indicate location of biological and oceanographic stations.

at depths of 650 to 900 ft. contained iron-bearing constituents. The newly installed salinity-temperature-depth apparatus was studied, calibrated, and tested.

GE Cruise 8, June 1966.--Off Bimini, the Bahamas. TABL joined with the BCF exploratory base at Pascagoula, the Woods Hole Oceanographic Institution, IMS, and the International Game Fish Association in a cooperative study of bluefin tunas. The study coincided with the 1966 Bluefin Tuna Tournament. Although shortened because of a hurricane threat, the cruise gathered considerable amounts of oceanographic and biological data.

UN Cruise 5, July-November 1966.--The West Indies to coastal waters of Brazil. Added to regular investigations of pelagic and bait-fishes and study of oceanographic features was the collection of fish from previously under-sampled areas of zoogeographic importance. For a substantial portion of the cruise severe weather impeded investigations, particularly the catching of pelagic fish. Between Trinidad and Rio de Janeiro, only 28 schools of tuna were sighted, most of them yellowfin and skipjack tunas. Near St. Vincent and St. Lucia Islands, concentrations of skipjack and yellowfin tunas again were seen on the Caribbean side of the islands. Phytoplankton and zooplankton were abundant in the region. Bait-fish (sardines and herring) were caught in good quantities at Port of Spain, Trinidad. Numerous marine specimens were gathered near Atol das Rocas and Fernando de Noronha (lat. 4° S.), including individuals from 26 families, and a new species of pomacentrid fish was discovered among the samples. Observers were aboard the vessel from the Smithsonian Institution, and IMS, as were government representatives (in marine biology, oceanography, and agriculture) from Trinidad, Tobago, and Brazil.

UN Cruise 6701,[5] February-March 1967--Southern Lesser Antilles (St. Vincent Island area), the north coast of Venezuela, and the southern Bahamas. Sightings of skipjack and yellowfin tunas again were made off St. Vincent Island; schools were estimated to range from 4 to 100 tons each. Baitfish were plentiful at Trinidad--200 scoops (200-300 fish per scoop) of anchovies were taken with little trouble on night-baiting sets--but not abundant in other regions. Several tuna schools were seen in the southern Bahamas, enough to suggest to observers that a commercial resource might exist in the region during early months of the year. About 250 yellowfin, skipjack, and blackfin tunas were caught and sampled. Observers from the United Nations Caribbean Fisheries Project were aboard.

UN Cruise 6702, March 1967.--Florida Straits and Cay Sal (Bahamas) Bank. The brief cruise to collect larval and juvenile fishes was noteworthy because a fish spotter made two air surveys in conjunction with surface studies from the vessel, and because guest biologists from the University of Miami collected reptiles on Elbow Cay, the Bahamas--an unusual activity for a marine research cruise. Observers saw no tunas on the first air survey; on the second flight, they spotted tunas in the southern Bahamas. The herpetologists captured 36 reptiles, mostly lizards.

UN Cruise 6703, March-May 1967.--Western Caribbean between the Yucatan Channel and Colombia. Standard biological and oceanographic investigations were made and the fish fauna in the Gulf of Honduras was investigated by means of bottom trawling, beach seining, and skin diving. Thirty-four tuna (blackfin, skipjack, and little tuna) were caught from 13 schools spotted off British Honduras, Panama, and Nicaragua. Tunas ranged from 3 to 8 lbs., and schools sighted (mostly blackfin tuna) were estimated at 2 to 20 tons. Various oceanographic observations were scheduled

[5] Cruise numbering system changed in 1967.

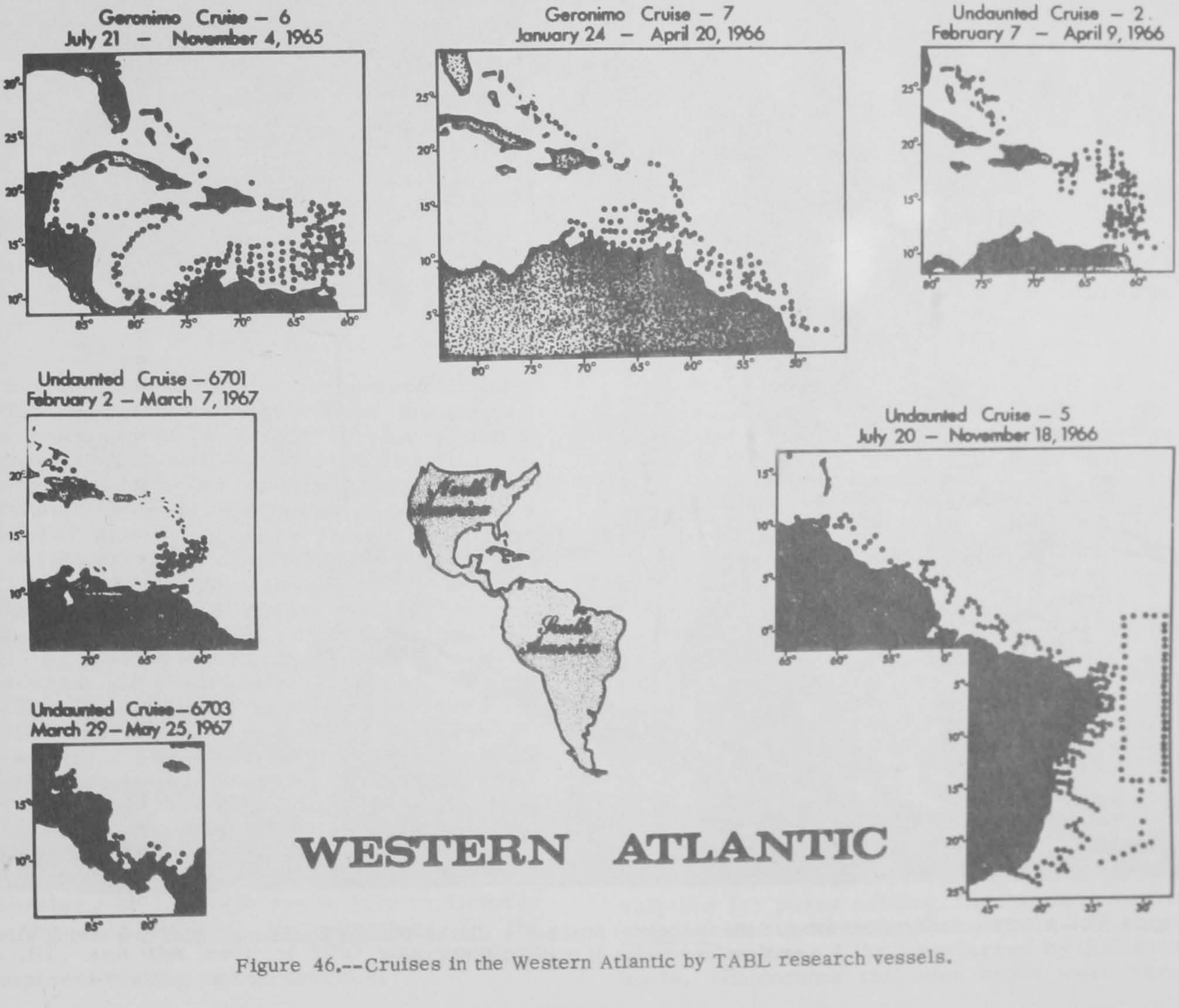

Figure 46.--Cruises in the Western Atlantic by TABL research vessels.

Figure 47.--A BCF oceanographer (aboard the Geronimo) attaches a Clarke-Bumpus plankton sampler to a towing wire on Equalant cruise II in the Gulf of Guinea.

Figure 48.--The ICITA net during a surface tow from the Geronimo, Equalant II.

throughout the cruise. A large assortment of fishes (more than 400 gallons of 300 species) was collected in the Gulf of Honduras, and 75 of the species were new to the TABL fish collection. Baitfish (primarily pilchards) were located in plentiful quantities at Porto Bello, Panama, and at Bonacca Island, Honduras. An incidental piece of intelligence volunteered by Honduran shrimp fishermen indicated that large Laurentian scallops were present in commercial quantities--2 bushels per 30-minute trawl by small trynet--off Caratasca, Honduras. An observer was aboard from the UN Special Fund. The Undaunted performed an act of charity on the cruise; its personnel delivered a gift of several thousand school books and 30 used bicycles donated by residents of Coral Gables, Fla. (under the program entitled "People to People") to the children of Cartagena, Colombia.

The Undaunted was on charter to the BCF laboratory at La Jolla from July to October on the EASTROPAC investigations in the Pacific, and the rest of 1967 was spent on equipment testing and in drydock.

UN Cruise 6801, January-May 1968.--Coast of western Africa, Sierra Leone to South-West Africa. One of the principal assignments was the investigation of the distribution of tunas in the Gulf of Guinea and off Angola in relation to the oceanographic feature called the Berrit Front. Collection of benthic fishes and invertebrates from the Continental Shelf was an added duty. Tuna fishing by trolling and live bait was excellent throughout most of the cruise. Eighty-eight tuna schools were sighted or otherwise detected, and 538 skipjack tuna and 195 yellowfin tuna were caught. Tunas were particularly abundant around São Tomé (off Gabon), as were whales and birds. Most of the larger skipjack tuna sampled (6-8 lbs.) in April in the São Tomé region were in advanced stages of maturity -- sampling revealed that ovaries contained large clear eggs with well-defined oil globules and the testes extruded milt. Most schools sighted appeared suitable for purse seining, though many of the skipjack tunas seen in the schools fell short of the size (over 4 lbs.) preferred by U.S. tuna boats. No commercial tuna boats were seen

Figure 49.--A BCF biologist attaches a Nansen bottle to the wire, aboard Geronimo, on Equalant II.

Figure 50.--The midwater trawl streams away from the stern of the Geronimo.

on the cruise. Ample quantities of several different kinds of baitfish were present in Lobito Harbor and at Cape Ledo, Angola. The many-faceted survey of the Berrit Front confirmed the findings of other workers: Plots of surface temperature revealed that the front was shaped in the form of a reversed "S," with the upper point of the S positioned northwest of the lower, or most southerly end, which was close to the Baia dos Tigres, Angola. On trawling transects, 75 gallons of fish were caught and preserved for later study; crustaceans and other invertebrates were given to specialists working on African species. An unusual catch was 30 juvenile billfishes (fig. 53). Commercial fishermen in Angola contributed two rare fishes to the TABL collection--a frilled shark and a large ratfish. Conferences were held aboard the vessel with a number of fishery experts from several African and European nations.

UN Cruise 6802, August-December 1968.--A four-phase survey of the coast of western Africa from the equator south to Angola, in cooperation with the U.S. Coast Guard's Rockaway and the research vessel, Goa, working for the Missão de Estudos Bioceanológicos de Pescas, Angola. In addition to an investigation of the oceanography and the distribution of tunas, the cruise plan called for the study of the physical and biological characteristics of the Gabon-Angola front. Movement of the front, its definition by specific isotherms, and the association of tunas with the front were parts of the study. Skipjack tuna were predominant in the 125 schools observed, but some schools were made up of yellowfin tuna, which generally were found in waters warmer than 23° C. (skipjack tuna were found in waters as cool as 20° C.). With few exceptions, tuna schools were limited to stretches some 30 to 90 miles off the coast; the inshore zone and the zone in-

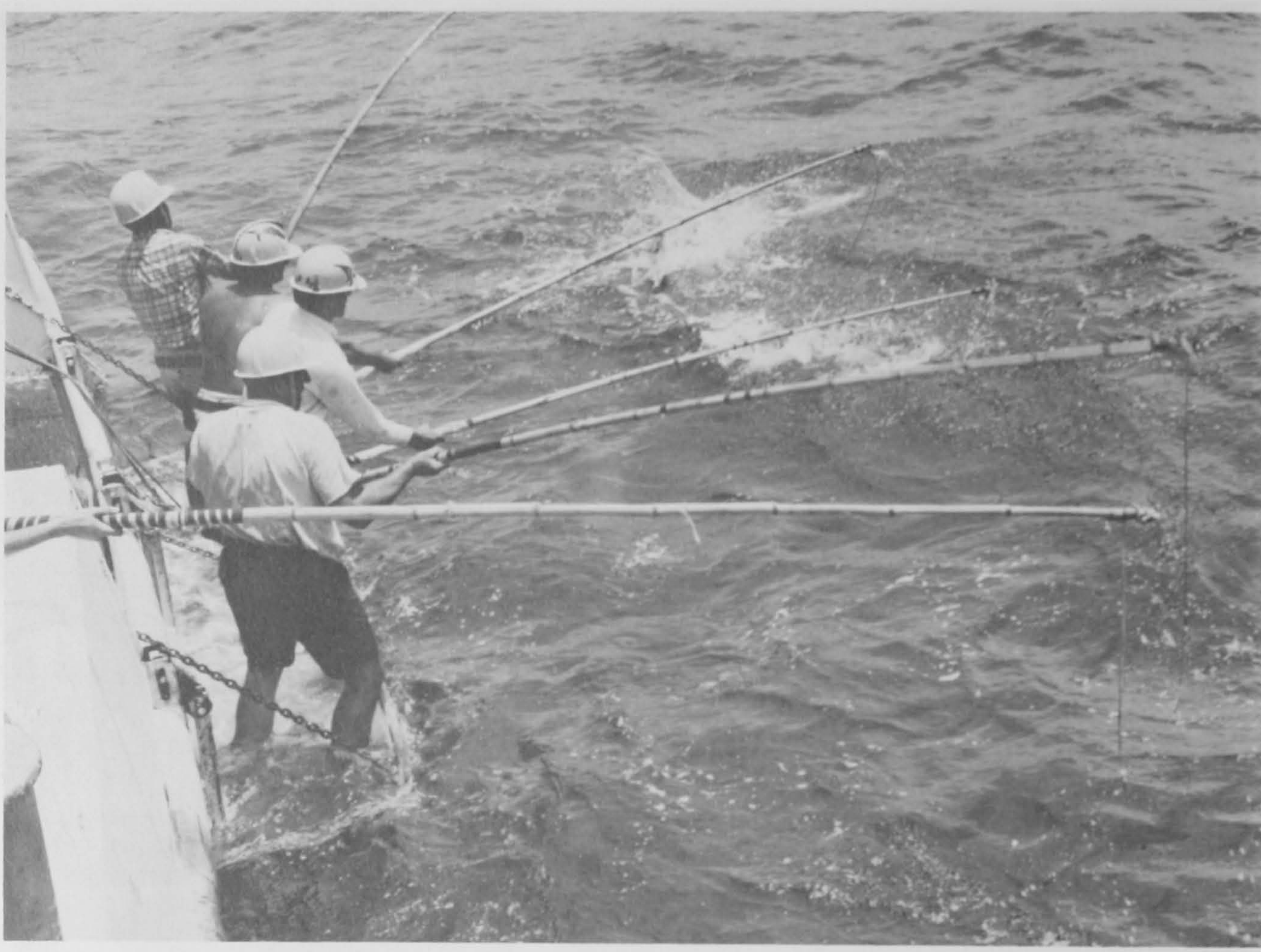

Figure 51.--Fishing for tunas from the TABL research vessel Geronimo, in the Gulf of Guinea.

vestigated outside the 90-mile demarcation line were nearly devoid of tuna. A total of 671 tuna were caught and sampled aboard the Undaunted. French, Portuguese, United States, and Canadian vessels engaged in surface fishery for tunas in the same period covered by the cruise appeared to confine their fishing to the same 30- to 90-mile grounds, from south of Cape Lopez (lat. 1° S.) to the Benguela region of Angola (13° S.). No commercial vessels were seen during a 2-day passage of the Undaunted from Luanda to Abidjan, during which 15 large schools of skipjack tuna and 2 schools of yellowfin tuna were sighted moving in a S. to SE. direction under large bird flocks. The Gabon-Angola front (warm surface water) appeared to move southward during the cruise from southwest of Cape Lopez (lat. 1° S.) to off Santa Marta (14° S.), a distance of about 720 miles, in about 53 days (average speed, 13.6 miles per day). The advancing mass of warm water (24° C. or higher) seemed to be in a layer about 10 fathoms thick, tapering to less than half a fathom thick on its advancing edge. Thermocline depths were shallow (average 5 to 8 fathoms) throughout the study area. Photographs (125) received aboard the Undaunted from the ESSA-6 satellite revealed, disappointingly, no detectable relation between cloud formation and the Gabon-Angola front. Data gathered on this recent cruise are still under study. Two observers from the ORSTOM stations at Abidjan and Pointe Noire were present for part of the cruise, and a representative of the Portuguese fishery laboratory of Angola spent 3 weeks aboard the ship.

UN Cruise 6903, June-August 1969.--Southern Lesser Antilles, as part of BOMEX, a task force of ships, aircraft, buoys, and satellites investigating 90,000 square miles (nautical) of the tropical Atlantic. Part of the cruise will be devoted to further investigation of stocks of tuna near St. Vincent Island (mentioned in preceding cruise reports).

TABL participation in other cruises.--A TABL biologist sailed as guest scientist aboard the Japanese research vessel Shoyo Maru, from

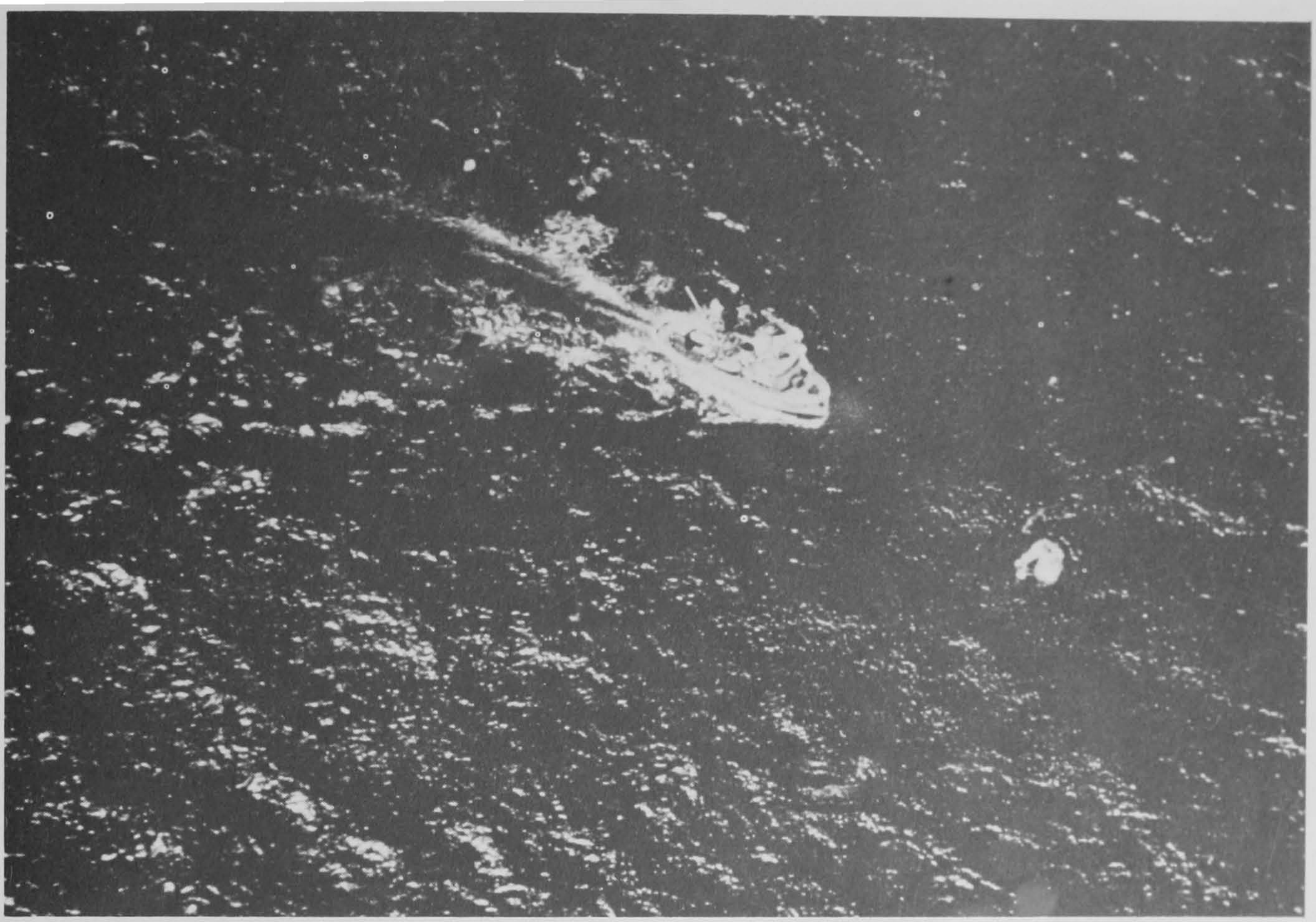

Figure 52.--The Undaunted viewed from an aerial spotter that accompanied the research vessel during part of a cruise in Caribbean waters. The white circular area directly ahead of the ship is a school of tuna breaking the surface.

Trinidad to Panama, in 1966. (The vessel was embarking on a long cruise from Trinidad to Tokyo.) The TABL observer reported on the various procedures used by the Japanese for biological and oceanographic research, and was able to gather useful, though random, data on Japanese investigations of tunas in the tropical Atlantic.

A TABL biologist spent October-December 1967 as an observer aboard the U.S. commercial tuna seiner Caribbean, which fished off the west coast of Africa. Fishing was most successful off Pointe Noire, Republic of Congo (Brazzaville), where 249 tons of skipjack tuna and 325 tons of yellowfin tuna were caught in 35 sets made over a 3-week period. In late November, 89 tons of yellowfin tuna were caught off Cape Palmas, Liberia. Samples from 634 skipjack tunas and 483 yellowfin tunas were delivered to TABL for study; 82 other whole specimens also were collected, including tunas, mackerels, and 11 unborn sharks.

A TABL physical science technician functioned as an observer aboard the FAO vessel Alcyon in September-October 1968. The Alcyon, following a cruise track that proceeded along the north coast of Venezuela east to Grenada Island then to Jamaica and Trinidad, sought to determine the seasonal availability of tuna in the southeastern Caribbean. Three schools of yellowfin, skipjack, and blackfin tunas were sighted between Jamaica and Bonaire Island; 63 scoops of baitfish (mostly herrings) were caught near Kingston, Jamaica.

Two representatives of the Fishery Oceanography program spent 2 weeks aboard ESSA's Oceanographer in the Indian Ocean (1967), testing zooplankton sampling devices. The Smithsonian Institution sponsored the trip. A member of the Fishery Oceanography program served for 2 months in 1968 aboard the USCG Rockaway, while the research vessel surveyed waters off western Africa.

A member of the Developmental Biology of Tunas program spent 5 weeks in the mid-Atlantic aboard an ESSA vessel in early 1969, collecting fish from seldom-investigated oceanic regions. He returned with 2,200 specimens--most of them caught under a night light.

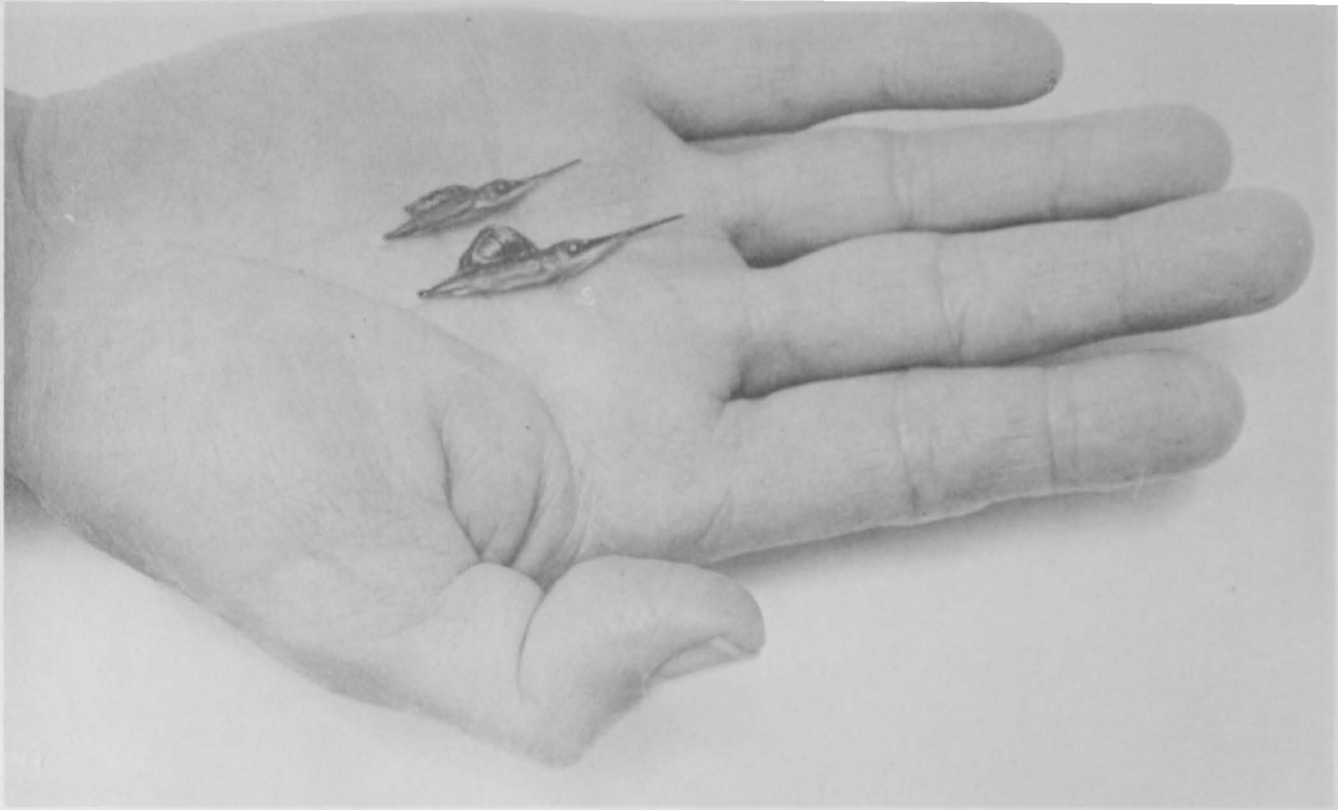

Figure 53.--Two of 30 juvenile billfish collected off western Africa on Undaunted cruise 6801.

SPECIAL EVENTS, ACTIVITIES, AND VISITORS

Since its dedication in late 1965, TABL has been involved continually in research-related activities. The following items represent a sampling that illustrates the scope of such activities.

The laboratory has played an important role in several international symposia and conferences. Former director Thomas S. Austin was co-President of the UNESCO/FAO/OAU Symposium on Oceanography and Fisheries Resources of the Tropical Atlantic, held at Abidjan, Ivory Coast, October 1966. TABL scientists presented major papers at this symposium. TABL staff members also participated in the ICES/FAO Symposium on the Living Resources of the African Continental Shelf from the Straits of Gibraltar to Cape Verde, held at Tenerife, Canary Islands, March-April 1968. In August 1968, an FAO meeting of tuna experts was held at TABL. Participants came from the major tuna fishing nations of the world, and an important document (FAO Fisheries Report No. 61, 1968) assessing the present status of world tuna stocks resulted from the meeting. Several staff members attended an international symposium on Oceanography and Resources of the Caribbean at Curaçao, the Netherlands West Indies, in November 1968, and presented six papers dealing with biology, taxonomy, oceanography, and zoogeography. The symposium was held as a preliminary planning meeting for CICAR (Cooperative Investigations of the Caribbean and Adjacent Regions) which is scheduled to begin in 1970. TABL personnel also participated, with the Gulf and Caribbean Fisheries Institute, in earlier preliminary planning for CICAR, at meetings in Miami. The TABL director participated in an organizational meeting of the FAO committee for the Eastern Central Atlantic Fisheries in Accra, Ghana, in March 1969.

National meetings and conferences have been strongly supported by TABL staff members. Several scientists from this laboratory annually attend and present papers at the Pacific Tuna Conference at Lake Arrowhead, Calif. In 1969 for the first time, the nature of the conference has been broadened to provide equal consideration of Atlantic tuna. TABL's assistant director acted as chairman of the panel, "Food and Drugs from the Sea" at the Governor of Florida's 3-day Conference on Oceanography, Miami, in early 1968. Several staff members have presented papers at special conferences on marine aquaculture held in Oregon, Arizona, Rhode Island, and Florida during the past 2 years. Laboratory scientists are also active in the annual meetings of the Gulf and Caribbean

Fisheries Institute--as discussion leaders, panel members, and participants in scientific sessions. Staff members take part in annual meetings and committee work of a number of scientific societies, including the American Fisheries Society, American Society of Ichthyologists and Herpetologists, American Society of Limnology and Oceanography American Society of Parasitologists, and others.

Travel related to the laboratory's research programs has been estensive and varied. In 1966, the leader of the Systematics of Fishes program spent several weeks in India on a trip sponsored by the Smithsonian Institution (under Public Law 480) to help set up local projects designed for study of the systematics and biology of clupeoid fishes; he also visited museums in Denmark and Norway enroute to India. The leader of the Tuna Biology program made two trips to West Africa in 1967 and 1968, to initiate a sampling program based on tuna landings from western Africa, which was carried out under a contract with the University of Miami.

TABL has enjoyed visits by a number of prominent scientists, politicians, and industry representatives. The Vice President visited the laboratory in late 1966 to inspect the facility and discuss its mission with staff members. The junior U.S. Senator from Rhode Island toured TABL in 1968.

Scientists, teachers, and graduate students from many institutions have traveled to the laboratory from all parts of the United States, and members of the scientific and fishery communities of England, France, Germany, India, Israel, Kenya, Korea, Nigeria, Portugal, South Vietnam, Taiwan, and Venezuela (to name only some of the countries represented) have spent varying periods at TABL.

ACADEMIC AND COMMUNITY ACTIVITIES

From its inception, TABL has entered wholeheartedly into community affairs related to marine study and development. The day the laboratory was dedicated--in joint ceremonies which also marked the 21st anniversary of the founding of the Institute of Marine Sciences--some one thousand persons inspected the new installation. TABL quickly became an integral part of the southeastern Florida oceanographic community.

A number of scientific staff members of TABL hold appointments to the adjunct faculty, RSMAS, University of Miami, and to the affiliate faculty in biology, Florida Atlantic University in Boca Raton. Senior staff members serve as thesis advisers, or as members of thesis committees for graduate students.

TABL has developed especially close relations with RSMAS. Several graduate students hold part-time appointments at TABL; staff members of TABL give lectures or courses at the University; a joint seminar series is held each year; and junior staff members of TABL take or audit university courses. The two organizations have for 3 years conducted an NSF-sponsored Research Participation Program for college teachers, which in 1969 brought six college and university faculty members to the laboratory for a summer semester of concentrated research.

TABL has participated for several years in the Dade County Laboratory Study Program for gifted high-school seniors. Under this program, outstanding science students work for an entire school year directly with laboratory staff members on projects of mutual interest. TABL also participated in 1969 in the pilot plan put forth by the President's National Council on Marine Resources and Engineering Development for the employment and instruction of gifted but economically limited high-school students. Throughout the summer, four students worked with laboratory staff members, in oceanographic and biological projects.

A twice-yearly "Open House for Students" is now a tradition at TABL. Working with the Dade County Board of Public Instruction, the laboratory invites senior high-school science students of proven interest and ability to visit TABL in groups of up to 350 in autumn and spring. The students and their teachers are exposed to marine science through a tour, lectures by staff scientists, and the viewing of an educational film. Rough estimates place the number of local students who have toured the laboratory during open-house days and on special occasions at about five thousand. TABL also participates in the Florida Science Study Program, in which about 150 gifted high-school seniors from 60 schools in 6 northeastern States annually spend the Christmas vacation touring scientific institutions in Florida. The laboratory also acts as host for the Florida High-School Teacher Lecture Program, which involves about 100 teachers three times a year.

TABL has participated actively in expansion of oceanographic activities in South Florida. Former director Austin played an important part in the formation, in 1966, of the Metro Mayor's Conference on Oceanography. The Conference assisted greatly in arranging tours, meetings, and conferences for the site-selection committee charged with investigating locations for ESSA's Atlantic Oceanographic and Meteorological Laboratories. The site finally selected was on Virginia Key, near TABL and IMS. In late 1968, TABL was host for two important local events: hearings held by the Florida State Subcommittee on Oceanography, at which the emphasis was on tax relief for ocean-related industry and changes in the law covering aquaculture ventures; and the Florida Bankers' Association Conference, during which discussions centered on how banks might encourage the establishment of marine-based businesses. The concept of an oceanographic center on Virginia Key was further advanced in 1969 when Dade County and the City of Miami designated a significant part of the Key as an Oceanographic Park, to be set aside for marine research, teaching, and development.

LIST OF PERSONNEL 1965-69

Allen, Donald M., fishery biologist, 1969-
Armistead, Gary R., biological aid, 1966-67.
*Austin, Thomas S., laboratory director, to 1967.
Bald, Dennis F., biological aid, 1966; 1967; 1968.
Beardsley, Grant L. Jr., fishery biologist, 1967-
Benson, Nell P., clerk-stenographer, 1969-
Bernreuter, John D., biological aid, 1967-68.
Berry, Frederick H., zoologist, 1965-
Borkowski, Marilynn R., computer programmer, 1967-
Bruce, Juel E., clerk-typist, 1967-
Brucks, John T., oceanographer, 1965-
*Burke, Catherine R., data processing assistant, to 1967.
Collier, Robert B., biological aid, 1968-69.
Cook, Margaret, clerk-typist, 1968-
Costello, Thomas J., fishery biologist, 1969-
Culverhouse, Benjamin J., Jr., electronic technician, 1966-
Daly, Richard J., fishery biologist, 1967-68.
Dewyer, Rita M., clerk-typist, 1967-
Donahue, Michael T., physical science technician, 1966-
*Donn, Helen V., secretary, to 1967.
Dragovich, Alexander, fishery biologist, 1966-
Drummond, Billy R., biological technician, 1968-
Esham, Edward E., maintenanceman, 1966-68.
Fabal, Mary E., library technician, 1966-67.
*Foulk, Howard, physical science technician, to 1966.
Fox, William W., Jr., fishery biologist, 1967-69.
*Goulet, Julien R., oceanographer, 1965-
Hall, Alice R., biological aid, 1967-68.
Harris, Alan S., maintenanceman, 1969-
Hathaway, Susan B., biological aid, 1968.
Hebard, J. Frank, oceanographer, 1967-
Heemstra, Phillip C., biological technician, 1966-67; 1968-69.
Hill, Phillip T., personnel management specialist, 1965-67.
*Hood, Gerald L., marine superintendent, 1963-
Houde, Edward D., fishery biologist, 1968-
Howard, Martin S., chemist, 1967-68.
Hudson, J. Harold, fishery biologist, 1969-

*Personnel who began employment at the BCF Biological Laboratory, Washington, D.C., before 1965.

Hyman, Edward E., physical science technician, 1966-
Ingham, Merton C., oceanographer, 1965-69.
Iwamoto, Tomio, fishery biologist, 1965-
Jensen, Ann, biological technician, 1967-
*Johnson, Craig, electronic technician, to 1966.
Jones, Albert C., assistant director, 1965-
*Jossi, Jack W., oceanographer, 1962-
Kimbro, Marlah C., clerk-typist, 1966-68.
Koss, William H., administrative assistant, 1967-69.
Leming, Thomas D., oceanographer, 1967-
Leonard, Elizabeth, librarian, 1968-
Love, Richard, clerk-typist, 1965-66.
*Mahnken, Conrad, V. W., oceanographer, to 1967.
Mann, Walter, fishery biologist, 1968-
Marshall, Sharon P., administrative clerk, 1965-69.
Maurin, Raissa, librarian, 1965-68.
*Mazeika, Paul A., oceanographer, to 1966.
McCabe, Mead M., biological technician, 1965-66.
McCarthy, Daniel L., maintenanceman, 1969-
*Merrick, Betty, clerk-typist, to 1966.
Miller, George C., zoologist, 1965-
Miller, Robert V., zoologist, 1965-
Mosby, Gwendolyn M., biological technician, 1965-69.
Palko, Barbara J., fishery biologist, 1967-
*Parker, Shirley M., general supply assistant, 1963-
*Potthoff, Thomas C., fishery biologist, 1965-
Pulos, Evelyn M., clerk typist, 1967-
Purnell, Ann M., clerk-typist, 1966-67.
*Ramsay, Andrew J., biological technician, 1964-
Ranallo, Gabrielle M., data processing assistant, 1965-
*Rawes, Robert M., general supply assistant, to 1966.
Reinert, Grady W., illustrator, 1965-
*Richards, William J., zoologist, 1963-
Sands, Marcel F., maintenanceman, 1965-
Scott, Edwin L., fishery biologist, 1966-67; 1968.
Sell, Esther, secretary, 1965-
*Siferd, Willis S. III, administrative officer, 1964-
*Simmons, David C., fishery biologist, 1965-
Sindermann, Carl J., laboratory director, 1968-
*Slade, Cora E., oceanographer, to 1967.
Smith, David G., biological technician, 1967-
Smith, Stuart W., physical science technician, 1966-
Smith-Vaniz, William F., biological technician, 1967-68.
Springsteed, Richard E., office draftsman, 1967-68.
Stimson, John H. G., computer systems analyst, 1967-
*Sund, Paul N., oceanographer, to 1967.
Tashiro, Joseph E., fishery biologist, 1967-
Thomas, Letha Mae, librarian aid, 1967-68.

*Van Landingham, John W., general physical scientist, 1962-
*Wagner, Donald P., physical science technician, to 1969.
Walsh, Patricia, clerk-typist, 1969-
Weeks, Ann, writer-editor, 1965-
Wilkins, Anzilia, chemist, 1966.
Wilson, Peter C., fishery biologist, 1967-69.
*Wise, John P., fishery biologist, 1965-

Vessels, Geronimo and Undaunted

*Adams, Richard E., first officer, to 1967.
*Appleton, Thomas H., radio officer, to 1969.
Babcock, Wilfred H., chief engineer, 1968-
*Birds, Charles, cook, to 1966.
Brady, Daniel P., wiper, 1969-
*Ciaramitaro, Frank A., skilled fisherman, 1963-
Coito, John A., skilled fisherman, 1965-67.
Connor, James P., fisherman, 1967-69.
*Debus, Frank W., first officer, 1965-66; 1967-69.
*Eide, Elias, skilled fisherman, 1962-66; 67-
*Fagan, Lawrence G., chief engineer, to 1965.
Ferguson, Robert M., second assistant engineer, 1965-68.
Forrest, John C., leading fisherman, 1965.
*Gislason, S. E., skilled fisherman, to 1966.
*Holdsworth, Harold R., chief engineer, to 1967.
*Joseph, Warren, skilled fisherman, to 1966.
*Karr, James E., steward-cook, 1964-
Kilbride, William J., mess attendant, 1965-66.
Lafavor, Louis C., mess attendant, 1967.
Luschei, Fredrick C., second assistant engineer, 1969-
Marts, Harvey J., first assistant engineer, 1967.
*Matsuhara, Harry T., skilled fisherman, to 1967.
Mattos, Robert M., first assistant engineer, 1969-
*Meyer, Roger E., chief engineer, 1964-66; first assistant engineer, 1967-69.
O'Donnell, George P., second cook, 1968-69.
Ogilvie, Harry W., first officer, 1968-
*Okamoto, Torao, skilled fisherman, to 1966.
Rodrigues, Joseph, skilled fisherman, 1968-
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