

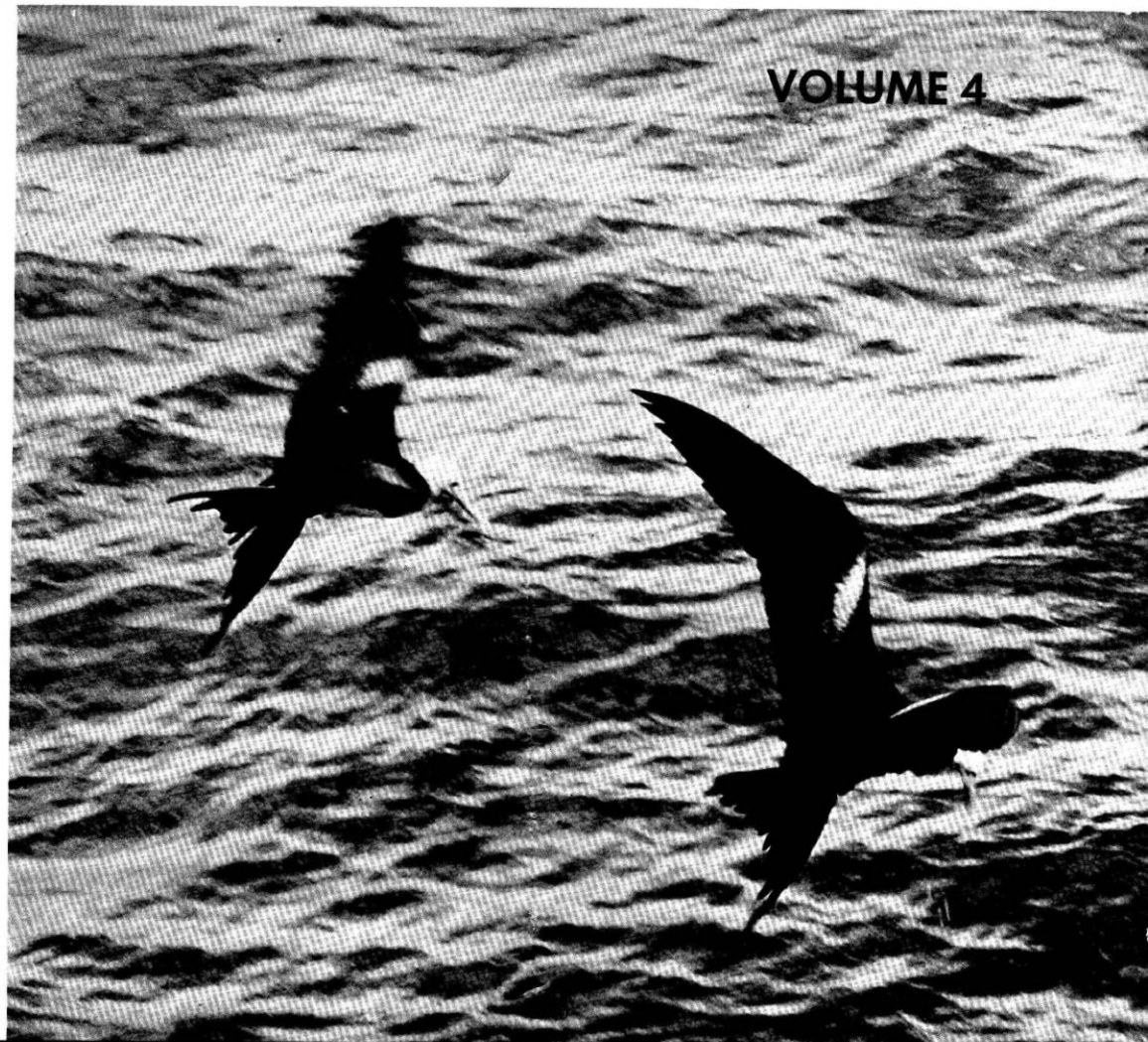
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**U.S. DEPARTMENT OF COMMERCE**  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION  
NATIONAL MARINE FISHERIES SERVICE

Circular 330

**VOLUME 4**



# EASTROPAC *Atlas*

## EASTROPAC *Atlas*

|           |   |                            |
|-----------|---|----------------------------|
| Volume 1  | Physical oceanographic and meteorological data from principal participating ships, first survey cruise, February-March 1967.  | In preparation             |
| Volume 2  | Biological and nutrient chemistry data from principal participating ships, first survey cruise, February-March 1967.  | In preparation             |
| Volume 3  | Physical oceanographic and meteorological data from principal participating ships, first and second monitor cruises, April-July 1967.                                     | In preparation             |
| Volume 4  | Biological and nutrient chemistry data from principal participating ships, first and second monitor cruises, April-July 1967.   | Published<br>November 1970 |
| Volume 5  | Physical oceanographic and meteorological data from principal participating ships, second survey cruise, August-September 1967.   | In preparation             |
| Volume 6  | Biological and nutrient chemistry data from principal participating ships, second survey cruise, August-September 1967.   | In preparation             |
| Volume 7  | Physical oceanographic and meteorological data from principal participating ships and <i>Oceanographer</i> , third and fourth monitor cruises, October 1967-January 1968. | In preparation             |
| Volume 8  | Biological and nutrient chemistry data from principal participating ships and <i>Oceanographer</i> , third and fourth monitor cruises, October 1967-January 1968.         | In preparation             |
| Volume 9  | Physical oceanographic and meteorological data from principal participating ships, third survey cruise, February-March 1968.  | In preparation             |
| Volume 10 | Biological and nutrient chemistry data from principal participating ships, third survey cruise, February-March 1968.  | In preparation             |
| Volume 11 | Data from Latin American cooperating ships and ships of opportunity, all cruises, February 1967-March 1968.   | In preparation             |

## ABSTRACT

This atlas contains charts depicting the distribution of physical, chemical, and biological oceanographic properties and associated meteorological properties observed during EASTROPAC. EASTROPAC was an international cooperative investigation of the eastern tropical Pacific Ocean (20° N. to 20° S., and from the west coasts of the American continents to 119° W.) which was intended to provide data necessary for a more effective use of the marine resources of the area, especially tropical tunas, and also to increase knowledge of the ocean circulation, air-sea interaction, and ecology. The Bureau of Commercial Fisheries (now National Marine Fisheries Service) was the coordinating agency. The field work, from February 1967 through March 1968, was divided into seven 2-month cruise periods. During each cruise period one or more ships were operating in the study area.

On completion of the field work the data seemed too numerous for a classical data report. Instead, it was decided to produce an 11-volume atlas of the results, with 5 volumes containing physical oceanographic and meteorological data from the principal participating ships, 5 volumes containing biological and nutrient chemistry data from the same ships, and 1 volume containing all data from Latin American cooperating ships and ships of opportunity. Extensive use was made of a computer and automatic plotter in preparation of the atlas charts. Methods used to collect and process the data upon which the atlas is based are described in detail by the contributors of the following categories of charts: temperature, salinity, and derived quantities; thickness of the upper mixed layer; dissolved oxygen; meteorology; nutrient chemistry; phytoplankton standing stocks and production; zooplankton and fish larvae; micronekton; birds, fish schools, and marine mammals.

Cover. Immature magnificent frigatebirds near Cocos Island.  
Photo by John H. Taylor, Scripps Institution of Oceanography.





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November, 1970

**NOTICE TO RECIPIENTS OF THE EASTROPAC ATLAS**

The introductory material from Volume 1, including the following sections: Preface, Introduction, Collection and Processing of the Data, and Literature Cited, as well as a complete set of station location charts, has been included in this volume, Volume 4, so that information concerning the objectives and history of EASTROPAC, the cruises undertaken, the observations made, and the methods used to process the data and prepare the charts will be available in the first volume published. When you receive your copy of Volume 1 at a later date, please remove the above-mentioned sections and the accompanying station location charts and insert them at the beginning of Volume 1.

Thank you.

Cuthbert M. Love, Editor  
EASTROPAC Atlas

# EASTROPAC Atlas

VOLUME 4

## ERRATA

October 1970

FIGURE 20-PP-v1  
FIGURE 20-PP-v4  
FIGURE 20-PP-v5  
FIGURE 20-PP-v6

The units of primary production shown in the caption should be corrected to read:

$\text{mg.C/m}^2/\text{day}$

FIGURE 30-ZhD

The units of standing stock should be corrected to read:

$\text{ml./1,000 m}^2$

FIGURE 20-NH<sub>3</sub>-100

The caption should be corrected to read: Ammonia-nitrogen (ug.-at./l.) at 100 meters, ---

UNITED STATES DEPARTMENT OF COMMERCE

Maurice H. Stans, *Secretary*

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Philip M. Roedel, *Director*

# EASTROPAC *Atlas*

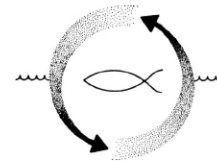
VOLUME 4 BIOLOGICAL AND NUTRIENT CHEMISTRY DATA  
FROM PRINCIPAL PARTICIPATING SHIPS, FIRST AND SECOND  
MONITOR CRUISES, APRIL - JULY 1967

CUTHBERT M. LOVE, *Editor*

CIRCULAR 330

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## PREFACE

During the last two decades a number of expeditions have worked in the eastern tropical Pacific Ocean, so that the general features of its circulation and biology have been described. (References to such investigations are to be found in the two reports of the Eastern Pacific Oceanic Conference—EPOC, cited below.) However, the accumulated observations are too poorly arranged in time and space to describe, in an adequate fashion, the monthly or seasonal variation in the distribution of physical or biological properties. Large-scale changes in the atmospheric circulation clearly lead to changes in mass transport within major components of the circulation, as well as causing variation in the intensity of vertical motion on the equator and along the continental margin. In order to understand and to predict the nature of such variation it was evident from the data of previous studies in the eastern tropical Pacific Ocean that a more solid data base for modeling circulation and biotic production in this region was necessary.

Many of the members of the EPOC are engaged in research in the eastern tropical Pacific, and a proposal for a detailed and comprehensive study of the upper ocean in this area originated in 1960 at the Seventh Annual Meeting of EPOC. The Conference appointed a Committee, chaired by Gerald V. Howard of the Bureau of Commercial Fisheries (BCF)<sup>1</sup> to consider the desirability, feasibility, and possible scope of a cooperative program of oceanic survey and research in the eastern tropical Pacific Ocean. This Committee reported the results of its study to the Eighth EPOC, held in September 1961, and published these as the *Report of EPOC on a Cooperative Program of Study of the Eastern Tropical Pacific Ocean*.

The recommendations called for a \$20-million oceanography program to begin in 1963 and run for a period of 8 years to encompass general survey work and special research in meteorology; physical, chemical, and biological oceanography (including fisheries); geology; and geophysics. It noted that such a program would not only greatly advance the marine sciences and provide opportunities for significant new understanding of the ocean, but would also be of value in providing the scientific basis for increasing the harvest of the fisheries of the region, forecasting weather, and improving shipping and navigation. It recommended that the U.S. Interagency Committee on Oceanography (ICO) and the individual agencies of the government should begin planning for support of the program. It also recommended that international participation and aid should be sought through appropriate international agencies and from Latin American institutions with oceanographic capabilities. The program then received the approval of the Intergovernmental Oceanographic Commission at its meeting in Paris in September 1961.

However, for various reasons, 4 years elapsed and little progress was made before implementation of the EPOC plan. Between the fall of 1963 and the spring of 1964, a group of scientists from several agencies engaged in oceanography in the eastern Pacific met to consider the EPOC program in the light of developments, or lack thereof, towards its implementation during the intervening years. This ad hoc group agreed that two major factors were deterrents to the program. The funding agencies appeared to consider the proposed survey and research too costly, and some parts of the program had not attracted the scientists who would be required to carry them out.

The ad hoc group decided to revise and trim the EPOC program as originally recommended in the hope of overcoming major obstacles apparently blocking its implementation. It took into consideration recent developments, especially in the fisheries of the eastern tropical Pacific and the present and potential manpower and facilities of the scientific community. It concluded that the geological-geophysical portion could be deleted because it dealt with time-independent properties not closely related to the rest of the program, and that the detailed meteorological program could be reduced. Also, it was decided that the research cruises and special research projects could be omitted from the basic plan since these would follow as people recognized their possibilities and importance. What remained of the original proposal, then, was the hard core of the field survey program for physical, chemical, and biological oceanography and essentials of the meteorological program, although even these efforts were reduced to coincide with reductions in research ship time. While trimming the overall oceanographic program as originally conceived, the ad hoc group recognized a need to include fishery surveys in the plan to insure that the fishing industries would obtain maximum benefit from the proposed work in

descriptive oceanography. The revised program was now labeled EASTROPAC *A Cooperative Effort Towards Understanding of the Oceanography of the Eastern Tropical Pacific Ocean*.

The ad hoc group prepared estimates of the total funds that would be required to launch the field operations associated with EASTROPAC, process the data collected, analyze the data, and prepare reports on the results. In making the estimates, the group took into account the existing capabilities—available scientific personnel and oceanographic programs underway in the laboratories already engaged in studies of the eastern tropical Pacific Ocean—that were available for the EASTROPAC expeditions. Thus, the major share of the budget prepared was for the support of ship operations and unmanned buoys.

EASTROPAC finally became a reality with the first cruise scheduled for February-March 1967. The investigations were to be coordinated by the Bureau of Commercial Fisheries through its laboratory in La Jolla, and in June 1966 a Coordinator, Dr. Warren S. Wooster, Scripps Institution of Oceanography (SIO), was appointed; in May 1967, Dr. Alan R. Longhurst, then of SIO, replaced Dr. Wooster. As his first task, Dr. Wooster enlisted the support of various Federal agencies and scientific institutions in providing ships and personnel, Mexico and a number of South American countries were also asked to participate because of the importance of these expeditions to Latin American fisheries.

By the time the first expedition was due to sail, an impressive number of agencies had pledged their support in one way or another; these included international and foreign organizations as well as United States universities and Federal agencies.

The organizations involved in EASTROPAC, and the nature of their involvement, were as follows:

### International:

*Inter-American Tropical Tuna Commission (IATTC), La Jolla, California.* Participation of biological and physical oceanographers and technicians aboard U.S. and Latin American research vessels. Performed analysis of meteorological data and sorting of zooplankton samples under contract to Bureau of Commercial Fisheries. Provided computer programming services and assistance in reduction and analysis of some Latin American data.

### Foreign:

*Chile—Instituto Hidrográfico de la Armada.* Organization and manning of research cruises off Chile on Chilean research vessel *Felcho* and through tropical area by *Esmeralda*.

*Ecuador—Instituto Nacional de Pesca.* Organization and manning (with IATTC) of research cruises off Ecuador with Ecuadorian research vessel *Huayayir*.

*Peru—Instituto del Mar.* Organization and manning of research cruises off Peru with Peruvian research vessel *Umanu*.

*Mexico—Dirección General de Pesca e Industrias Conexas.* Organization and manning (with IATTC) of research cruises off Mexico with Mexican vessels *Yolanda* and *Tuxpan* and a chartered U. S. vessel, *Defiance* (with IATTC and the U. S. Bureau of Sport Fisheries and Wildlife).

### United States:

*U.S. Coast Guard.* Provision of USCG research vessel *Rocksaw* for three major cruises off Central America and partial provision of her scientific party, the rest supplied by other agencies. Provided financial support for atlas publication.

*U.S. Department of Commerce (ESSA).* Provision on some of the major cruises of Weather Bureau personnel and equipment for taking surface and upper air observations. Designated one leg of the inaugural voyage of U.S. Coast and Geodetic Survey Ship *Oceanographer* for EASTROPAC participation.

*U.S. Department of the Navy (ONR).* Provision of funding in support of some of the university research vessels participating and of processing and analysis of data obtained. (*NAVOCEANO*). Designated a portion of a research cruise of the USNS *Charles H. Davis* for EASTROPAC participation.

*National Oceanographic Data Center (NODC).* Consultation and cooperation concerning standardization of observational and data-recording techniques. Sent one oceanographer to La Jolla for 6 months to assist in processing of physical oceanographic data. Provided financial support for atlas publication.

<sup>1</sup>Now National Marine Fisheries Service.

*National Science Foundation (NSF).* Funds in support of some university personnel and research ships.

*Smithsonian Institution.* Provision of ornithologists trained in sea-bird and fish-school observations for most of the major cruises.

*Stanford University.* Supplied data from research vessel *Te Vega* which operated concurrently in the survey area.

*University of California (Scripps Institution of Oceanography).* Provision of research vessels *Thomas Washington* and *Argo*, and partial provision of their scientific parties. Provision of two instrumented buoys to be moored in the survey area. Assistance subsequent to the expeditions in reduction and analysis of data.

*Texas A & M University.* Provision of research vessel *Alaminos* and partial provision of her scientific party. Supply of meteorological instruments for other vessels.

*U. S. Department of the Interior (Bureau of Commercial Fisheries).* Provision of coordination unit at La Jolla, of research vessels *David Starr Jordan* and *Undaunted* and their scientific parties; post-expedition reduction and analysis of data. Provided financial support for atlas publication.

The EASTROPAC expeditions were unique in their scope and in the degree of coordinated planning of the cruises. In size of area and number of observations, EASTROPAC was comparable with such major international efforts as the International Indian Ocean Expedition, yet, unlike IIOE, all participating ships worked tracks designated prior to the expeditions to survey comprehensively the designated area in space and time; all participating ships undertook to perform a standard and basic suite of physical and biological observations, using standardized gear and conforming to standards laid down by the EASTROPAC *Manual of Observations* (Staff EASTROPAC, 1967) issued before the first cruise and modified only very slightly during the 14 months the expeditions occupied. Such routine observations formed a very large part of the effort of each participating ship and other scientific activities were performed only on a "not to interfere" basis.

The expeditions were extremely fortunate in the small number of medical emergencies and ship breakdowns which disrupted planned observational patterns,

and only minor modifications had to be made to planned cruise tracks. This was due in no small part to the enthusiasm of the individual participants aboard the expedition ships, whose dedication to the idea behind the series of expeditions must be recognized and acknowledged by those involved in its planning.

It was decided by a meeting of the EASTROPAC Coordinating Committee in April 1968, that the data derived from the expeditions were so numerous as to render classical data reports impractical, and it was decided that all data should be archived on magnetic tape at the National Oceanographic Data Center after they had been used for production of a comprehensive atlas of the physical and biological results of the expeditions. It was also decided, in view of the volume of the data and the consequent number of sheets in the atlas, the preliminary data processing and chart analyses would be performed entirely by computer. Therefore only minimum hand computation and limited drafting were needed in this atlas. Only in this way could it have been produced in the short time available and as economically as it has been; the presentation may not be as aesthetically pleasing as in more classical atlases but it is hoped that our charts and sections will be equally as useful as hand-drawn ones.

In accepting the role of coordinating agency for EASTROPAC, the Bureau of Commercial Fisheries recognized that the expeditions were a necessary preliminary to fishery development in the eastern tropical Pacific Ocean to the west of the present-day tuna fisheries. A second-phase operation was visualized after data reduction, analysis, and presentation were completed for the original series of EASTROPAC expeditions. This second phase would consist of (1) stock assessment of oceanic tunas and determination of their availability to a fishery, in areas and at seasons indicated by analysis of EASTROPAC data; (2) further investigations of phenomena, physical or biological, demonstrated by the initial expedition data, what way these data and later monitoring operations (surface ships, buoys, or remote sensors) might be used to develop fisheries advisory services for the tropical tuna fleet.

At the time of writing, in early 1970, the Bureau of Commercial Fisheries is moving towards these second-phase objectives.

ALAN R. LONGHURST  
EASTROPAC Coordinator



## INTRODUCTION

### EASTROPAC CRUISES

The EASTROPAC field work was divided into seven, 2-month cruise periods. During each period there was a single- or multi-ship cruise. Each cruise was planned to last about 50 days; in practice some lasted longer. There were two types of cruises—survey and monitor. Survey cruises were multi-ship operations designed to provide simultaneous coverage of as much of the study area as possible. The study area was defined as latitude 20° N. to latitude 20° S. and from the coast of the American continents westward to longitude 119° W. There were three such surveys, 6 months apart. In each interval between survey cruises there were two, single-ship monitor cruises, making a total of four. The area covered by monitor cruises was determined partly by oceanographic considerations and partly by time and logistic constraints placed on a vessel operating from San Diego, but the purpose was to monitor changes in oceanographic conditions taking place between survey cruises.

Cruises by Latin American cooperating vessels were usually timed to coincide with survey cruises, and their coverage designed to supplement the survey cruises.

In addition to the major EASTROPAC cruises and Latin American cooperating vessels, certain ships of opportunity presented themselves. In some cases, such as *Te Vega*, the ship was operating in the same area and at the same time, and the

data were made available to EASTROPAC. In other cases, such as *Oceanographer* and *Charles H. Davis*, the observations made during a portion of each of their cruises were planned to be part of EASTROPAC. EASTROPAC personnel were aboard *Oceanographer* during that portion of her cruise.

The cruises are designated in the atlas by a two-digit numbering system. The first number, from 1 through 7, designates one of the seven, 2-month cruise periods beginning with February-March 1967. The second number indicates the track followed or area covered within that cruise period. The monitor cruise track is designated by 0. For the first survey cruise (4 ships) the tracks are designated 1 to 4 with the westernmost track having the lowest number. For the second and third survey cruises (3 ships each) the tracks are numbered 5, 6, and 7 with, again, the westernmost track carrying the lowest number. Thus, cruise 12 represents track 2 of the first survey cruise; 30 designates the second monitor cruise; 77 refers to track 7 (the easternmost track) of the third survey cruise. Local practice has been to include the name of the ship when referring to a cruise, e.g., *Jordan* 12, but it is not necessary for complete identification of the cruise. There has also been some use of the expressions "10-series cruises," "40-series cruises," etc., to refer to cruises made during the first survey cruise period, second survey cruise period, etc. Cruises of foreign cooperating vessels or ships of opportunity have been identified by the expedition names or cruise numbers assigned by the operating agency.

### SUMMARY OF EASTROPAC CRUISES

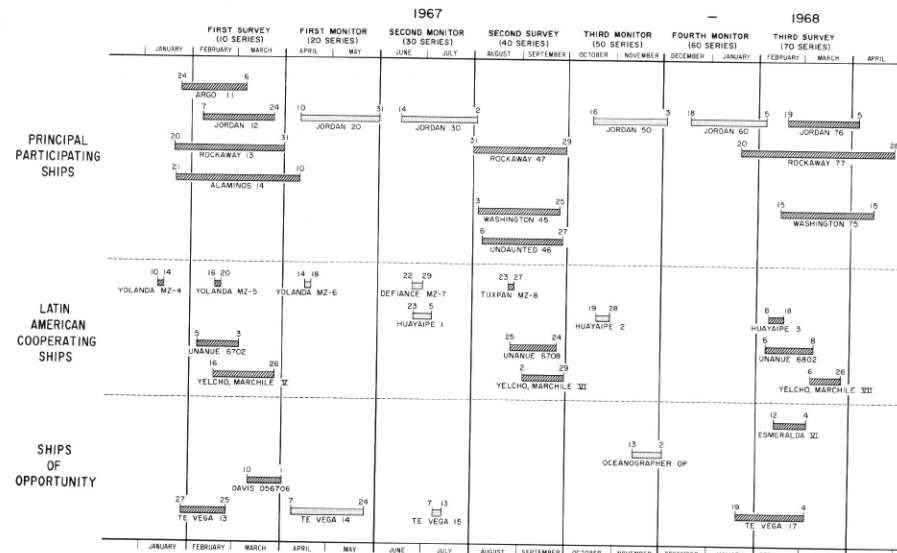


FIGURE 1. — Summary of EASTROPAC cruises.

Figure 1 is a graphical summary of EASTROPAC cruises. The affiliations of the participating ships are shown in the accompanying table (table 1).

| Category and ship                        | Country         | Agency or institution  |
|--|-----------------|--|
| <b>Principal participating ships:</b>    |                 |  |
| <i>Alaminos</i> .....                    | U.S.A.          | Department of Oceanography, Texas A & M University   |
| <i>Argo</i> .....                        | U.S.A.          | Scripps Institution of Oceanography, University of California  |
| <i>David Starr Jordan</i> .....          | U.S.A.          | Bureau of Commercial Fisheries, La Jolla   |
| <i>Rockaway</i> .....                    | U.S.A.          | U.S. Coast Guard   |
| <i>Undaunted</i> .....                   | U.S.A.          | Bureau of Commercial Fisheries, Miami  |
| <i>Thomas Washington</i> .....           | U.S.A.          | Scripps Institution of Oceanography, University of California  |
| <b>Latin American cooperating ships:</b> |                 |  |
| <i>Defiance</i> .....                    | Mexico & U.S.A. | Dirección General de Pesca e Industrias Conexas, Mexico, and U.S. Bureau of Sport Fisheries and Wildlife |
| <i>Huayaipé</i> .....                    | Ecuador         | Instituto Nacional de Pesca  |
| <i>Tuxpan</i> .....                      | Mexico          | Dirección General de Pesca e Industrias Conexas  |
| <i>Unanue</i> .....                      | Peru            | Instituto del Mar  |
| <i>Yelcho</i> .....                      | Chile           | Instituto Hidrográfico de la Armada  |
| <i>Yolanda</i> .....                     | Mexico          | Dirección General de Pesca e Industrias Conexas  |
| <b>Ships of opportunity:</b>             |                 |  |
| <i>Charles H. Davis</i> .....            | U.S.A.          | U.S. Naval Oceanographic Office  |
| <i>Esmeralda</i> .....                   | Chile           | Instituto Hidrográfico de la Armada  |
| <i>Oceanographer</i> .....               | U.S.A.          | Environmental Science Services Administration, U.S. Coast & Geodetic Survey                              |
| <i>Te Vega</i> .....                     | U.S.A.          | Stanford Oceanographic Expeditions, Stanford University  |

The field work began with the first survey cruise (10-series cruises) in February-March 1967 (figs. 10-TC-a, 10-TC-b). Major coverage was by four ships: *Argo* of the Scripps Institution of Oceanography, University of California, San Diego, and *David Starr Jordan* of the Bureau of Commercial Fisheries, Fishery-Oceanography Center in La Jolla, both operating from San Diego, and the U.S. Coast Guard Cutter *Rockaway* from New York, and *Alaminos* from the Department of Oceanography, Texas A & M University, which began their EASTROPAC operations after entering the Pacific from the Canal Zone. The area covered was from 20° N. to 20° S. and from the coast westward to longitude 126° W. It should be noted that this was the only cruise in which there was coverage on 126° W. Subsequent cruises only extended westward to 119° W. Additional coverage along the coast of cooperating nations was provided by *Yolanda* of the Dirección General de Pesca e Industrias Conexas, Mexico, (DGPIC) operating out of Mazatlán in a joint project with the Inter-American Tropical Tuna Commission (IATTC), *Unanue* of the Instituto del Mar of Peru (IMP) from Callao, and the MARCHILE V cruise run by *Yelcho* of the Instituto Hidrográfico de la Armada, Chile, (IHA) from Valparaíso. Ships of opportunity operating during the period were the USNS *Charles H. Davis* of the U.S. Naval Oceanographic Office from San Diego, which ran a north-south section on 85° W., and *Te Vega* of Stanford Oceanographic Expeditions, Stanford University, from Pacific Grove, which operated on a line from Cape San Lucas to the Galápagos.

Two monitor cruises by *David Starr Jordan*, cruise 20 in April-May (fig. 20-TC) and cruise 30 in June-July (fig. 30-TC), followed. During the first monitor period, *Yolanda* again operated from Mazatlán and *Te Vega* was working off the coast of Mexico between 13° and 24° N. During the second monitor cruise, *Defiance*, a chartered U.S. fishing vessel, operated out of Mazatlán instead of

*Yolanda* for a joint cruise sponsored by DGPIC, the U.S. Bureau of Sport Fisheries and Wildlife, and the IATTC; *Huayaipé* of the Instituto Nacional de Pesca, Ecuador (INPE), in conjunction with IATTC, operated in the waters between Guayaquil and the Galápagos; and *Te Vega* occupied stations in the entrance to the Gulf of California.

The second survey cruise (40-series) took place in August-September 1967 (figs. 40-TC-a, 40-TC-b). Only three ships were available for the principal coverage: *Thomas Washington*, SIO, *Undaunted* from the BCF Tropical Atlantic Biological Laboratory in Miami, and *Rockaway*. It was necessary to rearrange the cruise tracks, especially in the eastern portion of the area, and the extent of the southward coverage was reduced. Other vessels operating during this period were *Tuxpan* of DGPIC and IATTC from Mazatlán, *Unanue*, and *Yelcho* (MAR-CHILE VI).

The third and fourth monitor cruises were run by *David Starr Jordan*, cruise 50 in October-November (fig. 50-TC) and cruise 60 in December 1967-January 1968 (fig. 60-TC). During the third monitor period, the U.S. Coast and Geodetic Survey Ship *Oceanographer* made observations during part of her track between Callao and San Diego. This portion of her inaugural, round-the-world voyage had been designated for EASTROPAC participation. Also during this period *Huayaipé* made a second cruise in the area between Guayaquil and the Galápagos. *Te Vega* ran a north-south line on 100° W. and some stations in the vicinity of the Galápagos in a time period which overlapped between the fourth monitor and third survey cruise periods.

The principal observations during the third survey cruise (70-series) in February-March 1968 (figs. 70-TC-a, 70-TC-b) were made by three ships: *Thomas Washington*, *David Starr Jordan*, and *Rockaway*. The cruise tracks were similar to those of the second survey except that some of the north-south lines extended to 20° S. and there was no coverage along 92° W. Cooperating ships operating at the same time were *Huayaipé*, *Unanue*, *Yelcho* (MARCHILE VII), and *Esmeralda*. The latter, a training ship of the Chilean Navy, made a series of mechanical bathythermograph observations during a run from Valparaíso to Panama.

## PROGRAM OF OBSERVATIONS

The program of observations followed during principal EASTROPAC cruises was based on three types of stations, designated A, B, and C, which were arranged by the time of day. At A stations there was a Nansen bottle cast to 500 m., a lowering of the salinity-temperature-depth recorder (STD) to 500 m., a lexan bottle cast for primary production and plant pigment samples, an oblique plankton haul from 200 m. to the surface using paired 1-m. and 50-cm. nets along with a simultaneous surface haul with a 1-m. net, and a micronekton haul from 200 m. to the surface using a 5-ft.-square net. A stations were made twice daily at approximately 0000 and 1200 local time. B stations were taken at approximately 0400 and 1600 local time and consisted of a 1,000-m. Nansen cast, 1,000-m. STD lowering, and oblique plankton haul and surface haul as on A stations. The original program of observations called for a 1,000-m. Nansen and STD cast at A stations and 500-m. casts of both types at B stations. This system was changed in the course of the project in order to make the time on station at A and B stations more equal. On one monitor cruise, cruise 30, a 500-m. Nansen cast was paired with a 1,000-m. STD cast on A stations and vice versa on B stations. There were four C stations each day, scheduled approximately at mid-time between departure from an A station and arrival at a following B station or vice versa. C stations usually consisted of expendable bathythermograph (XBT) drops underway although sometimes STD lowerings to 300 m. or 500 m. were substituted. This made the sequence of stations for a 12-hour period starting at midnight as follows: A (0000) - C - B - C - A (1200). On principal cruises all stations were numbered consecutively regardless of type. The two-digit cruise number described previously was combined with a three-digit consecutive number to form a five-digit number that uniquely identifies each station; thus station 12.025 indicates the 25th consecutive station of *Jordan* cruise 12.

There were modifications to this routine of observations, and other types of observations were made which also contributed information to this atlas. Within

5° of latitude on each side of the equator most ships ran the so-called "equatorial detail" pattern where additional C stations, either XBT or shallow STD lowerings, were run in between the stations mentioned above. These made a 12-hour sequence: A-C-C-C-B-C-C-C-C-A. Bird observations by observers from the Smithsonian Institution were made on cruises 11, 12, 13, 30, 45, 46, 50, 75, and 76. The observers were usually stationed on the ship's bow or flying bridge during daylight hours. Equipped with binoculars and cameras, they attempted to identify and count all birds seen. A few birds were collected for study specimens. In addition, they made valuable observations of fish schools and marine mammals. Weather observers from the Weather Bureau, ESSA, were aboard during cruises 13, 20, 30, 47, and 77, and on *Oceanographer*, where they made twice daily radio-sonde observations to measure upper air conditions. Table 2 is a summary of observations made on EASTROPAC cruises.

TABLE 2.—Summary of types of observations made on EASTROPAC cruises.

| Item                               | Category of ships             |                                  |                      | Total |
|------------------------------------|-------------------------------|----------------------------------|----------------------|-------|
|                                    | Principal participating ships | Latin American cooperating ships | Ships of opportunity |       |
| STD casts .....                    | 2,683                         | 685                              | 128                  | 2,811 |
| Total Nansen casts .....           | 1,833                         | 685                              | 155                  | 2,673 |
| Nansen casts below 1,000 m. ....   | 137                           | 109                              | 61                   | 307   |
| XBT lowerings .....                | 2,206                         | .....                            | 222                  | 2,488 |
| Mechanical BT lowerings .....      | 386                           | 879                              | 81                   | 1,346 |
| <b>Meteorology:</b>                |                               |                                  |                      |       |
| Surface observations .....         | 3,820                         | 440                              | 200                  | 4,460 |
| Upper air observations .....       | 382                           | .....                            | 28                   | 410   |
| <b>Lexan casts:</b>                |                               |                                  |                      |       |
| Primary production experiments ... | 451                           | 259                              | 83                   | 833   |
| Plant pigment determinations ..... | 926                           | 292                              | 105                  | 1,323 |
| <b>Plankton hauls:</b>             |                               |                                  |                      |       |
| Oblique with paired nets .....     | 1,744                         | 132                              | 50                   | 1,926 |
| Surface .....                      | 1,600                         | 141                              | 49                   | 1,790 |
| Vertical .....                     | .....                         | 425                              | .....                | 425   |
| Micronekton hauls .....            | 810                           | .....                            | 39                   | 849   |

The information presented in this atlas is based primarily on the observations described above. There were a number of other measurements and observations made during EASTROPAC. Some were made on several cruises and others only on one. Some of the former are described below. Continuous recordings of bottom depths were made on most of the major cruises. In fact, the north-south portions of the monitor cruise tracks were shifted each time a few miles either to the east or west of the base meridians of 98° W., 105° W., 112° W., 119° W., so as to provide different bathymetric coverage. Table 3 shows the longitudes covered during monitor cruises. Sounding information from San Diego-based EASTROPAC ships has been turned over to the Department of Earth Sciences, SIO, for analysis. Although the data shown in this atlas extended only to 1,000 m. depth, there were 163 stations occupied during the project where Nansen casts deeper than 1,000 m. were made. In some cases these casts extended to within 100 m. of the bottom. There are tentative plans for these deep-station data to be published in a separate data report, but in any case, they will be sent to the National Oceanographic Data

TABLE 3.—Longitudes covered on north-south lines during EASTROPAC monitor cruises.

| Cruise | Base meridians |            |            |           |
|--------|----------------|------------|------------|-----------|
|        | 119° W.        | 112° W.    | 105° W.    | 98° W.    |
| 20     | 119°20' W.     | 112°20' W. | 105°20' W. | 98°20' W. |
| 30     | 118°30' W.     | 111°30' W. | 104°30' W. | 97°30' W. |
| 50     | 119°10' W.     | 112°10' W. | 105°10' W. | 98°10' W. |
| 60     | 118°45' W.     | 111°45' W. | 104°45' W. | 97°45' W. |

Center. The Scripps Institution of Oceanography provided two instrument platforms (buoys) to be moored in the study area during the period of EASTROPAC. These buoys were set out during the first survey cruise at two locations on longitude 119° W. in the Equatorial Counter Current, at approximately 6° N. and 9.5° N. They were equipped to measure and record subsurface temperatures at seven depths as well as surface water temperature and meteorological properties. The buoys were visited during each subsequent voyage to service the equipment. The buoy at 6° N. was not found in August 1967, during cruise 45, apparently having been swept away by bad weather. The one at 9.5° N. was located in October on cruise 50, but all sensors except one were inoperative so the instrument package was removed from the buoy. The buoy itself had disappeared when the area was searched in December during cruise 60. A preliminary data report issued by SIO (Evans, Schwartzlose, and Isaacs, 1968) showed that a maximum of 3307 hours of observations was obtained from the 6° N. buoy and 2369 hours from the one at 9.5° N.

Details of the observations made during the EASTROPAC cruises will be found in the various EASTROPAC Information Papers (Wooster, 1966a, 1966b, 1966c; Wooster and Love, 1967; Longhurst and Love, 1967; Longhurst, 1967a, 1967b, 1968, 1969a, 1969b; Love, 1969). In particular, Numbers 6, 8, and 9 of this series contain lists of stations occupied on all cruises showing date, time, position, and observations made. It is intended that most of the information collected, whether or not it appears in the atlas, will be made the subject of detailed research reports by the various investigators concerned.

Some of the Latin American cooperating ships and ships of opportunity followed the EASTROPAC routine of observations as well as their equipment, personnel, and time schedules would permit, while others followed their own routines. During the EASTROPAC portion of the *Oceanographer* voyage the prescribed routine was followed. Plans for the *Unanue* and *Yelcho* cruises called for the three types of stations previously mentioned and also for station spacing based on time of day. These ships were not equipped with an STD, however, nor were they able to make all the specified plankton or micronekton collections. *Charles H. Davis* ran the extra detail requested in equatorial regions during her transit on 85° W.

## PREPARATION OF ATLAS CHARTS

The processing of almost all the data mentioned in the preceding section involved the use of automatic data processing (ADP) equipment at some stage. The data were therefore already stored on punched cards or magnetic tape and readily available for plotting in various forms by computer-driven plotter.

The vertical sections of physical properties, dissolved oxygen, and nutrient chemicals were prepared almost entirely by computer plotter, including drawing of the contours. Hand work included accenting certain contours and the addition of contour labels. For phytoplankton properties and upper atmosphere sections the outline of the section and depths, or heights, of sampling were plotter-drawn, and then hand-drawn contours were traced onto the section from a preliminary contour version.

There was more variety in the methods used to prepare the charts of horizontal distributions. The options open to the contributors included hand or machine plotting of station positions and the data to be contoured, and then hand or machine drawing of the contours. Copies of the standard base map on which to plot data were available to all contributors. The base map was adapted from two U.S. Naval Oceanographic Office charts and is a Mercator projection. Some charts were plotted and contoured by hand; others were plotted automatically and contoured by hand. This latter was the most popular method of chart preparation. In either of the above methods the draftsman overlaid the preliminary version with a clean base map and copied the contours and station positions and applied shading as necessary. The charts showing zooplankton standing stock were plotted and contoured automatically. Drafting work on these charts was limited to touch-up work and application of shading.

## ORGANIZATION OF THE ATLAS

### Arrangement of Volumes

The EASTROPAC Atlas consists of 11 volumes. There are 10 volumes containing data from the principal participating ships plus *Oceanographer* and 1 volume containing data from the Latin American cooperating ships and other ships of opportunity. The first 10 volumes are arranged chronologically and by two general subject headings; 5 volumes contain physical oceanography and meteorology, and 5 volumes contain biological properties and nutrient chemistry. The following table indicates the arrangement. It should be noted that charts of horizontal distribution of properties which appear in the first 10 volumes do contain data from the Latin American ships and ships of opportunity as well as principal ship data. It is the vertical sections based on Latin American and ships of opportunity data which are found in volume 11.

| Volume number | Contents                                     | Ships and cruise period(s)   | Dates   |
|---------------|--|--|---|
| 1             | Physical properties and meteorology          | Principal ships—First survey cruise (10-series)  | February–March 1967                               |
| 2             | Biological properties and nutrient chemistry |  |   |
| 3             | Physical properties and meteorology          | Principal ships—First and second monitor cruises (20, 30 series)                           | April–May, June–July 1967                         |
| 4             | Biological properties and nutrient chemistry |  |   |
| 5             | Physical properties and meteorology          | Principal ships—Second survey cruise (40-series)   | August–September 1967                             |
| 6             | Biological properties and nutrient chemistry |  |   |
| 7             | Physical properties and meteorology          | Principal ships and <i>Oceanographer</i> —Third and fourth monitor cruises (50, 60-series) | October–November 1967, December 1967–January 1968 |
| 8             | Biological properties and nutrient chemistry |  |   |
| 9             | Physical properties and meteorology          | Principal ships—Third survey cruise (70-series)  | February–March 1968                               |
| 10            | Biological properties and nutrient chemistry |  |   |
| 11            | All properties                               | Latin American cooperating ships and ships of opportunity—All cruises                      | February 1967–March 1968                          |

### Color of Pages

In order to assist users to find the pages they want, pages showing different groups of properties have been printed on differently colored paper. Five colors have been used in each type of volume according to the following scheme:

Physical Oceanography and Meteorology (odd-numbered volumes):  
 Temperature, salinity .....White

Computed quantities (thermoelectric anomaly, geostrophic velocity, acceleration potential) .....Yellow  
 Oxygen .....Green  
 Depth of surfaces, including mixed layer depth .....Buff  
 Meteorological charts .....Blue

Biological Properties and Nutrient Chemistry (even-numbered volumes and volume 11):  
 Nutrient chemistry .....White  
 Phytoplankton .....Green  
 Zooplankton and micronekton .....Blue  
 Fish larvae .....Yellow  
 Sightings of birds, tuna schools, mammals .....Buff

### Figure Designation System

Although the atlas will initially be published in volumes arranged chronologically, as explained above, looseleaf binding permits users to rearrange the pages to suit their own needs. It was necessary to devise a figure designation system compatible with this flexibility. The system used consists of a series of numbers and letters or symbols which indicate the cruise or cruise period, the property represented, and whether it is a vertical section or horizontal distribution. In the latter case the designator further indicates whether the property is shown at a constant depth (phosphate-phosphorus at 10 m.), integrated over a layer (chlorophyll-a integrated over the euphotic layer), on a surface of constant thermoelectric anomaly (salinity on the 300 cl./t. surface), or whether the contours represent numbers collected or observed per station, per day, etc. (total *Aurelia* larvae taken in 1-m. oblique hauls). Sample figure designators and a complete list of abbreviations used are shown below. It should be noted that each figure bears a caption and each vertical section is also accompanied by a small index map to indicate its location so that the reader does not have to rely on the figure designator alone for a description of what the figure represents.

The following sample designators will illustrate the system:

12-T-v1 — First vertical section from cruise 12 showing distribution of temperature.  
 45-P-v2 — Second vertical section from cruise 45 showing distribution of phosphate-phosphorus.  
 The vertical sections are assigned consecutive numbers, v1, v2, etc., within each cruise which follow the chronological order in which the ship ran the sections.  
 40-NO<sub>3</sub>-10 — Distribution of nitrate-nitrogen at 10-m. during second survey cruise (40-series).  
 20-3300-z — Depth of 300 cl./t. thermoelectric anomaly surface during the first monitor period.  
 30-O<sub>2</sub>-8160 — Distribution of oxygen on the 160 cl./t. thermoelectric anomaly surface during second monitor period.  
 50-Ch-ei — Distribution of chlorophyll-a integrated over the euphotic layer during third monitor period.  
 70-ZhN — Standing stock of zooplankton taken in 50-cm. net hauls at night during third survey cruise period.

Table 4 shows all the abbreviations used in figure designators.

### Remarks Concerning the Charts

The editorial policy of the atlas allowed each contributor to decide whether or not he wanted to use shading to enhance his presentation. A uniform shading scheme was adopted and was followed on all charts where shading was used. Shading scales are not shown on most charts in the belief that the combination

TABLE 4.—Abbreviations used in figure designation system.

| Cruise or cruise period  | Property represented  | Mnemonic to explain choice of letters  | Indicator for vertical sections or type of horizontal surface   |
|--|---|--|---|
| Numbers 11, 12, 13, etc., indicate principal cruises. See figure 1.  | T Temperature<br>S Salinity<br>$\delta$ Thermobaric anomaly ( $\delta_T$ )<br>G Geostrophic velocity<br>O <sub>2</sub> Oxygen concentration<br>O <sub>2</sub> Sa Oxygen saturation<br>ML Thickness of the mixed layer<br>300 300 cl./t. thermobaric anomaly surface   |  | vt, vz, etc., indicate vertical sections.<br>Vertical sections are assigned consecutive numbers within each cruise which follow the chronological order in which the ship ran the sections.   |
| Letters or letter-number combinations indicate cruises of Latin American cooperating ships or ships of opportunity, as follows:                    | AP Acceleration Potential<br>P Phosphate-phosphorus<br>Si Silicate-silicon<br>NO <sub>3</sub> Nitrate-nitrogen<br>NO <sub>2</sub> Nitrite-nitrogen<br>NH <sub>4</sub> Ammonia-nitrogen  |  | Number 30 or 100 following O <sub>2</sub> Sa or horizontal P, Si, NO <sub>3</sub> , NO <sub>2</sub> , or NH <sub>4</sub> charts indicates distribution at that depth (m.).  |
| MZ-4 <i>Yolanda</i> , MZ-4<br>MZ-5 <i>Yolanda</i> , MZ-5<br>MZ-6 <i>Yolanda</i> , MZ-6<br>MZ-7 <i>Defiance</i> , MZ-7<br>MZ-8 <i>Tuxpan</i> , MZ-8 |   |  | s Distribution at the sea surface<br>300 Distribution on the surface where $\delta_T=300$ cl./t.<br>ei Distribution integrated over the euphotic layer<br>150i Distribution integrated to 150 m. depth<br>z Depth of a surface  |
| H1 <i>Huayaipae</i> -1<br>H2 <i>Huayaipae</i> -2<br>H3 <i>Huayaipae</i> -3   | Ch Chlorophyll-a<br>Ph Phaeophytin<br>PP Primary production<br>EL Thickness of the euphotic layer   |  |   |
| U1 <i>Unanue</i> 6702<br>U2 <i>Unanue</i> 6708<br>U3 <i>Unanue</i> 6802  | FCg Fish and cephalopod standing stock<br>Cr Crustacean standing stock<br>Nk Total micronekton standing stock<br>ZIN Zooplankton standing stock from 50-cm. net hauls, night  | Zooplankton, half-meter, Night   | Number 1 or 2 following SP or SW charts indicates one of two 6-month periods into which those observations were divided.  |
| Y5 <i>Yelcho</i><br>MARCHILE V   | ZIN Zooplankton standing stock from 1-m. net hauls, night   | Zooplankton, 1-meter, Night  |   |
| Y7 <i>Yelcho</i><br>MARCHILE VII   | ZIN Zooplankton standing stock from 50-cm. net hauls, day   | Zooplankton, half-meter, Day   |   |
| E6 <i>Esmeralda</i> BE VI  | ZID Zooplankton standing stock from 1-m. net hauls, day   | Zooplankton, 1-meter, Day  |   |
| OP <i>Oceanographer</i><br>CD <i>Charles H. Davis</i>  | FLN Total fish larvae, night hauls<br>FLD Total fish larvae, day hauls<br>FE Total fish eggs<br>FS Total skipjack tuna larvae<br>FA Total <i>Axius</i> larvae<br>FC Total <i>Coryphæna</i> larvae<br>FMN Total myctophid larvae, night hauls<br>FMD Total myctophid larvae, day hauls<br>FGN Total gonostomatid and sternopygid larvae, night hauls<br>FGD Total gonostomatid and sternopygid larvae, day hauls   | Fish Larvae, Night<br>Fish Larvae, Day<br>Fish, Skipjack<br>Fish, <i>Axius</i><br>Fish, <i>Coryphæna</i><br>Fish, Myctophid, Night<br>Fish, Myctophid, Day<br>Fish, Gonostomatid, Night<br>Fish, Gonostomatid, Day | Numbers 1 to 4 or 1 to 6 following MT or MW charts indicate one of the approximate 2-week periods into which those observations were divided. For all cruise periods except 40, the MT and MW charts were drawn for four 2-week periods. For the 40 cruise period these charts were drawn for six periods ranging from 12 to 16 days in length, but with several days overlap between some periods. Number 1 or 2 following MC charts indicates one of the monthly periods for which those charts were drawn. |
| T3 <i>Te Vega</i> 13<br>T4 <i>Te Vega</i> 14<br>T5 <i>Te Vega</i> 15<br>T6 <i>Te Vega</i> 16<br>T7 <i>Te Vega</i> 17                               | BP Relative abundance of plankton-feeding birds<br>BF Relative abundance of fish and cephalopod-feeding birds<br>SP Porpoise sightings<br>SW Whale sightings<br>ST Tuna school sightings, all cruises<br>UA Upper atmosphere meteorology<br>MW Surface meteorological analysis, winds and pressure<br>MC Surface meteorological analysis, clouds, dewpoint, temperature<br>MT Surface meteorological analysis, sea temperature, sea-air temperature difference, sea temperature anomaly<br>RM Reference map<br>TC Track chart | Birds, Plankton-feeding<br>Birds, Fish-feeding<br>Sightings, Porpoise<br>Sightings, Whales<br>Sightings, Tuna<br>Meteorology, Winds<br>Meteorology, Clouds<br>Meteorology, Temperature                             |   |

of shading and contours is self-explanatory. In cases where it was not considered so, a shading scale is used or an explanatory remark placed in the caption.

Since the atlas is in effect serving as a data report for the EASTROPAC field work, the editors decided that the charts should be as objective as possible. To this end, an effort was made not to extend contours or shading across areas where there were no data even though the trend of the truncated contours and their relation to other contours in the vicinity might indicate a logical extension across such an area. The principal lines of observations on most cruises ran north-south; in the case of the lines run on all monitor cruises and most survey cruises, these lines were 7° of longitude, or less, apart. For horizontal distributions it was decided not to extend contours or shading between north-south lines which were more than 7° of longitude apart. It was difficult to make definite rules for other lines of observations, and decisions where to end contours and shading in such areas were made by the contributors and the editor. An effort was also made not to extend the shading up to the coastline. EASTROPAC was a deepwater project, and the EASTROPAC *Manual of Observations* (Staff, EASTROPAC, 1967) specified that when leaving the coast, observations should not be begun until a water depth of at least 500 m. was reached. There were some exceptions made to this rule, but in general, shallow nearshore waters were not sampled.

Vertical sections extending to a depth greater than 300 m. have been divided into two panels, with the depth scale in the upper panel twice that of the lower panel. The sections showing geostrophic velocity components are an exception. They consist of one panel extending to 500 m., with no change of depth scale. Since the original versions of the vertical sections were drawn with a horizontal scale of 3 cm. equal to 1° of latitude or 60 nautical miles (111.2 km.) and a vertical scale of 1 cm. equals 10-m. depth on the upper panel or 1 cm. equals 20-m. depth on the lower panel, the vertical exaggeration of the upper panel is 37.07 times and that of the lower panel 18.53 times. Tick marks showing the location of all stations used in preparing the section are shown in the space between the top and bottom panels. In addition, location marks and numbers of all stations which were sampled to 1,000 m. or deeper appear along the bottom of the section. On sections based on Nansen or lexan cast observations (oxygen, nutrient chemicals, phytoplankton) the station numbers of all stations used in the section also appear in the space between panels. Because STD observations were made more often than Nansen casts in some areas, it was found to be impossible to show all the STD station numbers in the space between panels. Therefore, sections of temperature, salinity, etc., do not have this latter feature. If a user wants to identify a particular station in one of the STD sections, it is believed that the information on the figure plus the listings of station positions and observations given in the previously cited Information Papers will enable him to do so. On sections which extend only to 500 m., all station numbers appear in the space between panels.

Vertical sections of temperature, salinity, thermobaric anomaly, and geostrophic velocity components from all principal cruises as well as *Oceanographer* are based on STD observations. Since the STD is a continuous sampling instrument, no sampling depths at each station need be shown. Sections of temperature, salinity, etc. from ships not equipped with an STD as well as sections of oxygen, nutrient chemicals, and phytoplankton properties are based on data collected with Nansen or lexan bottles. On these sections dots indicate the sampling depths in the conventional manner. On some sections the deepest sampling depth at each station is indicated by an inverted T symbol superimposed on the dot.

On STD sections some small, enclosed contours are not labeled. This should cause no confusion as generally such contours have the same value as the nearest continuous contour. Also, some of these contours are accented or dashed indicating they have the same value as the nearest continuous contour similarly marked.

On north-south sections the station location marks are positioned by latitude, and on the few east-west sections they are positioned by longitude. On sections which run in a direction which is neither north-south nor east-west, or close to those directions, both latitude and longitude scales are shown. Since lines of

oceanographic stations rarely lie in a straight line, a combination graphical-computational method was used to project the position of each station onto a base line drawn between the first and last station of the section. Thus, the station location marks indicate the distance along the base line between the projected station positions, and the latitude and longitude marks appear where the parallels and meridians cross the base line.

As was explained above, the vertical sections have been numbered consecutively (v1, v2, etc.) within each cruise in the chronological order in which the ship ran the sections. Section v1 of cruise 11, for instance, represents the same geographical location regardless of the property represented. On some sections of some cruises, there were STD observations but no Nansen or lexan bottle casts. In these cases there are sections showing temperature, salinity, thermocline anomaly etc., but no corresponding sections of oxygen, nutrient chemicals, or phytoplankton properties.

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Cuthbert M. Love  
Editor

<sup>1</sup>Miller, Forrest R. and Kenneth A. Bliss. 1970. Processing STD data and the construction of vertical temperature and salinity sections by computer. Bureau of Commercial Fisheries Fishery-Oceanography Center, La Jolla, California. Unpublished manuscript.

## COLLECTION AND PROCESSING OF THE DATA

### TEMPERATURE, SALINITY, AND DERIVED QUANTITIES

The in situ salinometer (STD) was the principal source of temperature and salinity data on EASTROPAC. On most EASTROPAC cruises temperature and salinity data from Nansen casts were used as a check on the STD. Nansen cast data were used to draw profiles only when an STD instrument was unavailable or was not working properly. Foreign cooperating vessels and some ships of opportunity did not have STD instruments so that all of their sections are based on Nansen casts. Unless otherwise indicated atlas charts showing distributions of temperature, salinity, thermocline anomaly, and geostrophic velocity components are based on STD data. Sections of temperature, salinity, and thermocline anomaly which are based on Nansen cast data can be identified by the presence of small circles indicating the discrete sampling depths.

On many cruises STD data were recorded on magnetic tape in digital form on a data-logger. Processing of these data was carried out with techniques and computer programs described by Jones (1969). The programs smooth the data and produce vertical profiles of temperature and salinity with values interpolated at 1-m. intervals. The interpolated data were written on magnetic tape which was then used as a data input for a program to contour vertical sections.

When a data-logger instrument was not available, the STD analog record was hand-digitized. Inflection points on the salinity and temperature traces were read, and the data were punched on cards. A linear interpolation program was used to produce values at 1-m. intervals, and the interpolated values were written on tape as the input to the computer program which draws the sections.

Temperature measurements on Nansen casts were made with reversing thermometers. Two protected thermometers were used on each Nansen bottle, and their results averaged if the values were within 0.10° C. above 300 m. depth or within 0.05° C. below 300 m. Depths of Nansen bottles were determined with pairs of protected and unprotected reversing thermometers. Depths for the observations were obtained by drawing L-Z curves and reading off the accepted depths. Salinity samples were analyzed on a Hytech Model 6220P laboratory salinometer or a University of Washington conductivity bridge aboard *Alaminos*. Samples from *Unanue*, *Yelcho*, and *Huayaipe* cruises were analyzed with an Autolab inductive salinometer. As a preliminary check on the quality of the Nansen cast data, salinity-thermocline anomaly characteristic curves were plotted, and the suspicious values were eliminated before the data were punched on cards. The Nansen bottle temperature, salinity, and depth data were punched on cards, and a linear interpolation program was used to produce data at 1-m. intervals on magnetic tape.

All STD profiles were calibrated by comparing the STD output with Nansen cast temperatures and salinities. Differences between Nansen cast temperatures and salinities at approximately 400 m. and the STD temperatures and salinities at the corresponding depth were computed and plotted. At 400 m. the water is relatively isothermal and isohaline, and the offset in the STD can be determined without errors in depth strongly influencing the determination of the calibration factor. Least-square lines were fitted to the data by eye, and a set of average calibration factors was derived to make the STD and Nansen cast data compatible. In general, the calibration factors were less than 0.03 ‰ in salinity and 0.10° C. in temperature.

Vertical sections of temperature, salinity, and thermocline anomaly were plotted by computer. The input data to the computer consisted of one magnetic tape for each cruise containing the corrected STD data at 1-m. intervals. Each file (station) of STD data was preceded by an information record giving date, time, and location of the station.

The program read temperatures and salinities for selected stations to be included in a vertical section into a two-dimensional array. For the upper 500 m. the data were selected at 2-m. intervals beginning at the surface; intervals of 5 m. were used between 500 and 1,000 m. The array of salinity data to be contoured was stored temporarily on magnetic tapes or on disk file while the contour analysis was being performed on the temperature data.

The location of the preselected isotherms within the data array which were to be contoured was determined by a search routine which, initially, scanned the entire boundary of the array looking for the point to start the contour. From there the placement of the contour was determined by searching inward from the boundaries between adjacent points of data and locating a four point subset in which the isotherm lay. The exact placement of an isotherm within a subset was obtained by linear interpolation between adjacent points and also a linear interpolation along the diagonal between opposite corner points of the subset. This process was continued until all subsets of temperature data were searched for a particular isotherm. The grid points defining the location of an isotherm were scaled to inches (distance) from a specified plot origin, and they were written on tape together with the plotter commands. The location of all other isotherms followed by repeatedly searching the array. After all coordinates of the isotherms were located, scaled, and written on the plotter tape, the entire process was repeated with the salinity data. The preparation of STD data and the contouring routines were described in greater detail by Miller and Bliss (see footnote 1).

Because STD stations were not uniformly spaced along the cruise tracks, horizontal scaling factors were precomputed before running the contour program. The horizontal scaling information consists of assigned station numbers and distances (inches) between STD stations. These distances were based only on latitude for north-south sections and only on longitude for east-west sections; for all other sections they were based on both latitude and longitude. The scales for the vertical sections are: 3 cm. equals 60 miles horizontal distance; and 1 cm. equals 10 m. in depth for the 0 m. to 300 m. portion of the section, and 1 cm. equals 20 m. for the 300 m. to 1,000 m. portion of the section.

The STD contour program was written in FORTRAN-63 computer language for a Control Data Corporation (CDC) 3600 computer with a 32,000 (48 bit) word core memory. Some CDC type logic statements were used, but these were convertible to FORTRAN IV type statements. A minimum of two magnetic tape units was required during execution of the program. As many as 55 STD stations to a depth of 500 m. could be used during a single run of the program. Owing to the limitation of core memory size, the program allowed for only 38 stations with depths to 1,000 m. on a single run.

The electronic plotter used was a CALCOMP (model 763) 30-inch drum type with zip mode of operation. It has a plot resolution of 100 increments per inch. All EASTROPAC plots were made with a 0.2 size plotting pen using CALCOMP black ink. Plotter commands and data points references were written in FORTRAN language with calls to CALCOMP plot subroutines stored on a library tape at the University of California, San Diego (UCSD) Computer Center.

Geostrophic velocity computations were done relative to 500 db. Data for the computations were selected in the following ways. The computer went along the section and selected successive stations whose separation was greater than 110 km. (approximately 1° of latitude). The geopotential anomaly was computed at these two stations, and the difference in geopotential was used to compute the geostrophic velocity component. The sections represent the average geostrophic velocity component over distances that usually lie between 110 and 138 km. For example, on the north-south sections only rarely did the distance between stations exceed 125° of latitude. The same contouring program was used for drawing vertical sections of geostrophic velocity that was used for the temperature, salinity, and thermocline anomaly fields. Since the geostrophic velocity is an average velocity between two points, it is only continuous in the vertical. Montgomery and Stroup (1962) discussed the choice of a method of representation of geostrophic velocity and argued against the advisability of representing the geostrophic velocity with isotach (equal velocity) contours. As they pointed out, this type of representation is only appropriate to a field which is continuous vertically and laterally. The isotach representation was chosen to present the geostrophic computations in order to expedite the processing of the EASTROPAC data. It was felt that the programming effort required to develop a different representation for geostrophic computations was not justified. The main distortion

<sup>1</sup>References to trade names in this publication do not imply endorsement of commercial products by the Bureau of Commercial Fisheries.



of the field of geostrophic velocity by the contouring program is the linear interpolation of the contours between average velocities. The average geostrophic velocity field is basically discrete and not continuous. Lateral gradients of velocity are certainly distorted and should not be read directly from the contours.

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## THICKNESS OF THE UPPER MIXED LAYER

The bottom of the upper mixed layer was defined somewhat arbitrarily by the depth where the vertical temperature gradient first exceeded  $1^{\circ}\text{C}/\text{m}$ . To eliminate consideration of transient gradients, this criterion gradient was required to hold over a reasonable depth interval, usually 10 m. Though seldom violated, the condition also was imposed that no portion of a major halocline should overlie the depth found to represent the bottom of the mixed layers by the thermal criterion.

Most of the processing work was done from analog traces of the Bisett-Berman Salinity-Temperature-Depth (STD) system and the General Motors (cruise 11 only) expendable bathythermograph (XBT) systems, rather than from digital results. Where disagreement between STD and XBT series occurred, the STD results were used.

Plots of mixed layer thickness were made along cruise track lines and a smoothing line was eye-fitted to each track line segment to reduce the effect of internal waves and other sources of variation on scales too small to have been sampled adequately. The smoothing lines then were used to construct the charts showing the thickness of the upper mixed layer during each of the seven cruise periods of EASTROPAC.

Robert W. Owen, Jr.

## DISSOLVED OXYGEN

The Carpenter (1965) modification of the Winkler method of oxygen determination was used without further change with the exception that calibrated biochemical oxygen demand (B.O.D.) bottles were used rather than the Erlenmeyer flasks specified by Carpenter.

Upon return to shore, the data were processed at La Jolla in the following manner. With due regard to when reagents were changed, standard and blank titration values were plotted against time (days) for each cruise, and eye-fitted averaging lines were drawn through the points to establish computing values. Next, analyst's comments were scanned to rid the data of obvious errors, and the remaining titration values were computed, tabulated, and profiled using the CDC 3600 computer. Tabulations and profiles then were individually scanned and compared with neighboring station values; where "rogue" points were encountered, the analyst's original comments were referred to and the value was discarded either if the comments or departure from the normal pattern warranted rejection. Values which received an analyst's comment of uncertainty were retained if no departure from the normal profile could be discerned.

Edited card decks then were submitted to the computer facilities at the UCSD to be machine-contoured (vertical sections) or machine-plotted for hand contouring (horizontal fields). Vertical sections then were inspected, re-edited and rerun for the final version.

Closed contours isolating single observed values in the vertical sections were eliminated if the difference between the contour value and the observed value was less than  $0.05\text{ ml./l.}$  By comparison, the smallest contour interval used was  $0.25\text{ ml./l.}$

Horizontal charts of oxygen at 10-m. depth are presented in the form of percent saturation rather than oxygen concentration because it was felt that percent saturation was a better measure of oceanographic sources of variation (vertical mixing, plant production) and was a better measure of oxygen conditions in the surface mixed layer than was oxygen concentration itself. The 10-m. depth was chosen because surface values were erratic, possibly because of ship's influence, and because the 10-m. values do in fact represent surface conditions.

Saturation values were computed using a program which employs a polynomial fitted to the tables of saturation as a function of temperature and salinity given by Gilbert, Pawley, and Park (1967).

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## METEOROLOGY

### General

The meteorology described in this atlas consists primarily of surface analyses and data plots of selected sea surface meteorological elements observed over the oceanic areas of the eastern tropical Pacific (ETP) as defined below. On *Jordan 20* and 30 cruises and on the *Oceanographer* cruise, U.S. Weather Bureau, ESSA, personnel, who were on board the vessels, observed upper air temperature (by radiosonde) and humidity. On the *Rockaway* cruises, they observed the upper air winds, too. Upper air vertical sections are included in the atlas only along cruise tracks because of the sparsity of data elsewhere over the eastern tropical Pacific. Surface meteorological observations (International ship weather code: FM 22.D) were taken at 3- to 6-hour intervals along cruise tracks by U.S. Weather Bureau personnel when aboard or by the bridge crew on American vessels. Mexican and South American ships participating in EASTROPAC recorded weather on the bathythermograph logs in most cases.

In order to fill in as much of the eastern tropical Pacific,  $30^{\circ}\text{N.}$  to  $25^{\circ}\text{S.}$  and  $70^{\circ}\text{W.}$  to  $130^{\circ}\text{W.}$ , as possible, all other maritime weather observations (International ship weather codes: FM 22.D, FM 23.D, and FM 26.D) collected and made available by the Bureau of Commercial Fisheries, La Jolla, California, were included in the preparation of the meteorological data for the atlas.

Wherever data permitted, analyses were extended to the boundaries of the EASTROPAC base chart rather than restricting them to the areas along the cruise tracks. This permitted a more accurate and definitive presentation of the meteorology in areas over and adjacent to cruise tracks. Furthermore, the larger scale meteorological analyses provided background information which may be directly related to physical and biological environmental features of the oceans.

Meteorological observations were never uniformly distributed over the eastern tropical Pacific; but most of the data were distributed along EASTROPAC cruise tracks and over the shipping lanes into and out of the Panama Canal and along the coastlines of the Americas. In order to provide detailed analyses, observations were averaged over squares of  $2^{\circ}$  latitude and longitude. In regions of sparse data, particularly south of  $10^{\circ}\text{S.}$ , between  $70^{\circ}\text{W.}$  and  $110^{\circ}\text{W.}$ , climatology combined with averaged observations along the shipping lanes formed the only data base for extending the analyses. Reasonable analyses were possible over sparse data areas because the temporal and spatial distribution of ship's observations covered the period of analysis. Because of the relatively slow-changing weather patterns over the eastern tropical Pacific during most of EASTROPAC, data were composited into sets covering periods of 12 to 16 days. In general, these meteorological periods were centered around the dates when the research vessels were sailing along the principal cruise tracks. However, because of rapidly changing weather patterns north of the equator during the August-September summer survey (40-series cruises) the analytical periods were reduced to 8 to 10 days with a 3- to 4-day overlap for those cruises.

In order to present the meteorology of the eastern tropical Pacific in a manner which is most useful to the study of atmospheric (marine layer) conditions as they relate to the oceans and fishery ecology, three basic series of charts are

presented: one series depicts the surface air flow in terms of surface winds and pressure; another series represents surface sea and air temperature conditions, and the third series displays the clouds and moisture distribution over the eastern tropical Pacific with the total cloud cover, dew point temperature, and frequency of precipitation reported from ships. The first and second series cover semi-monthly periods. The third series has one chart per month because of the great variability in clouds and moisture and because there were insufficient data to obtain representative averages for periods less than a month over most of the ETP area.

### Processing the Observations

All of the meteorological observations taken aboard research vessels participating in EASTROPAC were punched on cards in the international ship weather code. Each observation was quality-checked with a computer program which set acceptance limits based on the climatology of each element reported. An observation considered erroneous was printed out and hand-checked for possible correction. After errors were corrected, wherever possible, selected elements were averaged by  $2^{\circ}$  and by  $5^{\circ}$  of latitude and longitude (referred to hereafter as  $2^{\circ}$  and  $5^{\circ}$  squares). The results were printed out and punched on cards by the computer. The processing of research vessel data was performed in subsets by cruise periods. Computer plots of  $2^{\circ}$  averaged data were made and analyzed for each cruise period. These analyses and data plots formed the composite sets which served as key or control analyses for coordinating the analyses of the larger data sets covering the entire EASTROPAC area.

The charts in the atlas are constructed from all observations available from research and merchant vessels sailing in the eastern tropical Pacific. The Bureau of Commercial Fisheries in La Jolla maintains punch card files of all available weather observations taken by ships in the Pacific Ocean. Merchant ship observations were processed for this atlas by computer and averaged by  $2^{\circ}$  squares in the same manner as described for research vessels. There were approximately 2,500 merchant ship observations available for each month, and about 10 percent of these contained one or more errors. Approximately 80 percent of the erroneous observations could be corrected and inserted back into the data files. These observations were well distributed diurnally and throughout the month so that daily or semi-monthly biases were minimized.

Because of the general sparsity of data over much of the eastern tropical Pacific, all merchant ship observations were combined with those from research vessels into composite sets. Preliminary analyses of each meteorological element were prepared from computer plots of the  $2^{\circ}$  averaged data. The atlas charts contain analyses based on  $2^{\circ}$  averages superimposed on plots of data averaged by  $5^{\circ}$  squares. The data plots show the large scale distribution of observations. The limitations in, and preparation of, averaged values of each meteorological element used in constructing the series of charts are described in the following paragraphs.

### Surface Winds

Surface wind observations on all research ships, and increasingly on merchant ships, are measured accurately by anemometer. Winds estimated from the state of the sea also are accurate enough to be used in the analysis when speeds are greater than 5 kn.

Surface winds represent the air flow in the marine layer of the tropical atmosphere more accurately than does the pressure field. Therefore, streamline and isotach analyses have been emphasized in representing the composite low level direction and speed of air flow over the eastern tropical Pacific. Streamlines are drawn parallel to mean resultant winds which are computed from the east-west and north-south components of wind direction and averaged by  $2^{\circ}$  and  $5^{\circ}$  squares. Isotach analyses are based on the mean resultant wind speeds which are obtained from averaged components of observed winds. A detailed discussion of wind analysis by the streamline-isotach method can be found in several textbooks on

tropical meteorology, including Riehl (1954). A good estimate of the mean wind speed, without regard to direction, can be obtained by multiplying the mean steadiness of the wind for a particular location and month, obtained from marine meteorological atlases (Marine Division of the Meteorological Office, 1965; U.S. Navy, 1959), by the mean resultant wind speed obtained from the appropriate chart in this atlas designated MW.

Streamlines and isotachs were not extended into areas where observations were not available. However, where winds were observed along shipping lanes for at least part of a month, the extended streamlines and isotachs reflect an estimate based on climatology modified by the available data over sparse data areas.

### Sea Surface Pressure

Surface pressures are usually observed aboard ships with precision aneroid barometers. They are reported more frequently than winds, especially during very light wind conditions. All surface pressure observations were checked for gross errors in reporting. Corrections for diurnal variation in pressure were applied as required, but because of the uniform distributions of observations (except in sparse data areas), the averaging over 2° squares eliminated most of the diurnal bias. The pressure field as depicted by isobars on charts designated MW reflects the general state of the atmosphere.

### Intertropical Convergence Zone

The intertropical convergence zone (ITCZ) is also displayed on each chart that depicts surface wind flow and pressure. The climatological position of the ITCZ for each month is based on 77 years of ship observations obtained from the National Weather Records Center and prepared at Goddard Space Flight Center, NASA (Allison, Kreins, Godshall, and Warnecke, 1969).

In the atlas the climatological position of the ITCZ can be compared with the average position of the ITCZ for the specified EASTROPAC period. The ITCZ is found where the winds (streamlines) of both hemispheres converge asymptotically, where surface pressures are lowest (approximately 1010 mb.), and where wind speeds are generally under 10 kn. This area is also referred to as the "doldrums."

### Sea Surface Temperature

Sea surface temperatures measured aboard research vessels participating in EASTROPAC were based on bucket thermometer or thermograph measurements. On most of the merchant ships sea surface temperatures were measured in the sea chest of the water injection system. Because of the accuracy of research vessel data, sea surface temperature analyses were completed from composite sets of these data to include an entire survey or monitor period. These analyses, which included surface temperatures from STD casts, provided the required quality control needed for checking the larger ETP area analyses based on all available sea surface temperatures averaged over 2° squares.

All sea surface temperatures were quality checked against a climatology derived from bathythermograph surface temperatures for the eastern tropical Pacific compiled by Scripps Institution of Oceanography and analyzed for each month (Wyrtki, 1964). The climatological sea surface temperatures provided a data base for computing sea surface temperature anomalies and for quality control checking the observations. The anomalies were useful also in constructing the sea surface temperature charts because accurately averaged temperatures usually showed consistent anomaly patterns. The temperature data which passed the initial computer checks but had small errors showed up on the charts as unusually large anomalies. Since significant anomaly patterns of sea temperature may be related to significant physical or biological changes in the ocean, the anomaly patterns have been superimposed on the isotherms (1° C. intervals) in charts designated MT. These patterns delineate areas which experienced anomalies in the sea surface temperatures of  $\pm 1^\circ \text{C}$ . or more.

### Surface Air Temperature

Surface air temperatures observed on all ships reflect large diurnal and areal variations. Heating of the ship during the day is often reflected in high temperatures, and ship observations taken near the Americas are affected frequently by the hot or cold temperatures advected seaward from land. However, most of the averaged air temperatures observed away from continental influence did not reflect diurnal bias.

In the chart series designated MT, the difference between sea surface and surface air temperatures, averaged over 5° squares, is plotted. This difference is not reliable in sparse data areas. However, it reflects the stability of the marine layer of the atmosphere, i.e., colder sea temperatures in upwelling areas are associated with a stable lower atmosphere. Air temperatures derived from the sea surface temperatures and sea-air temperature differences provide reasonable values of air temperature, except near coastlines and over sparse data areas. Sea-air surface temperature differences and the air temperatures averaged for 2° squares are available in the EASTROPAC data file.

### Dew Point Temperature

The surface dew point temperature is one of the elements which can be measured accurately at sea and reflects existing moisture or humidity conditions in the marine layer with less diurnal variation than the air temperature. This temperature is important also in determining the vapor pressure gradients between the sea surface and the lower atmosphere for energy budget computations.

Dew point temperature analyses appear in the cloud and moisture series of charts designated MC. The dew point isotherms are based on averages for 2° squares. They are superimposed over plots of dew points averaged over 5° squares. In the eastern tropical Pacific, high values of dew point temperatures are closely associated with extensive low and middle level cloudiness and the intertropical convergence zone. In areas of upwelling, dew point temperatures are usually lower than sea surface temperatures so that fog is seldom found over open ocean areas. The low surface dew point temperatures also reflect the general dryness of the tropical atmosphere above a shallow marine layer.

### Cloudiness

Clouds, their types and amounts, constitute one of the most variable meteorological elements observed over the eastern tropical Pacific. For the past several years weather satellite photographs have revealed this variability as well as the complexity in cloud structure over the eastern tropical Pacific.

Surface marine observations included fairly accurate estimates of the total cloudiness (sky cover). However, there were seldom enough observations which accurately report the vertical cloud structure. Because of the difficulty in accurately depicting the three-dimensional cloud patterns, analyses of total cloud amounts (low, middle, and high clouds combined and reported in eighths of the sky covered) were prepared. In sparse data areas total cloud cover analyses were based on satellite data from two sources: (1) photographs on 35-mm. film available from ESSA (Environmental Data Service, 1967, 1968a, 1968b), and (2) mean monthly total cloud cover charts derived from weather satellite nephelanalysis by Sadler (1969). An estimate of the predominant cloud type, associated with the cloud cover charts in the EASTROPAC Atlas, can be obtained by referring to marine meteorological atlases referenced in the section on surface winds.

### Precipitation

Observations of precipitation in the tropics show greater variability than any other observed element. Rainfall amounts cannot be accurately measured from a moving ship; therefore, the frequency of rainfall reported at or near a ship provides the only information available over oceanic areas of the eastern tropical Pacific.

Because of the relatively short period of EASTROPAC no attempt has been made to interpret in detail the percentage frequency of rainfall reported from ships. Rather, the average percentage frequency of all types of rainfall (within sight of a ship) taken over 5° squares was plotted on the charts designated MC. In addition, areas where ships reported rainfall for 15 percent or more of the time were outlined for quick reference to the more rainy areas of the eastern tropical Pacific. The large-scale precipitation patterns of the EASTROPAC period have not reflected unusually large deviations from those based on long-term means and displayed in meteorological atlases. Although the schematic presentation of rainfall frequencies in this atlas agrees well with the other meteorological elements that indicate bad weather for each chart period, the results should be reviewed with caution.

Forrest R. Miller

## NUTRIENT CHEMISTRY

Water samples drawn from Nansen bottles were analyzed aboard ship for the following phytoplankton nutrients: inorganic phosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen, and silicate-silicon. On survey cruises 11, 12, 45, 46, 75, and 76 and on monitoring cruises 20, 30, 50, and 60 the Technicon auto-analyzer was used with the methods of Armstrong, Stearns, and Strickland (1967), which are also described by Strickland and Parsons (1968). On other cruises nutrients were determined manually by the methods outlined by Strickland and Parsons (1968). The methods were standardized by running known concentrations of each nutrient along with samples from each Nansen cast.

Peak values of absorbance were read from the autoanalyzer charts or with a Beckman Model DU spectrophotometer; these were used to calculate nutrient concentration either at sea or ashore. Some calculations were done with desk calculators; others were done by computer. For each station, profiles or concentration vs. depth were plotted by computer plotter and checked for obvious errors by visual inspection. Errors that escaped this preliminary check were detected later when vertical sections were drawn.

For each cruise period, maps of the horizontal distribution of phosphate, nitrate, and silicate were drawn for depths of 10 and 100 m. Values were entered either by hand or by computer plotter and were contoured by visual inspection. The horizontal distribution of nitrite at 100 m. proved to be highly irregular and has not been shown in the atlas. All vertical sections were drawn by computer plotter using programs described by Miller and Elias (see footnote 1).

On some cruises, samples for ammonia analysis were frozen and analyzed ashore at La Jolla. The method of Richards and Kletsch (1964), which includes some labile amino nitrogen along with ammonia, was used. Ammonia values were low (generally  $<1 \mu\text{g-at. N/l}$ ) and were distributed irregularly so that vertical sections and horizontal maps could not be contoured. Values at 10 and 100 m. were entered on maps of the area so that the general magnitude of the ammonia concentration could be shown in the atlas.

William H. Thomas

## PHYTOPLANKTON STANDING STOCKS AND PRODUCTION

### Sample Collection

Samples were taken from special casts on two stations per day, at noon and midnight. Production and phytoplankton pigments were measured from the noon samples, and plant pigments alone were measured from the samples collected at night. Reversing bottles made of biologically inert lexan plastic were most generally used, supplanted on occasion by bottles made of polyvinyl chloride (PVC) plastic. In either case there was no contact of sample water with known ionic contaminants. Sampling bottles were scrubbed routinely to reduce biological contamination.

Sampling depths were calculated from the depth of disappearance of a 20-cm.-diameter Secchi disk. This depth was taken to represent the depth where green light was 16 percent of that at the surface at each noon station. The depth where light intensity corresponded to that in each of seven bottle spaces in the production experiment incubators then was selected off a semilogarithmic plot of transmittance vs. depth. These depths spanned the euphotic zone, as defined by the layer of water lying above the depth where light was 1 percent of surface intensity. At night stations, the depths sampled were those of the previous noon station. Additional depths below the euphotic layer generally were sampled for plant pigment analysis at both types of station.

The translucent sampling bottles were taken into the laboratory directly upon recovery to reduce the adverse effect of direct exposure to full sunlight on noon stations. Water was drawn soon after collection to minimize sedimentation of cells. Samples for plant pigments were drawn into rinsed 270-ml. plastic bottles and placed out of direct light until filtration. Samples for production experiments were drawn into scrubbed and rinsed 270-ml. glass bottles and stored dark until incubation.

### Shipboard Sample Processing

**Pigments.**—Samples in 270-ml. plastic bottles were filtered under low vacuum (not exceeding  $-7$  p.s.i.g.) through Whatman GF/C glass fiber filters (2.4-cm. diameter) having a thin magnesium carbonate coating. Filtration was nearly always completed within a half hour after sample collection.

Filters then were placed in 90 percent v/v spectral-quality acetone, ground for 30 seconds in a motor-driven tissue grinder and stored dark for 10 minutes to permit full extraction of the pigments. Filters and extract were separated by centrifuging for 10 minutes. Extract volume was brought up to 10.0 ml.; about 5 ml. was placed in a cuvette and submitted to a Turner fluorometer, Model 111, for fluorometric analysis by the method of Holm-Hansen, Lorenzen, Holmes, and Strickland (1965). A blue-pass Corning 5-60 primary filter and a red-pass Corning 2-64 secondary filter were used in conjunction with the light source and the detector, a red-sensitive multiplier phototube (Hamamatsu R 136).

**Production.**—Samples in 270-ml. glass bottles received 1.00 ml. of sterile  $\text{NaH}^{14}\text{CO}_3$  solution buffered at pH 9.0. Activity was usually  $20 \mu\text{Ci}/\text{ml.}$ , but in the richer waters of the easternmost part of the survey region, solutions having  $10 \mu\text{Ci}/\text{ml.}$  were sometimes used. Directly after inoculation, samples were loaded into two cylindrical incubators, one completely opaque and the other made to transmit 100, 50, 25, 12, 6, 3, and 1 percent of incident sunlight across discrete segments along its length to accommodate one sample in each segment with sufficient room between samples to insert opaque bumpers. The body of the light incubator was of lucite plastic wrapped with neutral density fabric screens which in turn were protected by an outer sheath of lucite plastic tubing. The opaque incubator was constructed of PVC plastic.

When loaded with inoculated samples the incubators were placed on deck under full exposure to sun and sky radiation. Timing of sample collection and inoculation was such that deck incubation could be started at local apparent noon.

Incubation continued until local sunset, when the samples were recovered for filtration.

Filtration was conducted in subdued light at vacuum not ordinarily exceeding  $-7$  inches of mercury using Gelman membrane filters (2.5-cm. diameter) with  $0.45\text{-}\mu\text{m.}$  pore diameters. Filters then were glued lightly to identified copper planchets, placed in perforated pill boxes, and stored in desiccators until their return to shore for radioassay.

### Sample Processing Ashore

**Pigments.**—As mentioned previously, plant pigments usually were analyzed at sea. On occasion, however, a fluorometer failure occurred and sample filters were folded, stored dark in a freezer, and analyzed later if the instrument could be repaired, or returned frozen to La Jolla for analysis. Values so obtained were multiplied by 1.1 to account for the consistent 10 percent loss that occurs when samples are stored for more than a day. Data on file to which this correction has been made are identified by asterisks.

**Production.**—Upon their return to shore for radioassay, membrane filters from production experiments were fumed over concentrated HCl for 10 minutes, sorted by station and returned to their desiccators to await beta-assay. As soon as possible after fuming, samples were turned over to Gulf General Atomic Corporation, La Jolla, where by contract agreement samples were counted in their radiological laboratories on Beckman wide-beta gas flow counters. Detector end windows were of  $80\text{-}\mu\text{g.}/\text{cm}^2$  Mylar with 5.72-cm. diameters. Samples were counted for 3 minutes. Background counts, subtracted from each sample count, were determined each day and usually did not exceed three counts per minute. Counter efficiencies were 27.0 and 34.0 percent during the entire period of analyses of EASTROPAC samples, as determined from point-source standards calibrated against those maintained by the National Bureau of Standards.

### Computation

All phytoplankton data were card punched, verified, and submitted to the CDC 3600 computer at UCSD for calculation of basic phytoplankton parameters. Computed and listed by cruise, station, and depth were chlorophyll *a* concentration, phaeo-pigment concentration,<sup>3</sup> total pigment concentration, phytoplankton production per unit volume, and several parameters for use in editing and interpreting these basic values. Also printed were interpolations and vertical profiles of pigment and production values.

Pigment concentrations were calculated from the equations given by Lorenzen (1966):

$$\text{chlorophyll } a \text{ (mgm}^{-3}\text{)} = \frac{F_0/F_{a \text{ max}}}{(F_0/F_{a \text{ max}}) - 1} (k_x) (F_0 - F_a) \text{ liters filtered}$$

$$\text{phacophytin } a \text{ (mgm}^{-3}\text{)} = \frac{F_0/F_{a \text{ max}}}{(F_0/F_{a \text{ max}}) - 1} (k_x) [F_0/F_{a \text{ max}} (F_0 - F_a)] \text{ liters filtered}$$

where:  $F_0$  = fluorescence before acidification  
 $F_a$  = fluorescence after acidification  
 $F_0/F_{a \text{ max}}$  = maximum acid factor which can be expected in the absence of phacophytin  
 $k_x$  = calibration constant for a specific sensitivity scale.

The  $k_x$  factors were determined by submitting known concentrations of chlorophyll *a* to each fluorometer and observing fluorescence units. Linearity of

<sup>3</sup>Phaeo-pigments are degradation products of chlorophyll *a* and represent detrital pigment.

each instrument was checked by serial dilution of pigment extracts. The  $F_0/F_{a \text{ max}}$  factor was determined by observing fluorescence before and after acidification of extracts of diatom and dinoflagellate cultures sampled in logarithmic phase of growth; phaeo-pigments thus were absent.

Production rate of the phytoplankton was calculated from the equation:

$$\text{Production (mg. C/m}^3\text{/day)} = (L \cdot D) \left( \frac{W}{A \times E} \right) \times 1.05 \times 1.51 \times 2$$

where:  $L$  = counting rate (counts per minute) of the phytoplankton in the light bottle

$D$  = counting rate (counts per minute) of the phytoplankton in the dark bottle

$W$  = weight of carbonate carbon in the water assumed to be 25,000 mg./m.<sup>3</sup>

$A$  = discharges per minute by the radiocarbon added to each sample; usually  $4.44 \times 10^6$  d.p.m.

$E$  = counter efficiency, 0.270 and 0.340 for the two counters used

1.05 = factor to allow for difference in uptake rate of  $^{14}\text{C}$  as compared with that of  $^{12}\text{C}$

1.51 = correction to bring incubator values close to those found by true in situ incubation (Doty, Jitts, Koblenz-Mishke, and Saijo, 1965)

2 = correction from the half day incubation period to full day.

### Editing

**Pigments.**—Values were examined station by station. Constancy of the shape of each vertical profile was considered and in the few cases where a deep maximum occurred that was defined by a single observation, a scale reading error was presumed to have occurred and the value was rejected. In addition, the profile of the acid factor, the proportional change of pigment fluorescence upon acidification of the extract, was examined. This factor normally decreased monotonically from surface layer values near 2 to deep (150 to 200 m.) values near 1. Where single significant departures from this pattern occurred, sample values either were justified from the basic data, or, if no simple change of values could be supported in terms of analyst error, the observation was rejected. Apparent errors and rejections both were rare, never exceeding 0.1 percent on most cruises.

**Production.**—Predictably, plant production experiment results required more editing than did those of pigment analyses. One batch of  $^{14}\text{C}$  solution, provided by a commercial source in sterilized ampoules, later proved to have been contaminated by fungus. Because the strands, or hyphae, were "hot" and because they were deposited on filters in varying concentrations, much of the production data obtained on the first set of survey cruises (10-series) and on part of the first monitor cruise (20) had to be rejected. Neither fuming nor autoradiography proved of value in salvaging data.

Criteria for rejection of production values with good  $^{14}\text{C}$  stocks were developed after samples from all cruises were processed to provide uniform applicability. We first rejected values for which the corresponding dark count exceeded 100 counts per minute except when the production value was consistent with others in the same vertical profile.

Next, production/chlorophyll ratios were examined statistically for each cruise at each light level. In nitrate-deficient waters, production values were rejected when this ratio exceeded two standard deviations of the mean value for the light level and cruise in question. We felt this necessary in view of the occasional erratic values encountered that were due to unidentifiable errors in experimental procedure or contamination of the sample. Values obtained from

richer waters were rejected only if they exhibited a radical departure from the normal vertical profile pattern.

Values for entire stations were rejected when the vertical profile was so erratic as to indicate light leaks in the incubator, inadvertent exposure to ambient light during filtration, or contamination of the sample.

### Integration Over Depth

Integrations with respect to depth were performed on both plant pigment and production data using computer programs written for the CDC 3600. The programs were based on Simpson's Rule for irregular areas and therefore use a linear interpolation between observations.

Plant pigments, both chlorophyll *a* and phaeo-pigment concentrations, were integrated to 150 m. to express the total pigment under a square meter of sea surface. Except in the extreme southern portion of the survey tracks (south of about 16° S.), there exist only minute quantities of plant pigments below 150 m. Where observations did not reach 150 m., the fraction below the last observed depth was estimated from other stations in the vicinity (sometimes from other cruises to the same area) and added to the observed integral.

Plant production and chlorophyll *a* were computer integrated to the euphotic depth at each station to express total production per unit of sea surface area and total pigments involved in photosynthesis.

### Mapping

Horizontal distributions of surface and integrated values of phytoplankton parameters were hand-plotted and contoured. The resulting charts are somewhat smoother than would have resulted from computer contouring because some interpretive selection was used, e.g., at saddle points or at two closely spaced values.

Vertical sections were computer-plotted and hand-contoured.

Shading of plots is arbitrary and serves only to impart a more immediate sense of the field of values than do labeled contours alone. The shading scheme for each parameter is, however, consistent throughout the atlas.

Robert W. Owen, Jr.  
Berni Zeitzschel

## ZOOPLANKTON AND FISH LARVAE

During EASTROPAC cruises zooplankton hauls were routinely taken with three types of nets four times daily at the prime oceanographic stations. Oblique hauls between about 200 m. and the surface were made with 50-cm. and 1-m. mouth diameter nets in a paired-frame, and a horizontal haul at the surface was made with a 1-m. mouth diameter net. Collections taken with the 50-cm. net were for zooplankton biomass studies and with the 1-m. nets for fish eggs and larvae studies. In addition special zooplankton collections were taken with a Longhurst-Hardy Plankton Recorder and submerged pump on selected cruises; these will be discussed in future research papers. Only collections taken in the oblique hauls are considered in this atlas.

The 50-cm. net has a length of 3.5 m. and is constructed throughout of 333 Nitex nylon mesh (mesh aperture 0.333 mm.). It is fixed to a hoop in a frame assembly which also contains a hoop for the 1-m. net. The 1-m. net has a body 4.3 m. long which is constructed of 505 Nitex nylon mesh (mesh aperture 0.505 mm.), and a cod-end 0.35 m. long which is constructed of 333 Nitex nylon mesh. The frame assembly holding the two nets was attached to the towing wire by a short four-lead bridle preceded by a rope 3 to 4 m. long. The rope was clamped to the towing wire about 3 m. above a 45-kg. weight attached to the end of the wire. The haul was taken with the ship steaming slowly in an attempt to maintain a wire angle of 45°; the speed of the ship was usually about 1.5 to 2 kn. To make the haul, 300 m. of towing wire was payed out at 50 m. per minute, held at

maximum depth for 30 seconds, and retrieved at 20 m. per minute. A wire angle reading was taken at each ½-minute interval during the retrieval of the net.

The depth of towing was estimated from wire angle and length of wire out, assuming that the wire described a straight line in the water during the haul (Ahlstrom, 1952). A maximum depth of 200 m. was desired, but estimated depths ranged from 75 to 254 m. The mean estimated depth for all hauls was 204 m. with a standard deviation of 13.21 m. A mechanical depth gauge was attached to the net frame on one cruise for 88 hauls to compare estimated and measured maximum depths. In many cases the measured maximum depth of sampling varied considerably from the estimated depth. The estimated maximum depth was deeper than the measured depth in 98 percent of the hauls (range 1 to 120 m.) and shallower in 2 percent of the hauls (range 16 to 27 m.). The differences between estimated and measured depths were especially pronounced at stations near the equator, where surface and subsurface currents often flow in opposite directions.

The amount of water strained during each haul was measured by a TSK flowmeter suspended in the mouth of each net. The flowmeters were calibrated before and after each cruise, and the average of these calibrations was used to compute the volume of water in cubic meters for each haul. The zooplankton collections were preserved at sea in buffered 10-percent Formalin sea water.

The standing stock of zooplankton taken with the 50-cm. net is expressed as milliliters of displacement volume of the catch of small organisms per 1,000 m.<sup>3</sup> of water strained; organisms greater than 5 cm. in length or greater than 5 ml. in volume are excluded in the displacement volume measurements. The method of measuring displacement volume is described by Ahlstrom and Thraillkill (1963). Standardization calculations were done by computer.

Analysis of variance and analysis of covariance indicated that night-day differences in the zooplankton standing stock were highly significant. Various methods of combining night and day hauls by time-adjustment were attempted, including the method of King and Hida (1954), running mean, and night/day ratio, but none appeared to be satisfactory. Instead, night and day hauls are treated separately, and separate charts are presented for night and day samples. Examination of Simrad echo-sounding profiles indicated that the greatest rate of change in depth and configuration of scattering layers occurred between about 1 hour before and 1 hour after sunrise and sunset. Hauls taken between 1 hour after sunrise and 1 hour before sunset were regarded as day hauls, and hauls taken between 1 hour after sunset and 1 hour before sunrise were regarded as night hauls. Hauls taken during twilight, i.e., between 1 hour before and after sunrise and sunset, are not included in the analyses.

Estimates of sampling variability were obtained from a series of 17 zooplankton hauls made with the 50-cm. and 1-m. nets over a 24-hour period at roughly the same geographical position. Hauls made during darkness and daylight were regarded as replicates for night and day, respectively. The coefficients of variation were smaller for replicate collections made with the 1-m. net (night 17 and day 24 percent) than with the 50-cm. net (night 37 and day 63 percent).

The charts of zooplankton standing stock presented in the atlas were generated by computer with only minor alterations and drafting done by hand. In practice, the value of the standardized zooplankton displacement volume at each station for each cruise period was plotted by computer plotter, and a separate plot of the contours of the data field and station position markers for each cruise period was also generated. The contour plot was quality checked by overlaying it on the plot showing the displacement volume for each station. Sometimes minor corrections of the contour plot were necessary at the edge of the data field or in locations of sharp gradients, and these changes were made by hand. The labels on the contours were hand-drafted and values greater than 200 ml./1,000 m.<sup>3</sup>, which indicate areas of high standing stock of zooplankton, were shaded. The circular symbols on the charts show the location of stations where data were collected.

All fish eggs and larvae were sorted from the total sample of each 1-m. oblique net haul collection. The larvae were identified to species or to whatever taxon practicable. Fish larvae other than tuna were identified by E. H. Ahlstrom and tuna larvae were identified by W. L. Klawe. Because of the large number of

fish larvae species identified, it was necessary to limit charts in the atlas to the selected categories mentioned below. Distributional studies of fish larvae will be discussed in detail in future research reports. The computer was used to plot the number of larvae of each species or category collected at each station for each cruise period, and the data were contoured by hand. Separate day and night charts were prepared for total fish larvae and the larvae of the gonostomatids and stenopterygiids and myctophids. Also a single diel chart was prepared for larvae of skipjack tuna, *Katsuwonus pelamis*, frigate mackerel, *Auriz*, and dolphin (fish), *Coryphaena*, and total fish eggs.

R. Michael Laurs

### MICRONEKTON

Micronekton consists of organisms including fishes, cephalopods, and crustaceans between about 1 and 10 cm. in size. It was collected in oblique hauls of the large net, 1.5 m. square at the mouth, described by Blackburn (1968). The net is of uniform mesh, approximately 5.5 x 2.5 mm., which retains animals greater than or equal to 1 cm., but not smaller (Jerde, 1967). On most EASTROPAC cruises usually two micronekton hauls were made per diel, one near local noon and one near local midnight. The daytime catches were of the order of one-tenth the size of the night catches as expected, an effect of net avoidance and diel vertical migration of many kinds of animals. Thus, the data on day catches underestimate the standing stock of micronekton and are not considered in this atlas, although they will be used in a research report on distribution of tuna forage. The hauls were made at ships speeds that were estimated at 5.0 kn. for *Argo*, *David Starr Jordan*, *Alaminos*, *Thomas Washington*, and *Oceanographer*, 4.0 kn. for *Undaunted* and 6.4 kn. for *Rockaway*. The other EASTROPAC ships did not make micronekton hauls. *Rockaway* did not make micronekton hauls on cruise 13.

The method used for micronekton hauls was to pay out 800 m. of towing cable at 50 m. per minute and then retrieve it immediately at 30 m. per minute. The maximum depth of the net on each haul was expected to be about 200 m. at a ship speed of 5 kn. For 294 hauls on which maximum depth was measured by a depth sensor the arithmetic mean and standard deviation were 197 m. and 36.4 m., the range was 100 to 348 m., and the coefficient of variation was 18.5 percent. The collections were preserved at sea in buffered 10-percent Formalin sea water.

An estimate of sampling variability for night hauls is given by a series of 11 hauls made during one night at approximately the same geographical position. The coefficient of variation of the catch volumes was 20 percent.

All the night micronekton catches were sorted in the laboratory into the following groups: (1) *Vinciguerria* spp., (2) other epipelagic fish, (3) *Pleuroncodes* spp., (4) other crustaceans, (5) cephalopods, (6) other mesopelagic fish, and (7) leptocephali. Other animals in the catches, mainly large zooplankters such as tunicates and medusae, were not considered as micronekton and were ignored. The displacement volume of each group was measured in milliliters. The preserving fluid was removed from the animals by placing them on screens and allowing them to drain, and then measuring their displacement volume in water. The crustaceans were sorted further, approximately to family level, and displacement volumes were measured for those groups after removing the preserving fluid with a vacuum pump. This gave a check on the displacement volume of total crustaceans, which is more difficult to measure than that of fishes or cephalopods; some fluid tends to be retained between the appendages of crustaceans while the preservative drains off them, so that it is hard to tell when filtration is complete. In general the agreement between the two measurements of crustacean volume was good, which indicates that the displacement volumes of the other groups are probably accurate.

The displacement volume for each of the groups 1 through 7 was expressed as ml./1,000 m.<sup>3</sup> water strained (standardized volume). The amount of water strained by the net on each haul was estimated from the duration of the haul, ship

speed, mouth area of net, and an assumed filtration coefficient of 0.80. The filtration coefficient was approximately the mean of three observed values, namely 0.74, 0.76, and 0.88. Blackburn (1968) described the procedure by which the first two observations were made; the third was made later in the same way. The calculations were made by computer with a program that printed all seven standardized volumes for each haul together with date, time (start and end of haul), position, and observed maximum depth. These volumes were totalled in different combinations to yield volumes of total fish and cephalopods (groups 1, 2, 5, 6, and 7), total crustaceans (groups 3 and 4), and total micronekton (all groups), each standardized in ml./1,000 m.<sup>3</sup>, for each haul. Charts were prepared showing the distribution of each of these three volumes in each of the seven cruise periods. The values were computer-plotted on blank maps and then contoured by hand.

Maurice Blackburn

## BIRDS, FISH SCHOOLS, AND MARINE MAMMALS

The observations of pelagic birds, marine mammals, and fish schools were based on sightings made by personnel from the Smithsonian Institution Pacific Ocean Biological Survey Program.<sup>4</sup> Usually observations were conducted on an average of 8 hours each day in the time from sunrise to sunset, except when the ship was stopped for oceanographic station work. Most observations were made from the flying bridge, although some were made from the bow or other locations

<sup>4</sup>The charts portraying bird observations should be considered as Paper Number 55, Pacific Ocean Biological Survey Program, Smithsonian Institution, Washington, D.C. 20560.

on the ship, depending on what position gave the best view of the surrounding ocean and the type of avifauna present. In most instances bird sightings were largely of birds which could be seen with the unaided eye and with binoculars if necessary for identification.

Emphasis was placed on data for birds. As a result, more information is available on the geographical and seasonal variations in the abundance of birds than for the marine mammals or fish schools. About 63,000 birds representing 83 species were observed. For convenience sake, species of birds were lumped into two categories based on their general feeding habits as determined from the literature, from stomach analyses, and from actual observations of feeding.

The two categories of birds selected were fish-and-cephalopod feeders and zooplankton feeders. The most important species included in the fish-and-cephalopod-feeding group were the sooty tern, the Maui shearwater, the wedgetailed shearwater, and the Juan Fernandez petrel. Of moderate importance were the brown, red-footed, and blue-faced boobies and the black tern. Of lesser importance were the white-winged petrel and the great frigatebird. The most abundant species in the zooplankton-feeding group were the northern phalarope, Leach's storm petrel, and Galapagos storm petrel.

The numbers of birds in each category were standardized on the basis of the number of birds observed per nautical mile and the percent of birds in flocks; five or more individuals observed together were considered a flock. On the atlas charts showing pelagic bird observations, the abundance of birds is indicated by the size of the circle, and X's indicate that observations were made but no birds were sighted. There is one symbol for each day's observations. The percentage of bird flocks is denoted by the amount that a circle is shaded.

Charts showing the distributions of porpoise sightings in northern hemisphere winter (October-March) and summer (April-September) are shown in the atlas. On the charts each circle represents the sighting of one or more porpoises and the numbers to the side of the circles indicate the month and year of the sighting;

cruise tracks along which observations were made are indicated by lines. It is emphasized here that the observations of porpoise reported are only sightings which do not include data on their abundance.

The distribution of whale sightings made during northern hemisphere winter (October-March) and summer months (April-September) is also shown. On the charts each symbol represents the sighting of one or more whales and the numbers at the side of the symbols indicate the month and year of the sighting; cruise tracks along which observations were made are indicated by lines. Except for pilot whales, which often approached the ship, there were few instances when it was possible to make specific identifications since often only the spout of a whale was observed and so recorded. When specific identifications were possible, most in the oceanic waters were sperm whales. Along the coast of Baja California they were California gray whales.

Sightings of tuna schools made on EASTROPAC cruises are summarized in one figure. In addition to those sighted by the bird observers, some tuna schools were sighted by officers aboard the research vessels and are included on the chart. The circles on the chart indicate tuna schools which were identified as skipjack and the squares indicate schools of yellowfin, black skipjack, or tuna which were not identified. The numbers at the side of each symbol indicate the month and year that the school was sighted. The stippled lines indicate cruise tracks along which the sightings were made. A total of 59 tuna schools were sighted of which 22 were skipjack. Since the effort to observe tuna schools was not uniform and the observations were not made by skilled observers, the records must be considered only as sightings and can not be used to infer distribution patterns. The fact that no tuna were observed in a given area does not necessarily indicate that they were not present.

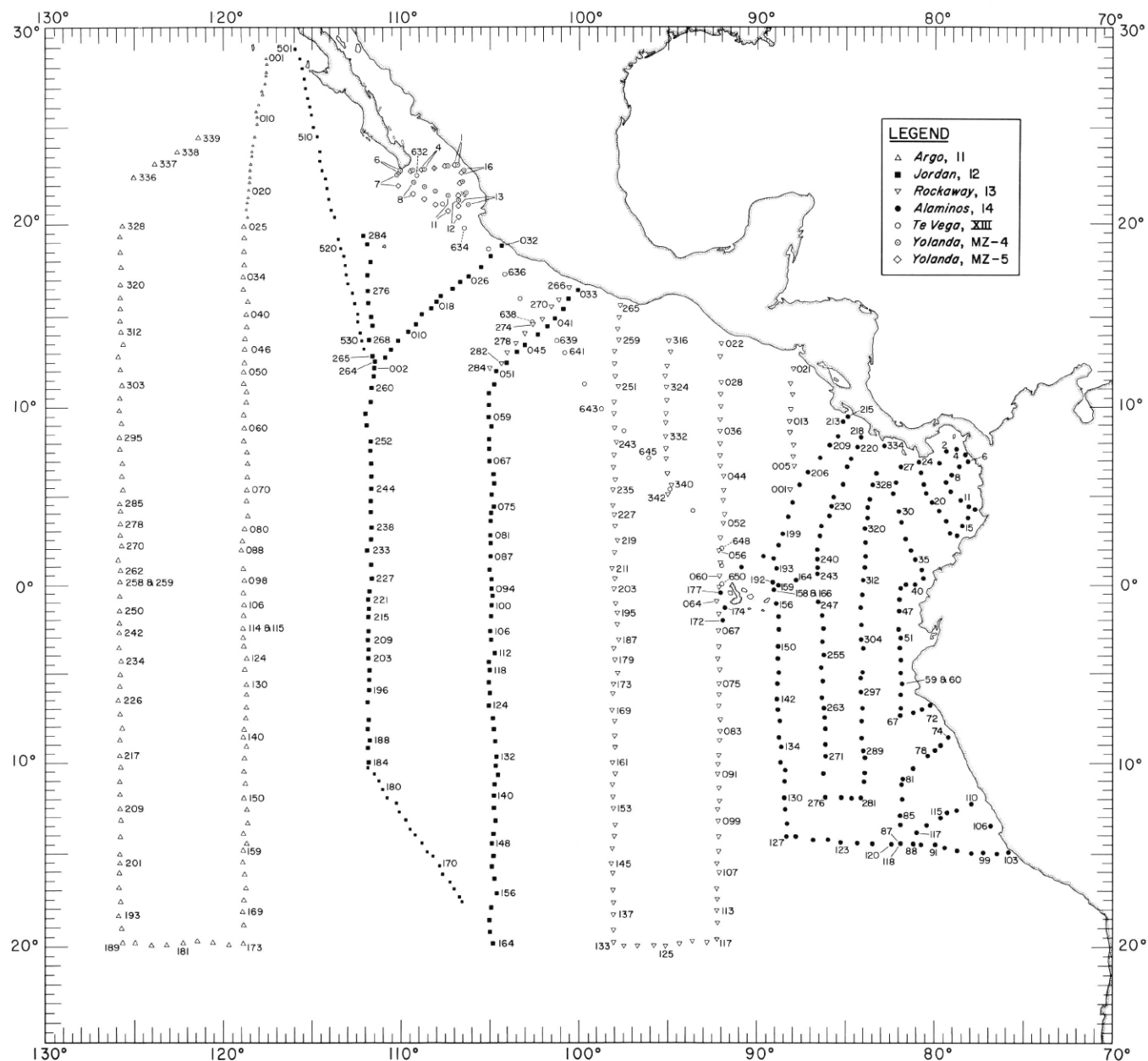
R. Michael Laurs

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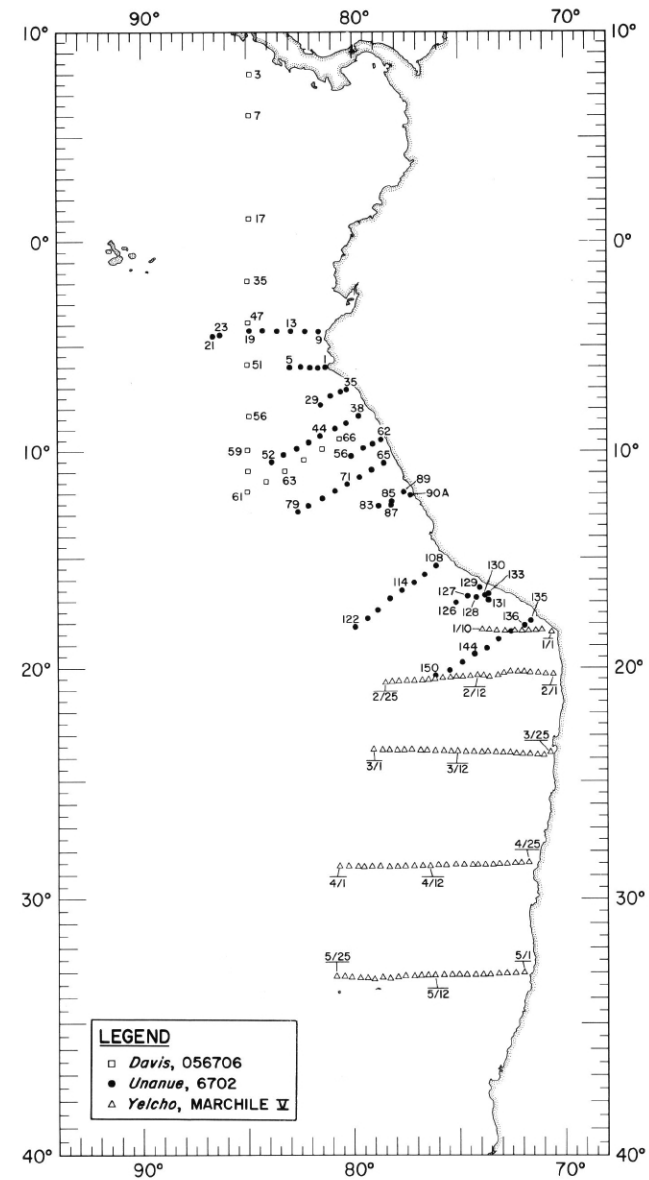
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10-TC-a.

FIGURE 10-TC-a. — Locations of stations occupied by participating ships in the main portion of the EASTROPAC area during the first survey period, February-March 1967.



10-TC-b.

FIGURE 10-TC-b. — Locations of stations occupied by participating ships in the southern coastal portion of the EASTROPAC area during the first survey period, February-March 1967.

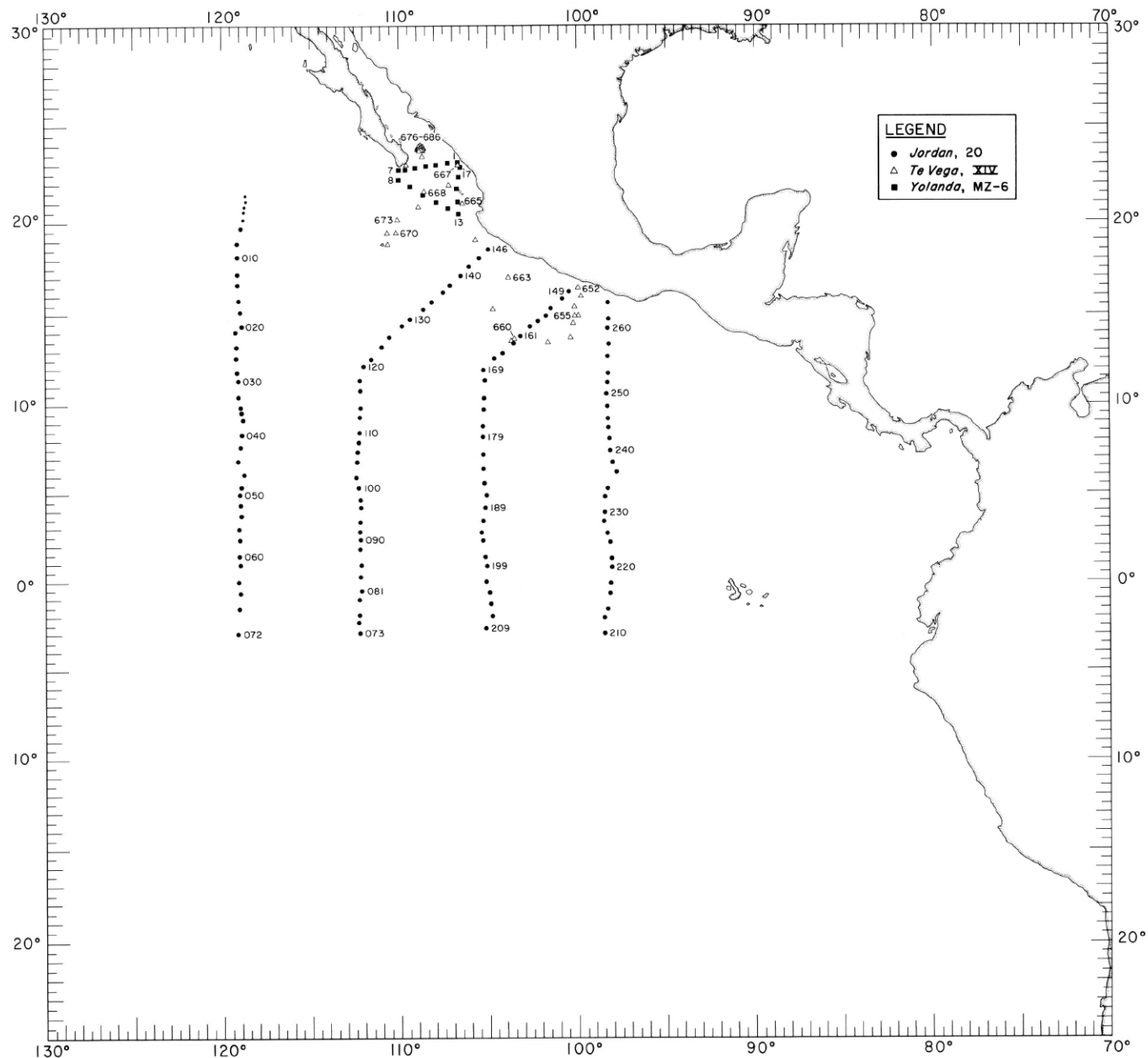
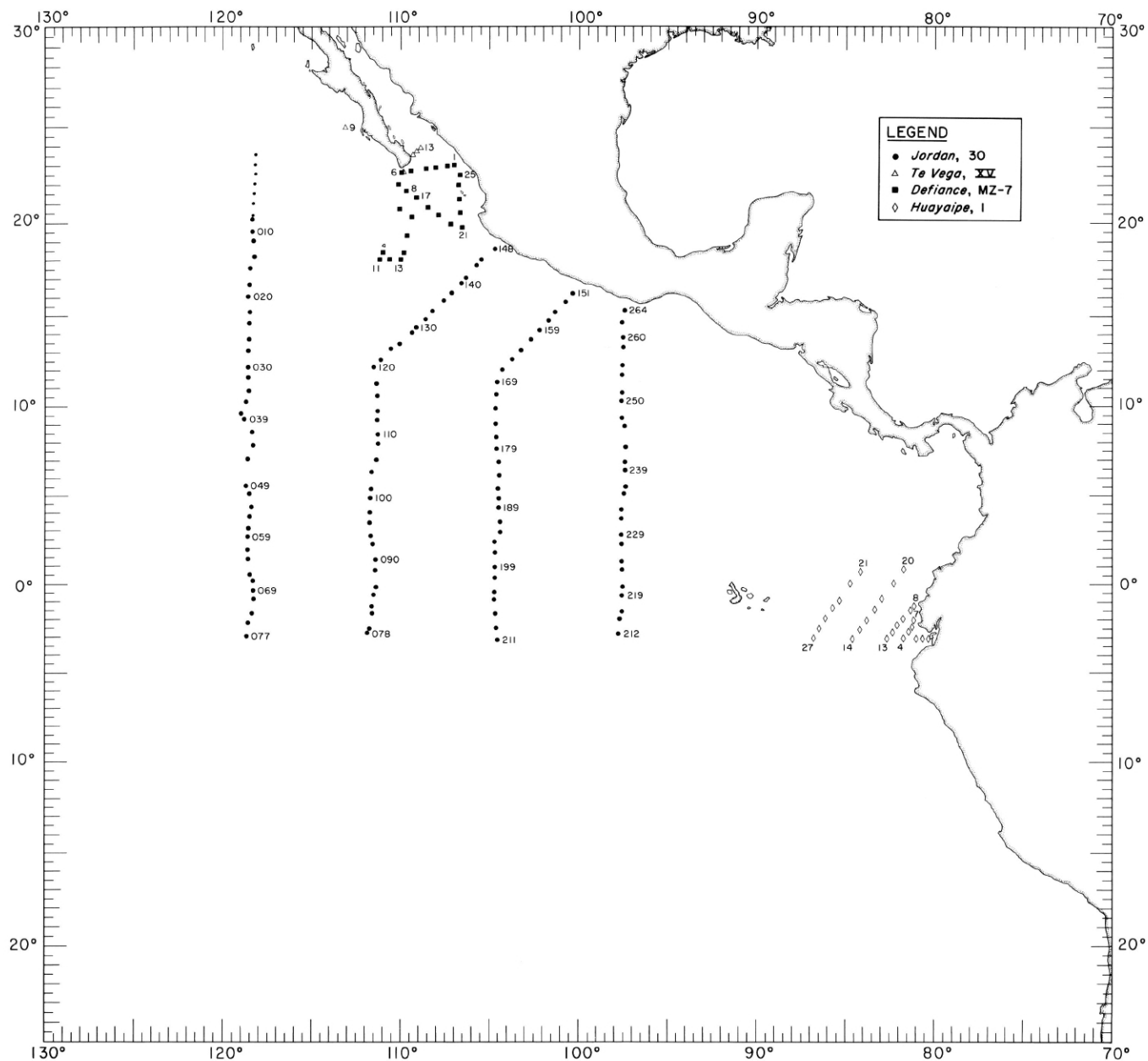
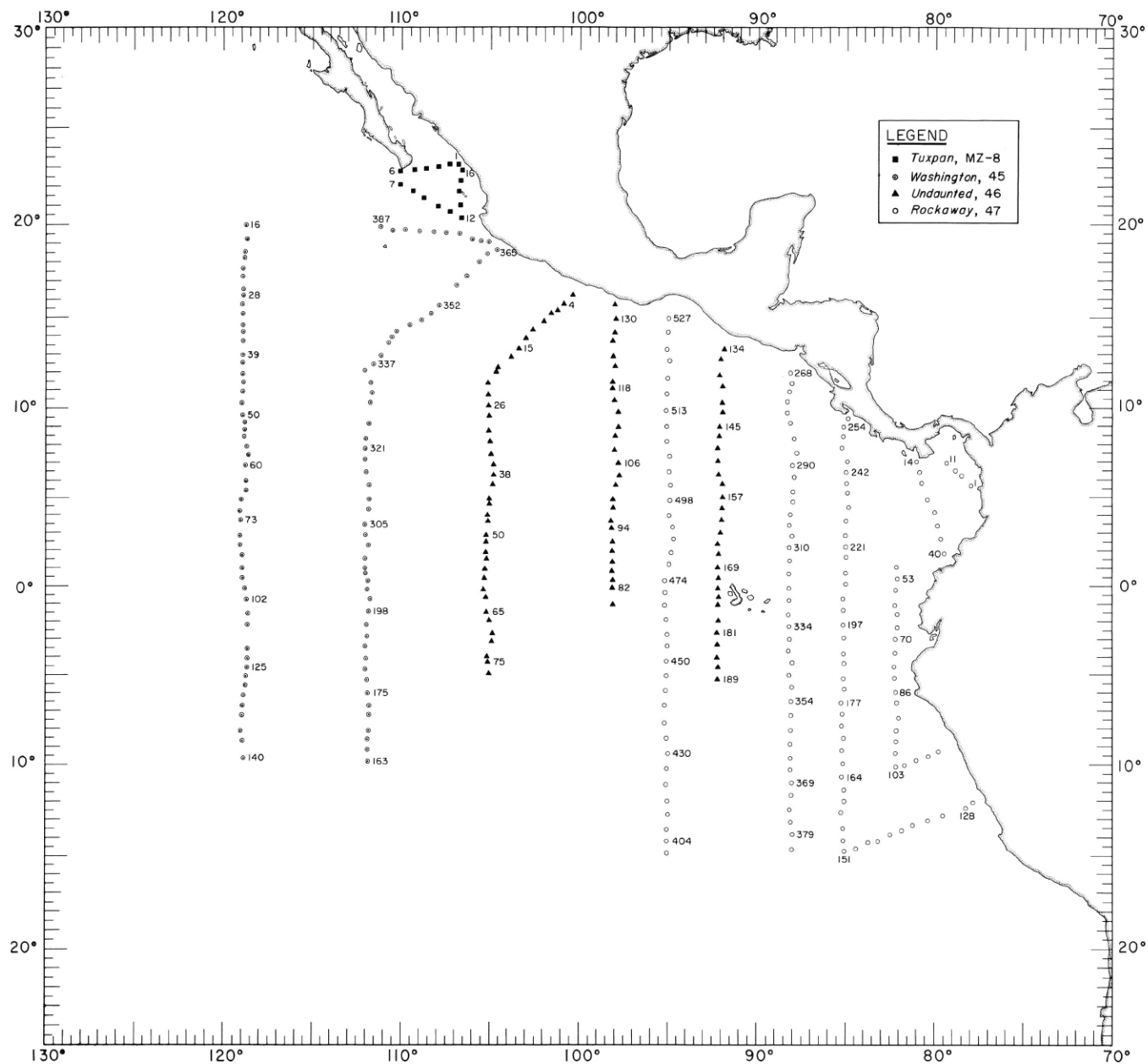


FIGURE 20-TC. — Locations of stations occupied by participating ships during the first monitor period, April-May 1967.



30-TC.

FIGURE 30-TC. — Locations of stations occupied by participating ships during the second monitor period, June-July 1967.

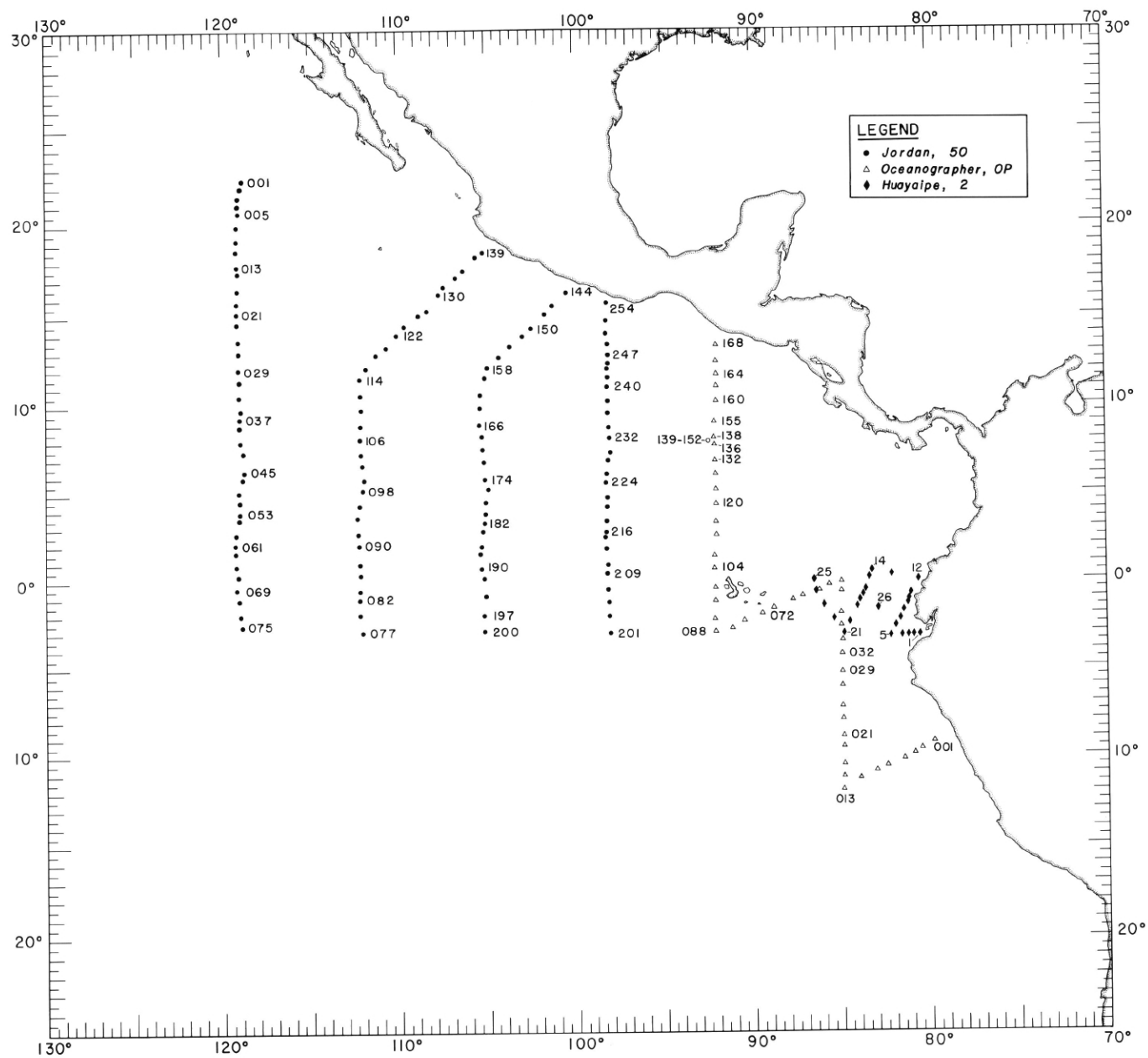


40-TC-a.

FIGURE 40-TC-a. — Locations of stations occupied by participating ships in the main portion of the EASTROPAC area during the second survey period, August-September 1967.

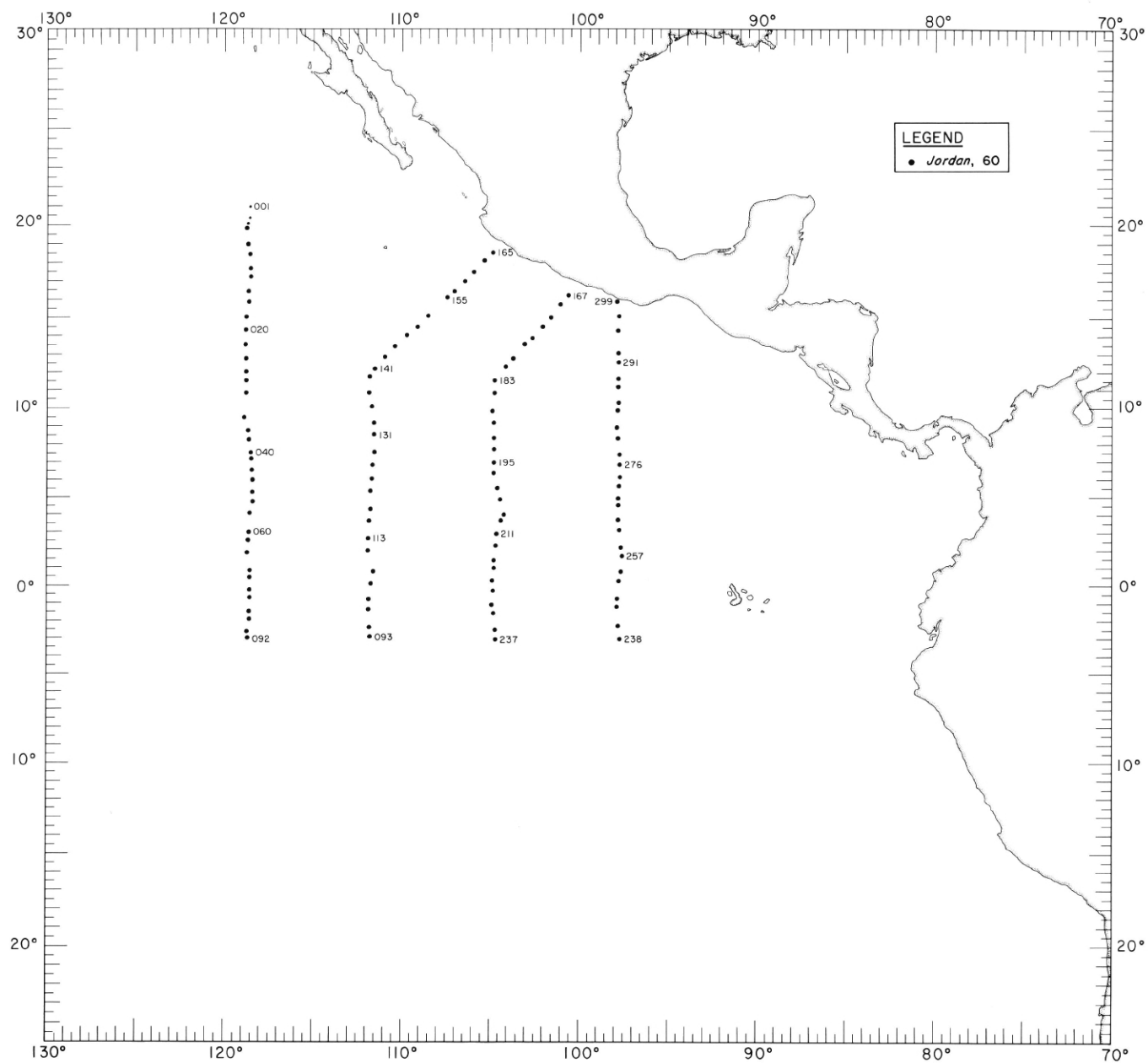






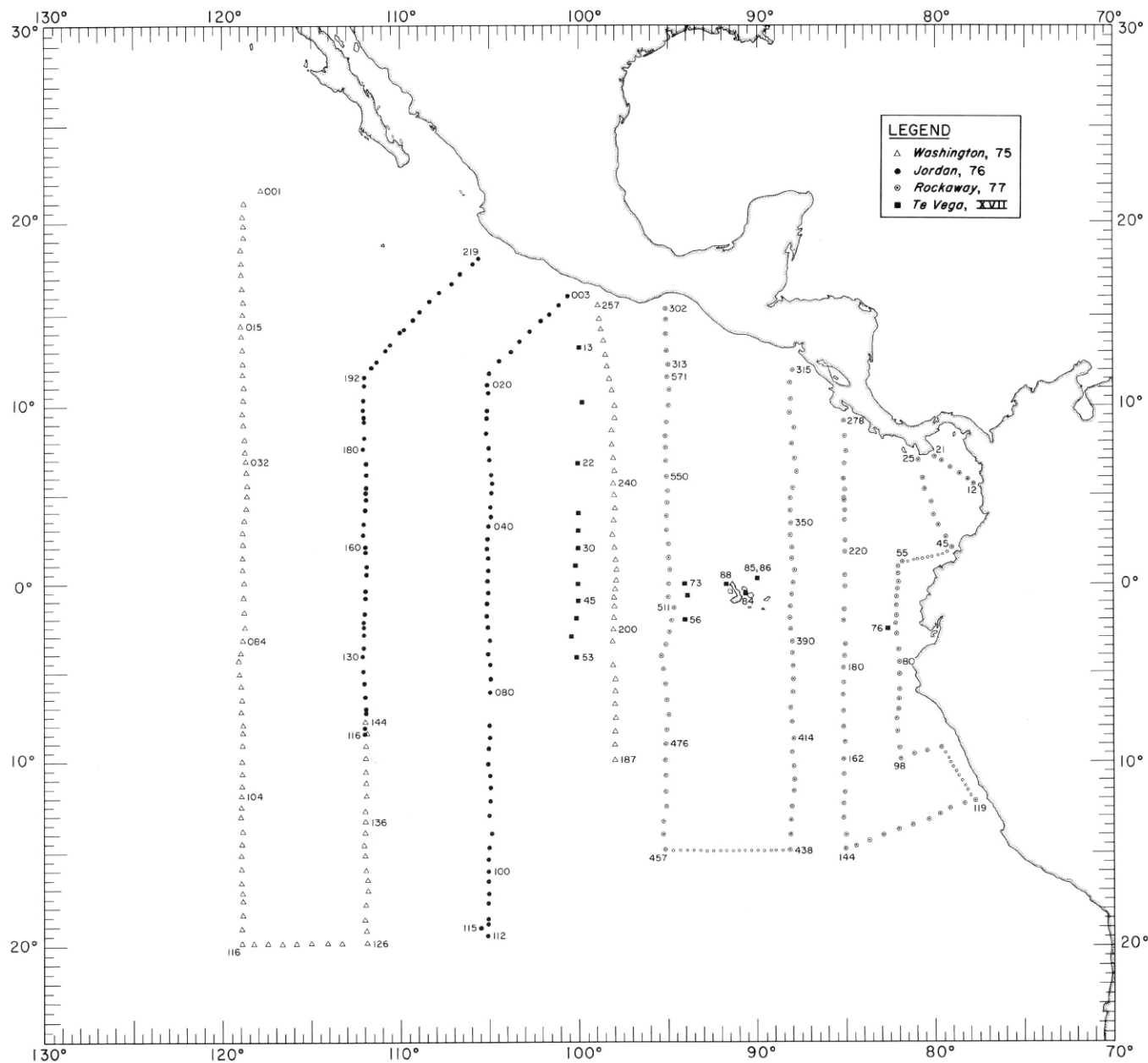
50-TC.

FIGURE 50-TC. — Locations of stations occupied by participating ships during the third monitor period, October-November 1967.



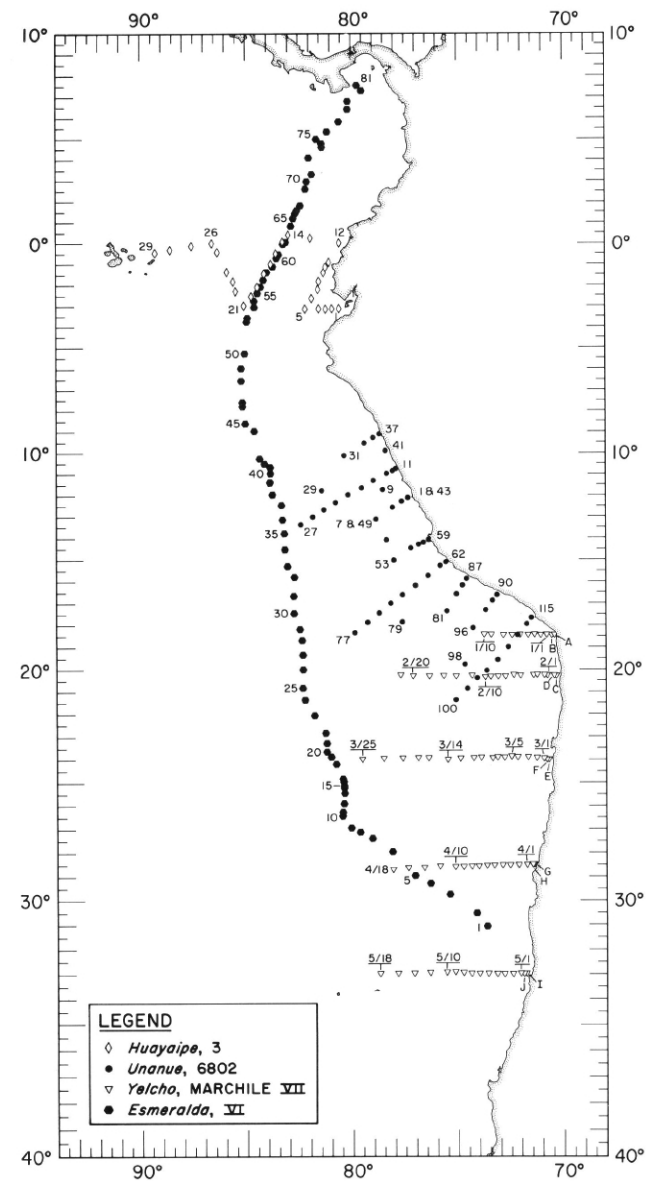
60-TC.

FIGURE 60-TC. — Locations of stations occupied by participating ships during the fourth monitor period, December 1967-January 1968.



70-TC-a.

FIGURE 70-TC-a. — Locations of stations occupied by participating ships in the main portion of the EASTROPAC area during the third survey period, February-March 1968.



70-TC-b.

FIGURE 70-TC-b. — Locations of stations occupied by participating ships in the southern coastal portion of the EASTROPAC area during the third survey period, February-March 1968.

## INTRODUCTION

EASTROPAC was an international cooperative investigation of the eastern tropical Pacific Ocean which was intended to provide data necessary for a more effective use of the marine resources of the area, especially tropical tunas, and also to increase knowledge of the ocean circulation, air-sea interaction, and ecology. The Bureau of Commercial Fisheries (BCF) (now National Marine Fisheries Service) was the coordinating agency. The field work, from February 1967 through March 1968, was divided into seven 2-month cruise periods.

At a meeting of the EASTROPAC Coordinating Committee held at La Jolla in April 1968, it was decided that the data derived from the cruises were so numerous as to render classical data reports impractical and that a comprehensive atlas of the physical and biological results of the project should be produced instead. The atlas has been divided into 11 volumes, with 5 volumes containing physical oceanographic and meteorological data from the principal participating ships, 5 volumes containing biological and nutrient chemistry data from the same ships, and 1 volume containing all data from Latin American cooperating ships and ships of opportunity.

Volume 4 contains biological and nutrient chemistry data collected mainly by the principal participating ships during the first and second monitor cruise periods: cruise 20, April-May 1967, and cruise 30, June-July 1967. The companion volume presenting the corresponding physical oceanographic and meteorological data is volume 3. The locations of stations occupied by participating ships are shown in figure 20-TC and figure 30-TC.

Information concerning the history and organization of EASTROPAC, a description of the cruises undertaken, the program of observations, the methods used for preparation of the charts, and remarks on the organization of the atlas are contained in volume 1 with descriptions by the contributing scientists of the methods used to collect and process the data upon which the atlas charts are based.

CUTHBERT M. LOVE  
Editor

## LIST OF FIGURES

FIGURE 20-TC.—Locations of stations occupied by participating ships during the first monitor period, April-May 1967.  
FIGURE 30-TC.—Locations of stations occupied by participating ships during the second monitor period, June-July 1967.  
FIGURE 20-P-10.—Phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.  
FIGURE 20-Si-10.—Silicate-silicon ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.  
FIGURE 20-NO<sub>3</sub>-10.—Nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.  
FIGURE 20-NO<sub>2</sub>-10.—Nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.  
FIGURE 20-NH<sub>3</sub>-10.—Ammonia-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.  
FIGURE 20-P-100.—Phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) at 100 meters, April-May 1967.  
FIGURE 20-Si-100.—Silicate-silicon ( $\mu\text{g-at./l.}$ ) at 100 meters, April-May 1967.  
FIGURE 20-NO<sub>3</sub>-100.—Nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) at 100 meters, April-May 1967.  
FIGURE 20-NH<sub>3</sub>-100.—Ammonia-nitrogen ( $\mu\text{g-at./l.}$ ) at 100 meters, April-May 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.  
FIGURE 20-Ch-s.—Chlorophyll-a ( $\text{mg./m.}^3$ ) at the sea surface, April-May 1967.  
FIGURE 20-Ch-ci.—Chlorophyll-a ( $\text{mg./m.}^3$ ) integrated over the euphotic layer, April-May 1967.  
FIGURE 20-Ch-150i.—Chlorophyll-a ( $\text{mg./m.}^3$ ) integrated from the sea surface to 150 meters depth, April-May 1967.  
FIGURE 20-Ph-150i.—Phaeophytin ( $\text{mg./m.}^3$ ) integrated from the sea surface to 150 meters depth, April-May 1967.  
FIGURE 20-PP-s.—Primary production ( $\text{mg. C/m.}^3/\text{day}$ ) at the sea surface, April-May 1967.  
FIGURE 20-PP-ei.—Primary production ( $\text{mg. C/m.}^3/\text{day}$ ) integrated over the euphotic layer, April-May 1967.  
FIGURE 20-EL.—Thickness of the euphotic layer in meters, April-May 1967.  
FIGURE 20-FCp.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of total fish and cephalopods taken in night micronekton hauls during April-May 1967.

FIGURE 20-Cr.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of total crustaceans taken in night micronekton hauls during April-May 1967.  
FIGURE 20-Nk.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of total micronekton taken in night micronekton hauls during April-May 1967.  
FIGURE 20-ZhN.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of zooplankton taken in 50-cm. net hauls at night, April-May 1967.  
FIGURE 20-Z1N.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of zooplankton taken in 1-m. net hauls at night, April-May 1967.  
FIGURE 20-ZhD.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of zooplankton taken in 50-cm. net hauls during the day, April-May 1967.  
FIGURE 20-Z1D.—Distribution of standing stock ( $\text{ml./1,000 m.}^3$ ) of zooplankton taken in 1-m. net hauls during the day, April-May 1967.  
FIGURE 20-FLN.—Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls at night during April-May 1967.  
FIGURE 20-FLD.—Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, April-May 1967.  
FIGURE 20-FE.—Total fish eggs (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.  
FIGURE 20-FS.—Total skipjack tuna, *Katsuwonus pelamis*, larvae (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.  
FIGURE 20-FA.—Total frigate mackerel, *Aurix*, larvae (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.  
FIGURE 20-FC.—Total dolphin (fish), *Coryphaena*, larvae (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.  
FIGURE 20-FM.—Total myctophid larvae (number/haul) taken in 1-m. oblique plankton hauls at night during April-May 1967.  
FIGURE 20-FMD.—Total myctophid larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, April-May 1967.

FIGURE 20-FGN.—Total gonostomatid and sternoptychid larvae (number/haul) taken in 1-m. oblique plankton hauls at night during April-May 1967.

FIGURE 20-FGD.—Total gonostomatid and sternoptychid larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, April-May 1967.

FIGURE 20-P-v1.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.

FIGURE 20-P-v2.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

FIGURE 20-P-v3.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

FIGURE 20-P-v4.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.

FIGURE 20-P-v5.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

FIGURE 20-P-v6.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.

FIGURE 20-Si-v1.—Vertical distribution of silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.

FIGURE 20-Si-v2.—Vertical distribution of silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

FIGURE 20-Si-v3.—Vertical distribution of silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

FIGURE 20-Si-v4.—Vertical distribution of silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.

FIGURE 20-Si-v5.—Vertical distribution of silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

FIGURE 20-Si-v6.—Vertical distribution of silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.

FIGURE 20-NO<sub>3</sub>-v1.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.

FIGURE 20-NO<sub>3</sub>-v2.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

FIGURE 20-NO<sub>3</sub>-v3.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

FIGURE 20-NO<sub>3</sub>-v4.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.

FIGURE 20-NO<sub>3</sub>-v5.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

FIGURE 20-NO<sub>3</sub>-v6.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.

FIGURE 20-NO<sub>2</sub>-v1.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.

FIGURE 20-NO<sub>2</sub>-v2.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

FIGURE 20-NO<sub>2</sub>-v3.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

FIGURE 20-NO<sub>2</sub>-v4.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.

FIGURE 20-NO<sub>2</sub>-v5.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

FIGURE 20-NO<sub>2</sub>-v6.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.

FIGURE 20-Ch-v1.—Vertical distribution of chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.

FIGURE 20-Ph-v1.—Vertical distribution of phaeophytin ( $\text{mg.}/\text{m.}^3$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.

FIGURE 20-PP-v1.—Vertical distribution of primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 20-Ch-v2.—Vertical distribution of chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

FIGURE 20-Ph-v2.—Vertical distribution of phaeophytin ( $\text{mg.}/\text{m.}^3$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

FIGURE 20-PP-v2.—Vertical distribution of primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 20-Ch-v3.—Vertical distribution of chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

FIGURE 20-Ph-v3.—Vertical distribution of phaeophytin ( $\text{mg.}/\text{m.}^3$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

FIGURE 20-PP-v3.—Vertical distribution of primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 20-Ch-v4.—Vertical distribution of chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.

FIGURE 20-Ph-v4.—Vertical distribution of phaeophytin ( $\text{mg.}/\text{m.}^3$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.

FIGURE 20-PP-v4.—Vertical distribution of primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 20-Ch-v5.—Vertical distribution of chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

FIGURE 20-Ph-v5.—Vertical distribution of phaeophytin ( $\text{mg.}/\text{m.}^3$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

FIGURE 20-PP-v5.—Vertical distribution of primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 20-Ch-v6.—Vertical distribution of chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.

FIGURE 20-Ph-v6.—Vertical distribution of phaeophytin ( $\text{mg.}/\text{m.}^3$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.

FIGURE 20-PP-v6.—Vertical distribution of primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 30-P-10.—Phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) at 10 meters, June-July 1967.

FIGURE 30-Si-10.—Silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) at 10 meters, June-July 1967.

FIGURE 30-NO<sub>3</sub>-10.—Nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) at 10 meters, June-July 1967.

FIGURE 30-NO<sub>2</sub>-10.—Nitrite-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) at 10 meters, June-July 1967.

FIGURE 30-NH<sub>4</sub>-10.—Ammonia-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) at 10 meters, June-July 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.

FIGURE 30-P-100.—Phosphate-phosphorus ( $\mu\text{g.}/\text{at./l.}$ ) at 100 meters, June-July 1967.

FIGURE 30-Si-100.—Silicate-silicon ( $\mu\text{g.}/\text{at./l.}$ ) at 100 meters, June-July 1967.

FIGURE 30-NO<sub>3</sub>-100.—Nitrate-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) at 100 meters, June-July 1967.

FIGURE 30-NH<sub>4</sub>-100.—Ammonia-nitrogen ( $\mu\text{g.}/\text{at./l.}$ ) at 100 meters, June-July 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.

FIGURE 30-Ch-s.—Chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) at the sea surface, June-July 1967.

FIGURE 30-Ch-ei.—Chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) integrated over the euphotic layer, June-July 1967.

FIGURE 30-Ch-150i.—Chlorophyll-a ( $\text{mg.}/\text{m.}^3$ ) integrated from the sea surface to 150 meters depth, June-July 1967.

FIGURE 30-Ph-150i.—Phaeophytin ( $\text{mg.}/\text{m.}^3$ ) integrated from the sea surface to 150 meters depth, June-July 1967.

FIGURE 30-PP-s.—Primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) at the sea surface, June-July 1967.

FIGURE 30-PP-ei.—Primary production ( $\text{mg. C}/\text{m.}^3/\text{day}$ ) integrated over the euphotic layer, June-July 1967.

FIGURE 30-EL<sub>0.1</sub>—Thickness of the euphotic layer in meters, June-July 1967.

FIGURE 30-FCP.—Distribution of standing stock ( $\text{ml}/1,000 \text{ m.}^3$ ) of total fish and cephalopods taken in night micronekton hauls during June-July 1967.

FIGURE 30-Cr.—Distribution of standing stock ( $\text{ml}/1,000 \text{ m.}^3$ ) of total crustaceans taken in night micronekton hauls during June-July 1967.

FIGURE 30-Nk.—Distribution of standing stock ( $\text{ml}/1,000 \text{ m.}^3$ ) of total micronekton taken in night micronekton hauls during June-July 1967.

FIGURE 30-ZhN.—Distribution of standing stock ( $\text{ml}/1,000 \text{ m.}^3$ ) of zooplankton taken in 50-cm. net hauls at night, June-July 1967.

FIGURE 30-Z1N.—Distribution of standing stock ( $\text{ml}/1,000 \text{ m.}^3$ ) of zooplankton taken in 1-m. net hauls at night, June-July 1967.

FIGURE 30-ZHd.—Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 50-cm. net hauls during the day, June-July 1967.

FIGURE 30-ZID.—Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 1-m. net hauls during the day, June-July 1967.

FIGURE 30-FLN.—Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls at night during June-July 1967.

FIGURE 30-FLD.—Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, June-July 1967.

FIGURE 30-FE.—Total fish eggs (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.

FIGURE 30-FS.—Total skipjack tuna, *Katsuwonus pelamis*, larvae (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.

FIGURE 30-FA.—Total frigate mackerel, *Auris*, larvae (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.

FIGURE 30-FC.—Total dolphin (fish), *Coryphaena*, larvae (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.

FIGURE 30-FMN.—Total myctophid larvae (number/haul) taken in 1-m. oblique plankton hauls at night during June-July 1967.

FIGURE 30-FMD.—Total myctophid larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, June-July 1967.

FIGURE 30-FGN.—Total gonostomatid and sternopychid larvae (number/haul) taken in 1-m. oblique plankton hauls at night during June-July 1967.

FIGURE 30-FGD.—Total gonostomatid and sternopychid larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, June-July 1967.

FIGURE 30-BP.—Relative abundance of plankton-feeding birds (birds/mile), June-July 1967.

FIGURE 30-BF.—Relative abundance of fish and cephalopod-feeding birds (birds/mile), June-July 1967.

FIGURE 30-P-v1.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along 118°30' W., June 17-26, 1967.

FIGURE 30-P-v2.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along 111°30' W., June 28-July 4, 1967.

FIGURE 30-P-v3.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

FIGURE 30-P-v4.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967.

FIGURE 30-P-v5.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along 104°30' W., July 13-18, 1967.

FIGURE 30-P-v6.—Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along 97°30' W., July 20-27, 1967.

FIGURE 30-Si-v1.—Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along 118°30' W., June 17-26, 1967.

FIGURE 30-Si-v2.—Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along 111°30' W., June 28-July 4, 1967.

FIGURE 30-Si-v3.—Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

FIGURE 30-Si-v4.—Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967.

FIGURE 30-Si-v5.—Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along 104°30' W., July 13-18, 1967.

FIGURE 30-Si-v6.—Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along 97°30' W., July 20-27, 1967.

FIGURE 30-NO<sub>3</sub>-v1.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along 118°30' W., June 17-26, 1967.

FIGURE 30-NO<sub>3</sub>-v2.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along 111°30' W., June 28-July 4, 1967.

FIGURE 30-NO<sub>3</sub>-v3.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

FIGURE 30-NO<sub>3</sub>-v4.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967.

FIGURE 30-NO<sub>3</sub>-v5.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along 104°30' W., July 13-18, 1967.

FIGURE 30-NO<sub>3</sub>-v6.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along 97°30' W., July 20-27, 1967.

FIGURE 30-NO<sub>2</sub>-v1.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along 118°30' W., June 17-26, 1967.

FIGURE 30-NO<sub>2</sub>-v2.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along 111°30' W., June 28-July 4, 1967.

FIGURE 30-NO<sub>2</sub>-v3.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

FIGURE 30-NO<sub>2</sub>-v4.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967.

FIGURE 30-NO<sub>2</sub>-v5.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along 104°30' W., July 13-18, 1967.

FIGURE 30-NO<sub>2</sub>-v6.—Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along 97°30' W., July 20-27, 1967.

FIGURE 30-Ch-v1.—Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 118°30' W., June 17-26, 1967.

FIGURE 30-Ph-v1.—Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 118°30' W., June 17-26, 1967.

FIGURE 30-PP-v1.—Vertical distribution of primary production (mg. C/m.<sup>3</sup>/day) along 118°30' W., June 17-26, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 30-Ch-v2.—Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 111°30' W., June 28-July 4, 1967.

FIGURE 30-Ph-v2.—Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 111°30' W., June 28-July 4, 1967.

FIGURE 30-PP-v2.—Vertical distribution of primary production (mg. C/m.<sup>3</sup>/day) along 111°30' W., June 28-July 4, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 30-Ch-v3.—Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

FIGURE 30-Ph-v3.—Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

FIGURE 30-PP-v3.—Vertical distribution of primary production (mg. C/m.<sup>3</sup>/day) along a section from 12° N., 111°30' W., to Manzanillo, July 4-7, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 30-Ch-v4.—Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967.

FIGURE 30-Ph-v4.—Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967.

FIGURE 30-PP-v4.—Vertical distribution of primary production (mg. C/m.<sup>3</sup>/day) along a section from Acapulco to 12° N., 104°30' W., July 10-13, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 30-Ch-v5.—Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 104°30' W., July 13-18, 1967.

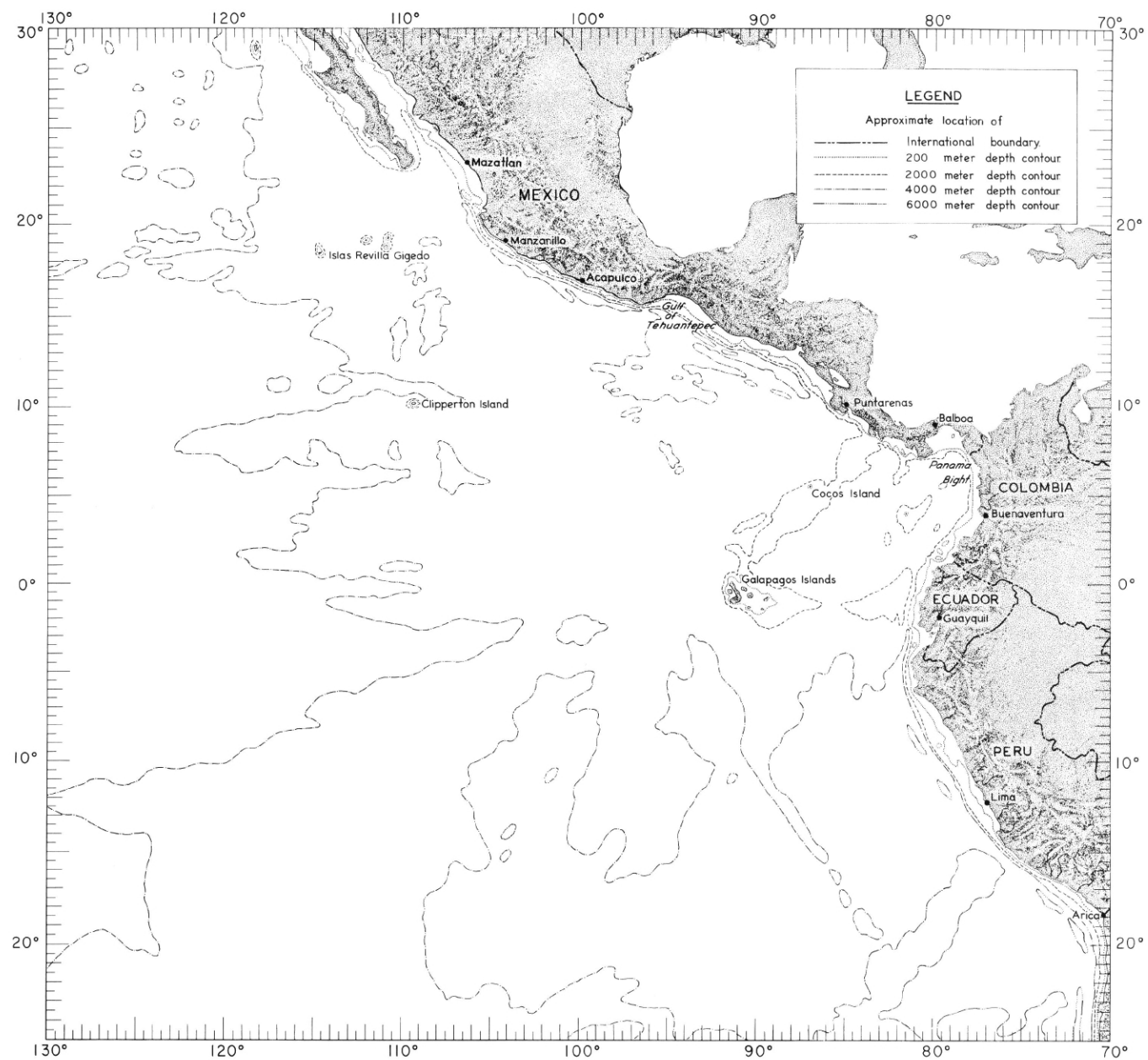
FIGURE 30-Ph-v5.—Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 104°30' W., July 13-18, 1967.

FIGURE 30-PP-v5.—Vertical distribution of primary production (mg. C/m.<sup>3</sup>/day) along 104°30' W., July 13-18, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

FIGURE 30-Ch-v6.—Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 97°30' W., July 20-27, 1967.

FIGURE 30-Ph-v6.—Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 97°30' W., July 20-27, 1967.

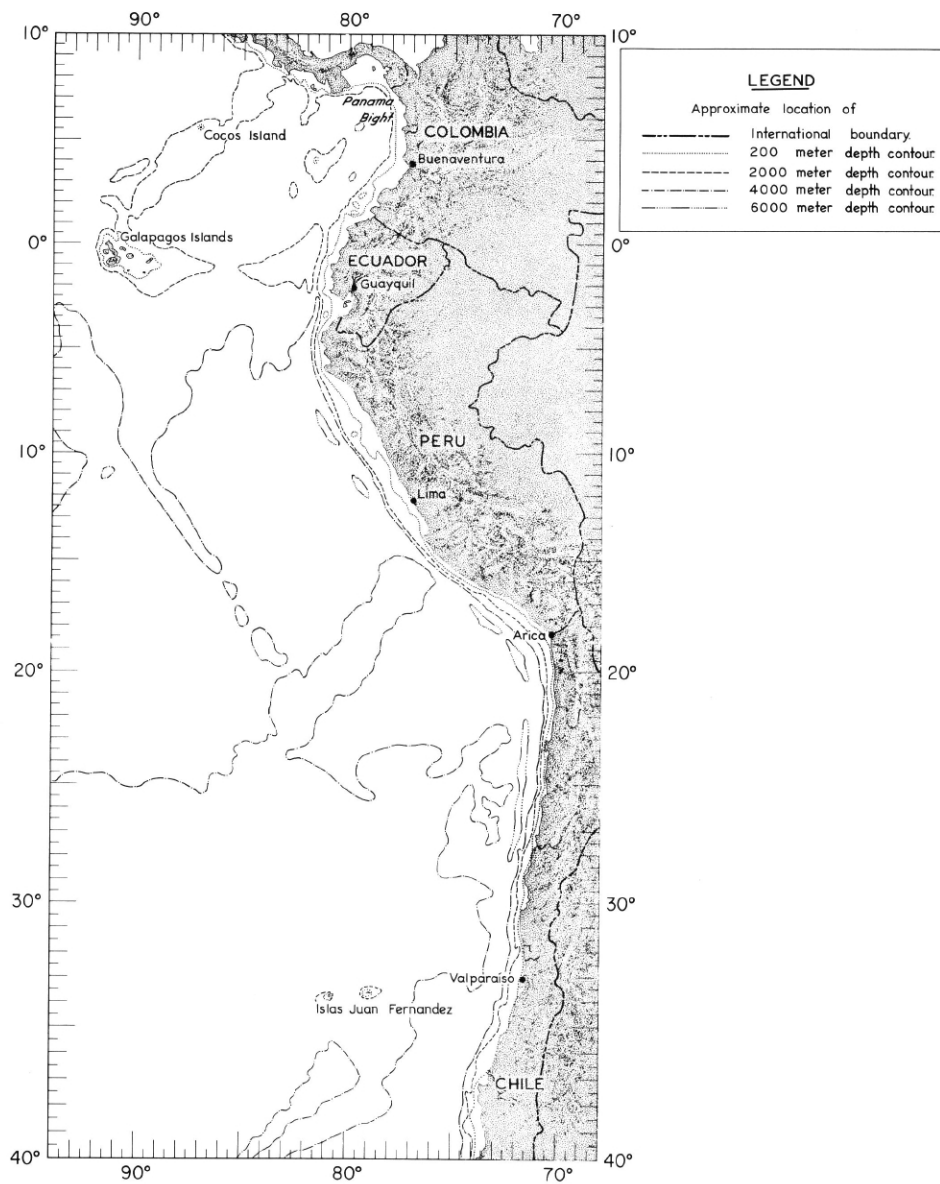
FIGURE 30-PP-v6.—Vertical distribution of primary production (mg. C/m.<sup>3</sup>/day) along 97°30' W., July 20-27, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



RM-a.

FIGURE RM-a. — Reference Map of the main portion of the EASTROPAC area. The topographic shading and bathymetric contours are approximate only and should not be considered as portraying the latest available information.





RM-b

FIGURE RM-b — Reference map of the southern coastal portion of the EASTROPAC area. The topographic shading and bathymetric contours are approximate only and should not be considered as portraying the latest available information.

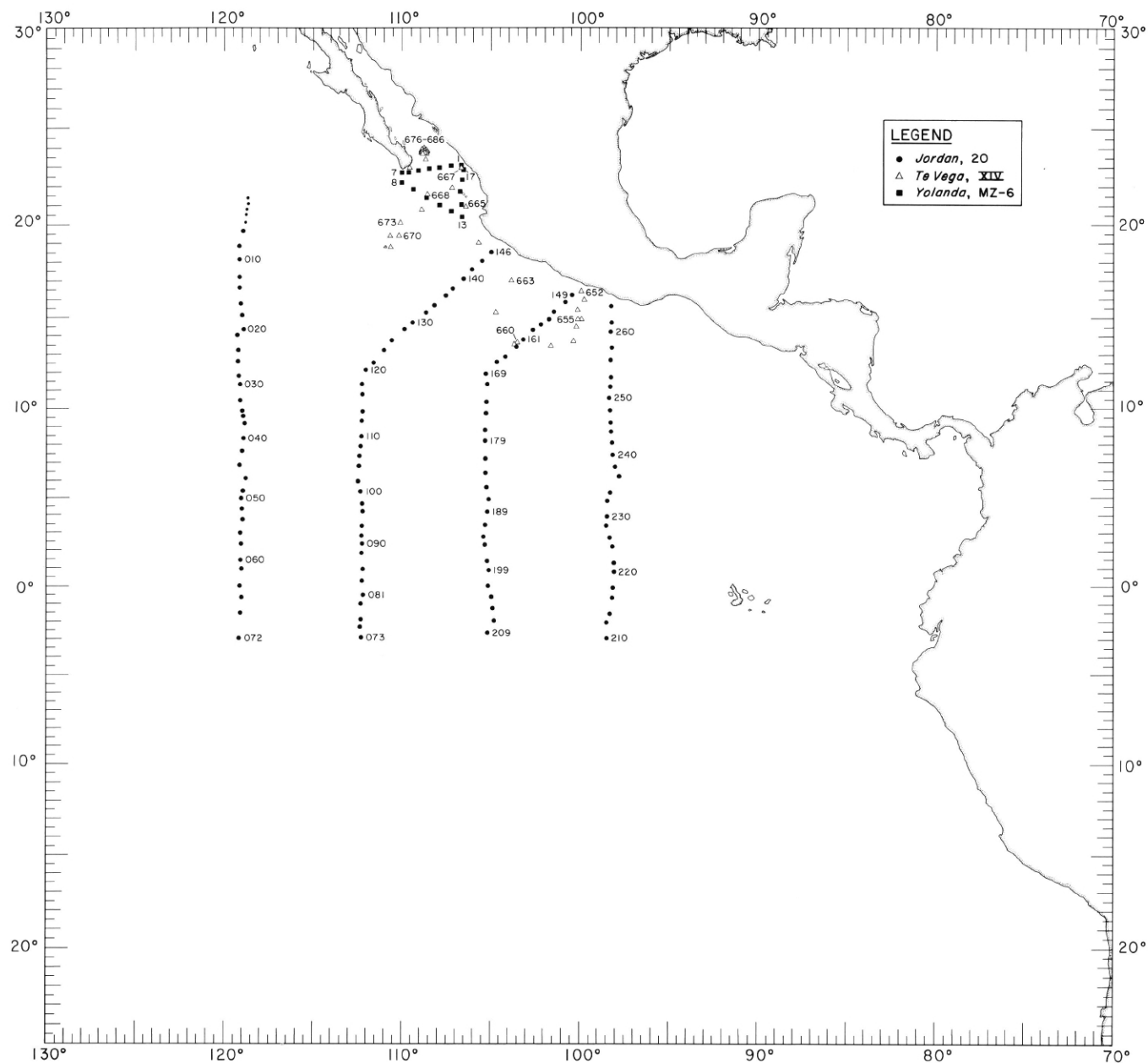
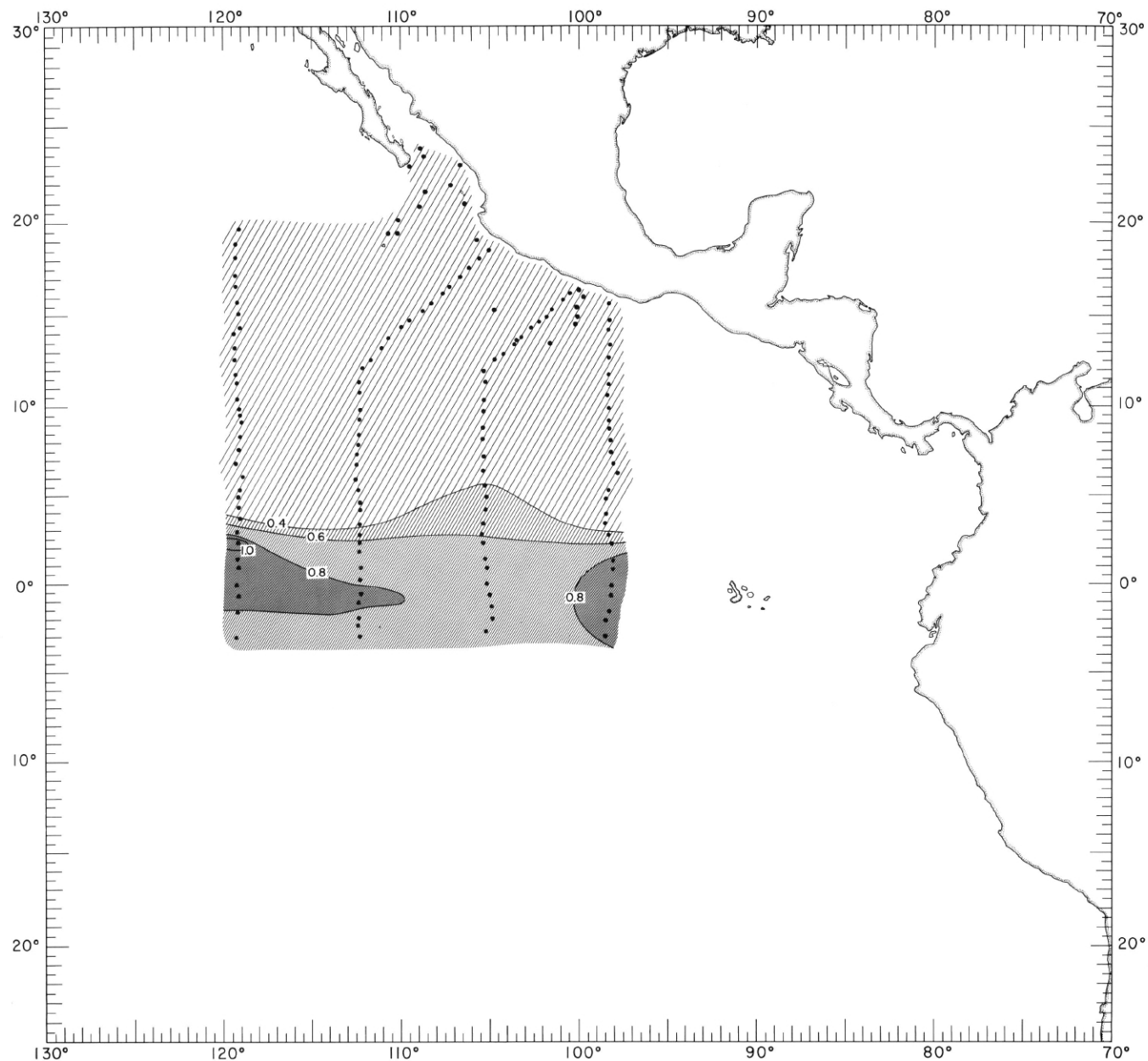


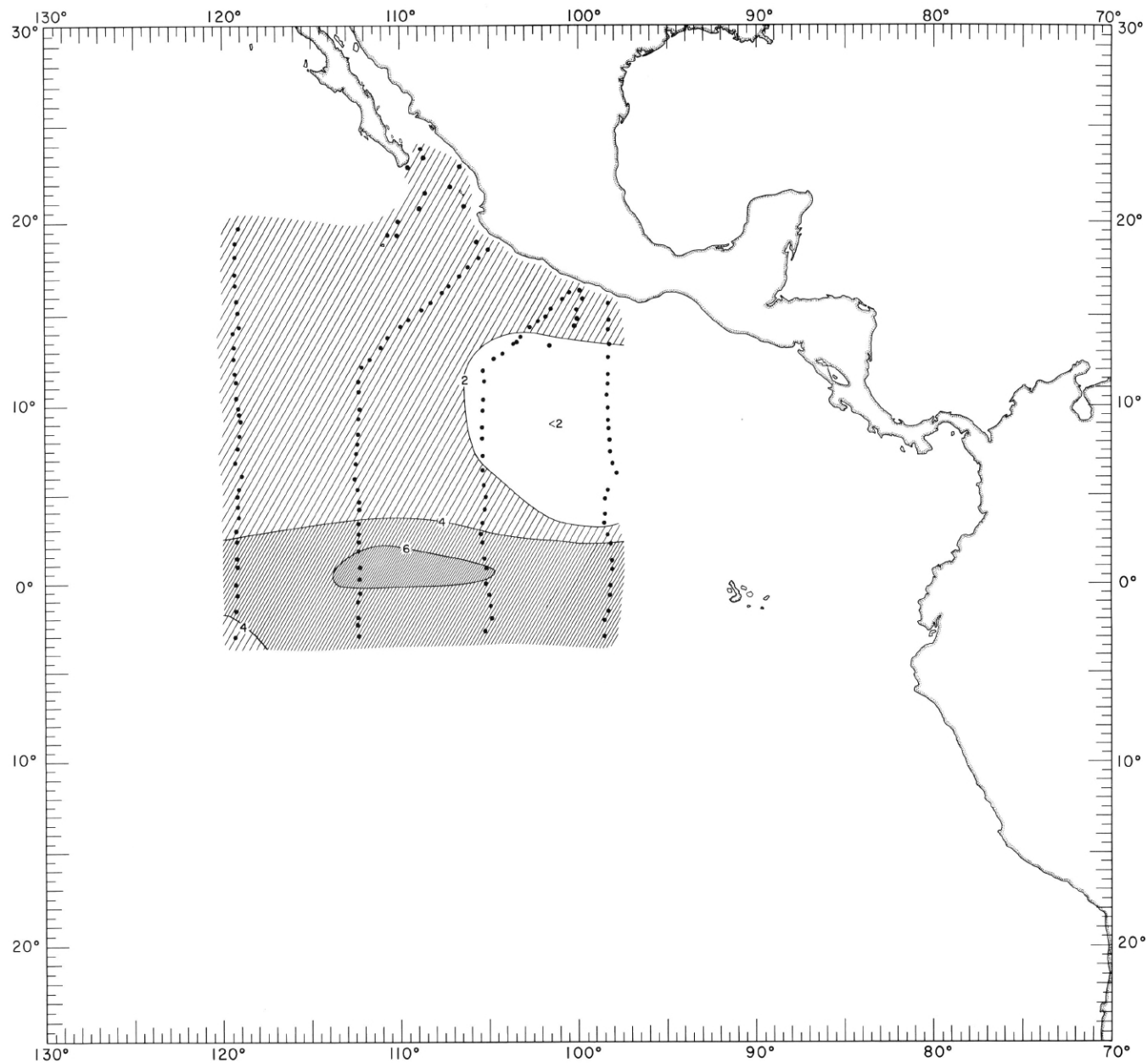
FIGURE 20-TC. — Locations of stations occupied by participating ships during the first monitor period, April-May 1967.





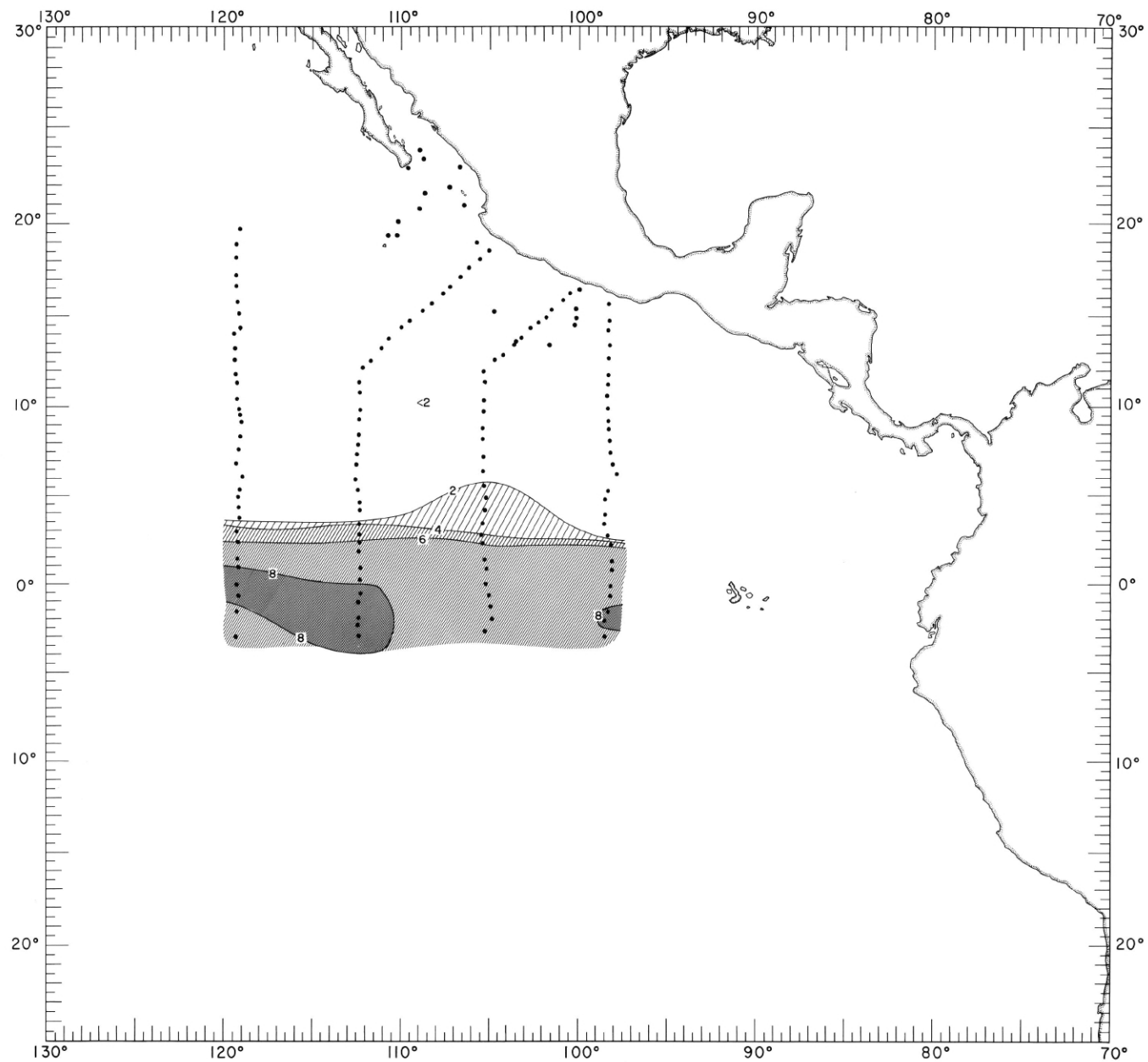
20-P-10.

FIGURE 20-P-10. — Phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.



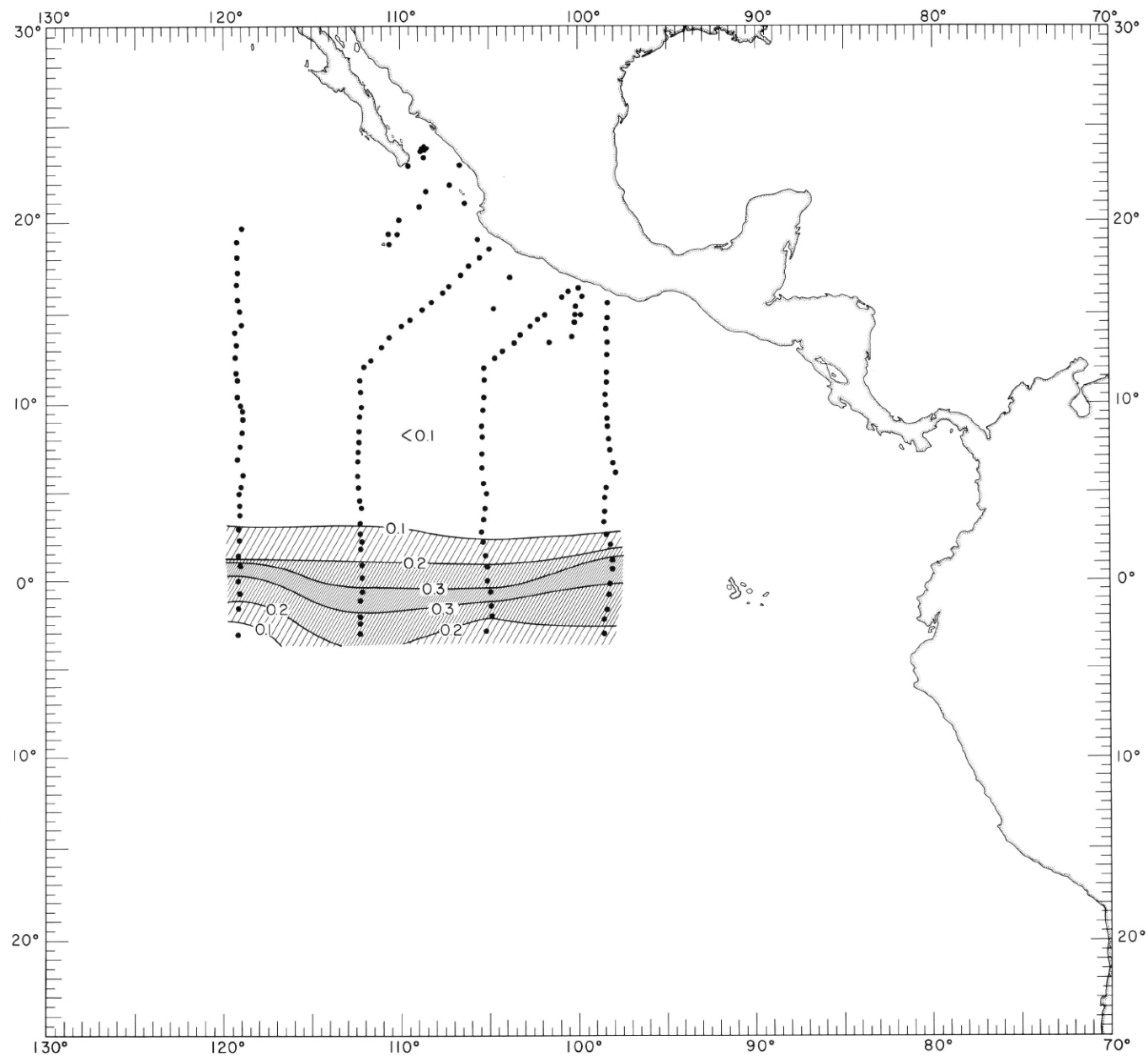
20-Si-10.

FIGURE 20-Si-10. — Silicate-silicon ( $\mu\text{g.-at./l.}$ ) at 10 meters, April-May 1967.



20-NO<sub>3</sub>-10.

FIGURE 20-NO<sub>3</sub>-10. — Nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.



20-NO<sub>2</sub>-10.

FIGURE 20-NO<sub>2</sub>-10. — Nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967.

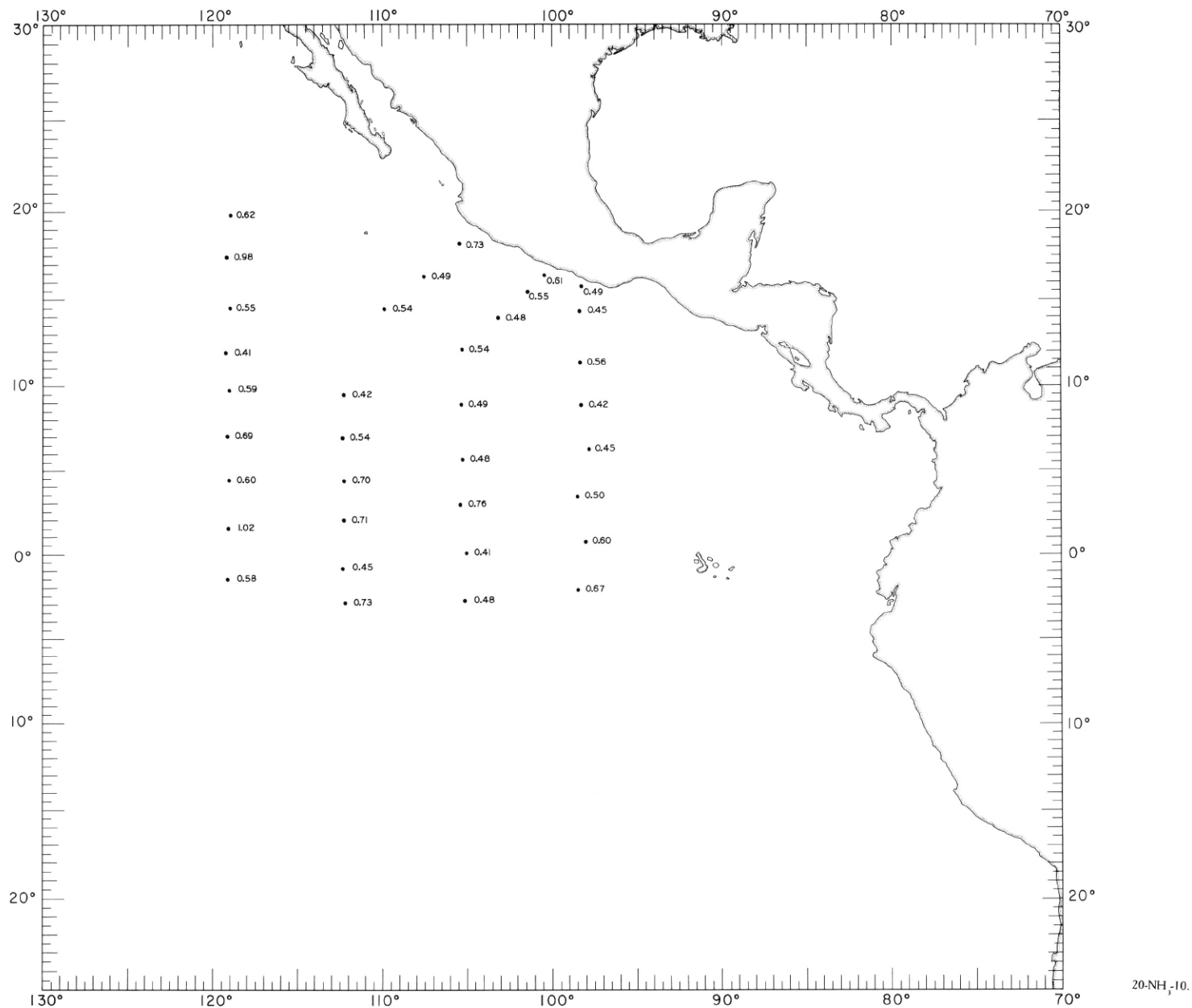
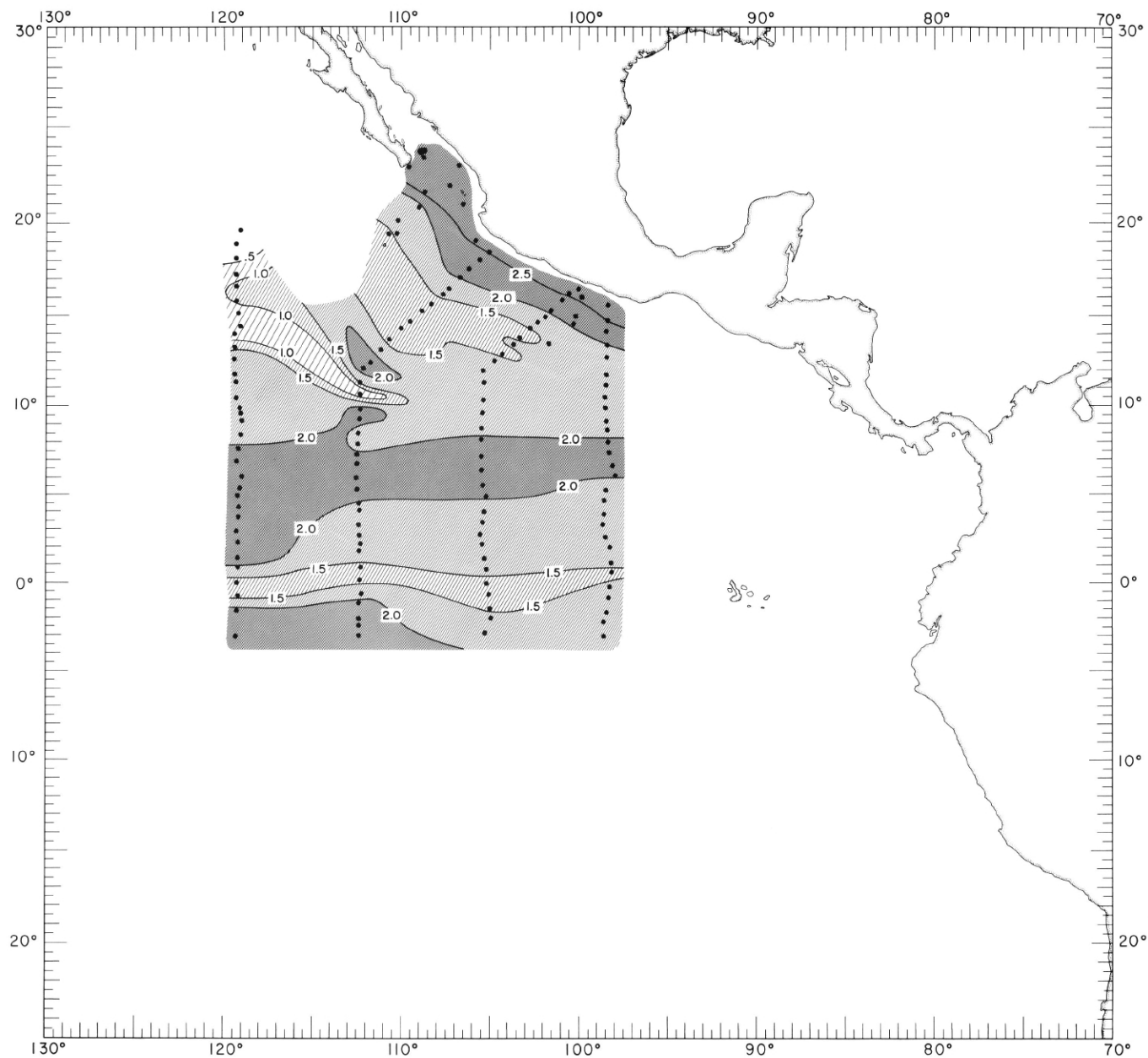


FIGURE 20-NH<sub>5</sub>-10. — Ammonia-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.





20-P-100.

FIGURE 20-P-100. — Phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) at 100 meters, April-May 1967.

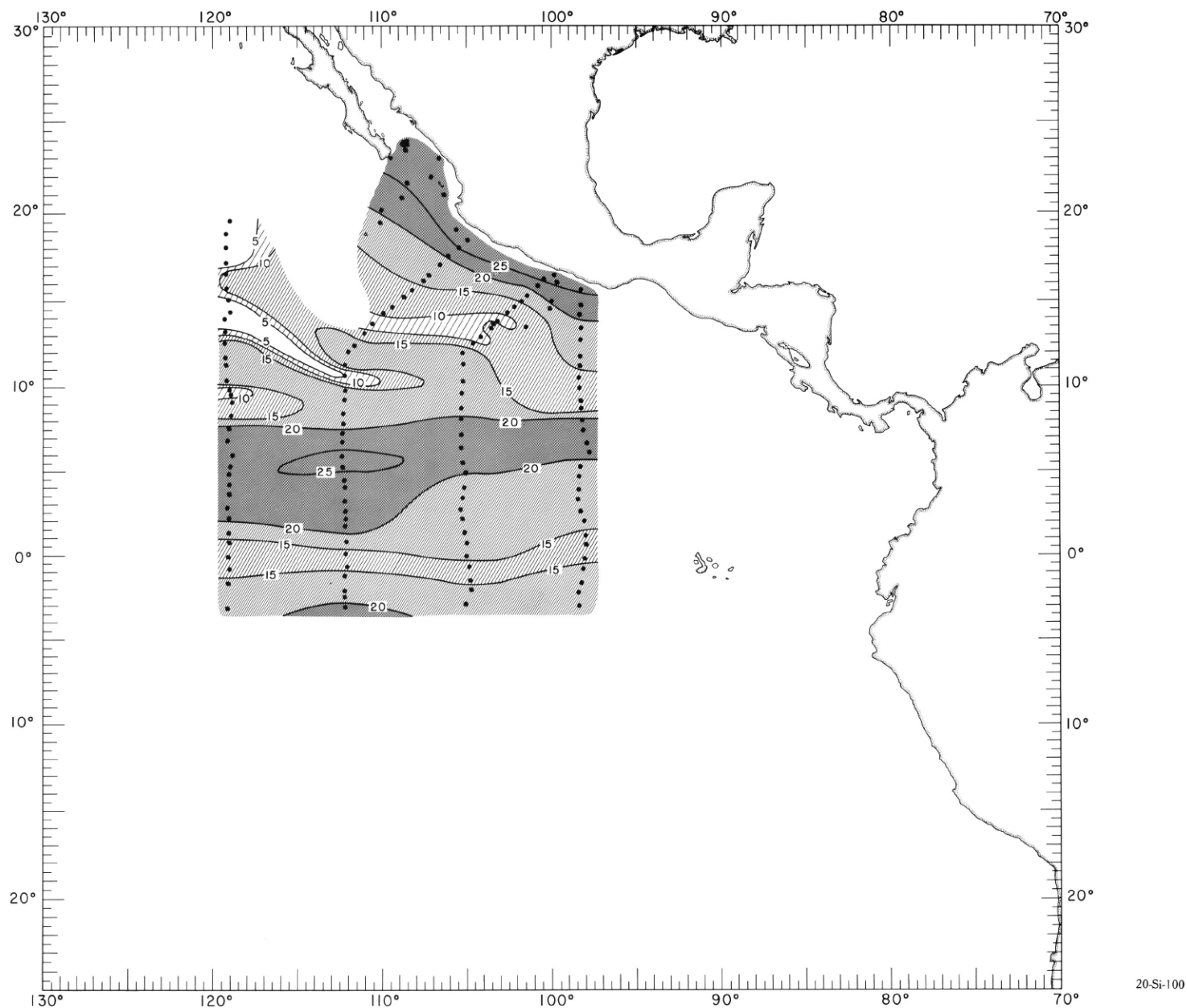
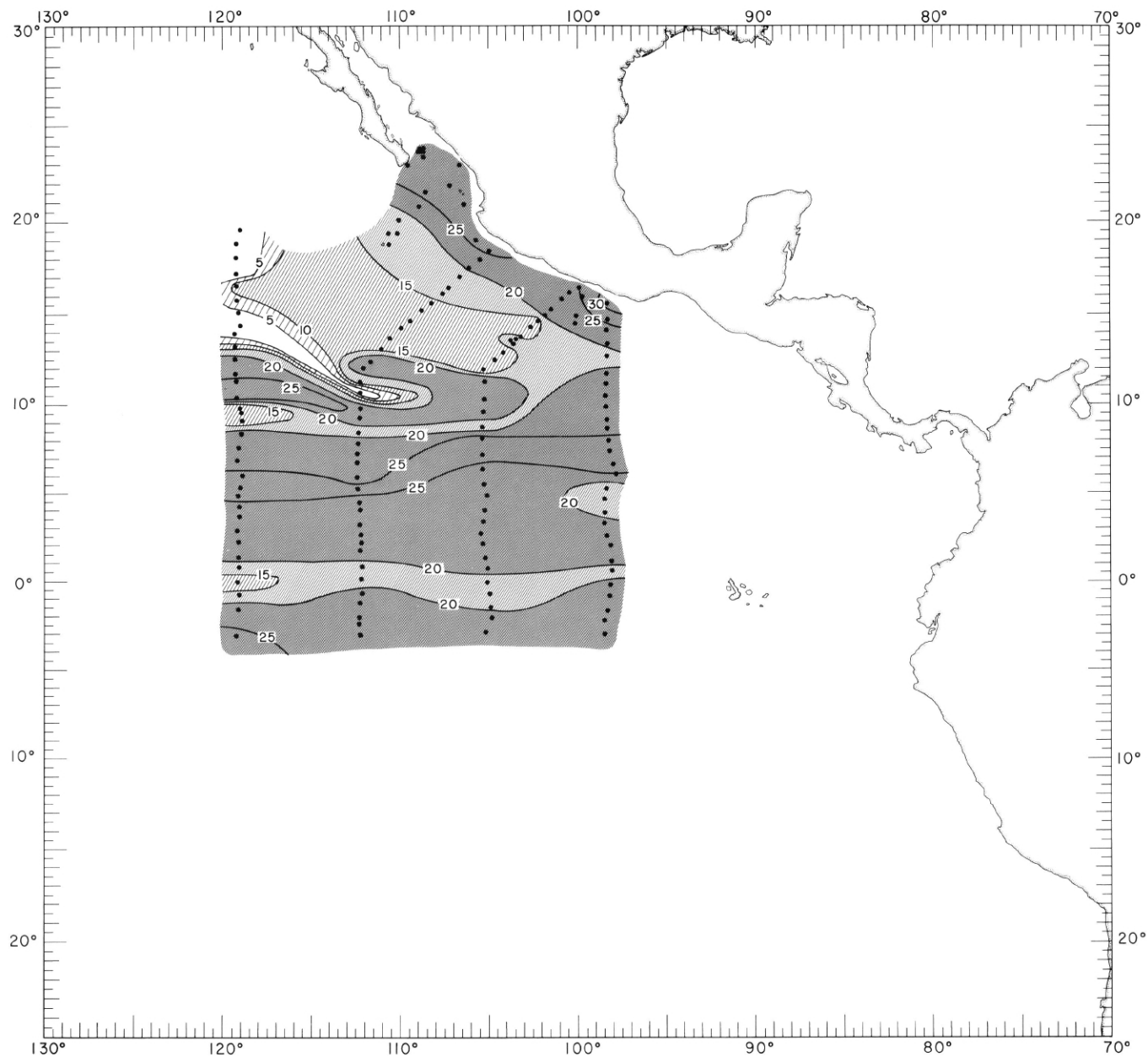


FIGURE 20-Si-100 — Silicate-silicon ( $\mu\text{g-at./l.}$ ) at 100 meters, April-May 1967.



20-NO<sub>3</sub>-100.

FIGURE 20-NO<sub>3</sub>-100. — Nitrate-nitrogen ( $\mu\text{g-at./L}$ ) at 100 meters, April-May 1967.

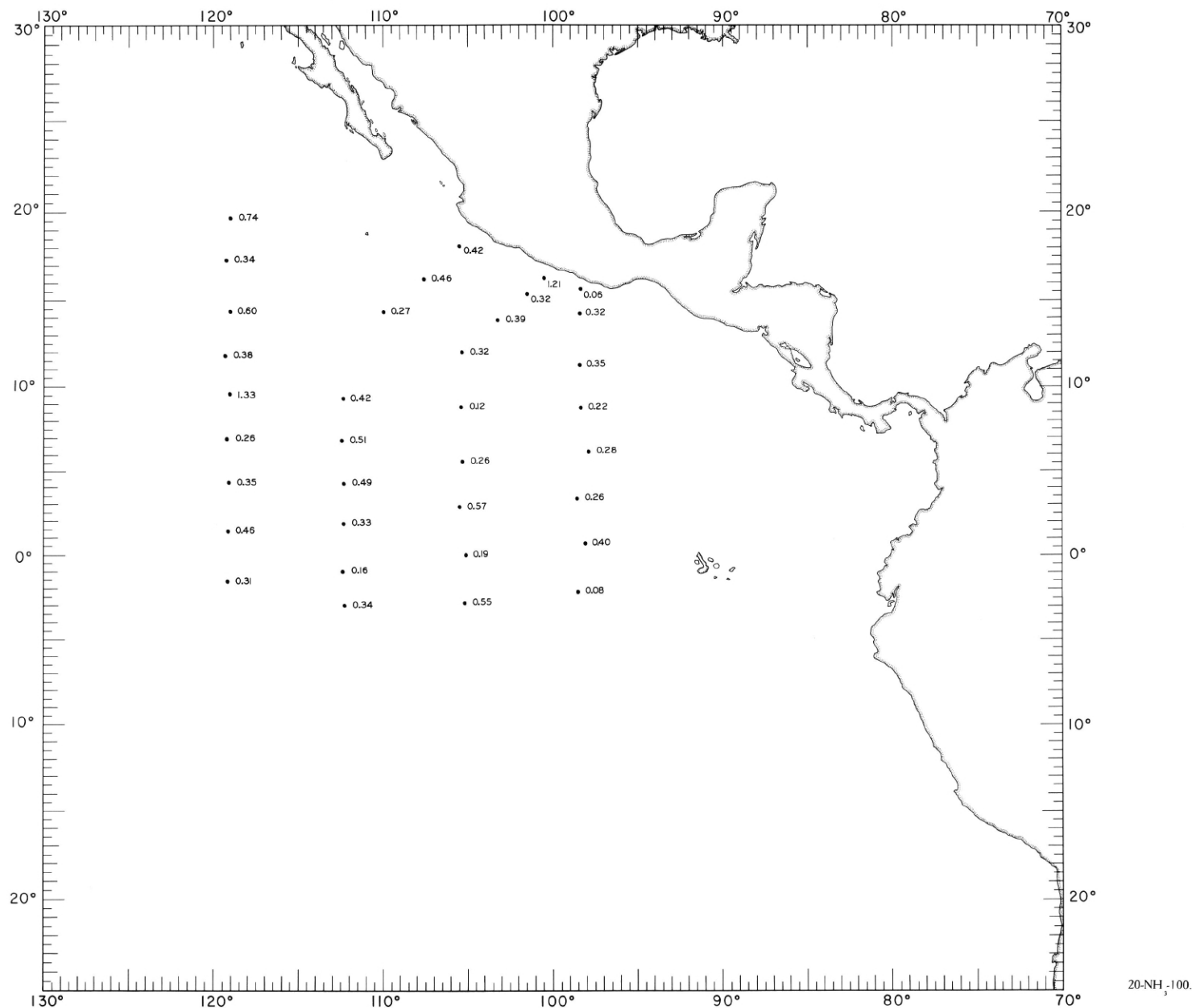


FIGURE 20-NH<sub>3</sub>-100. — Ammonia-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, April-May 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.

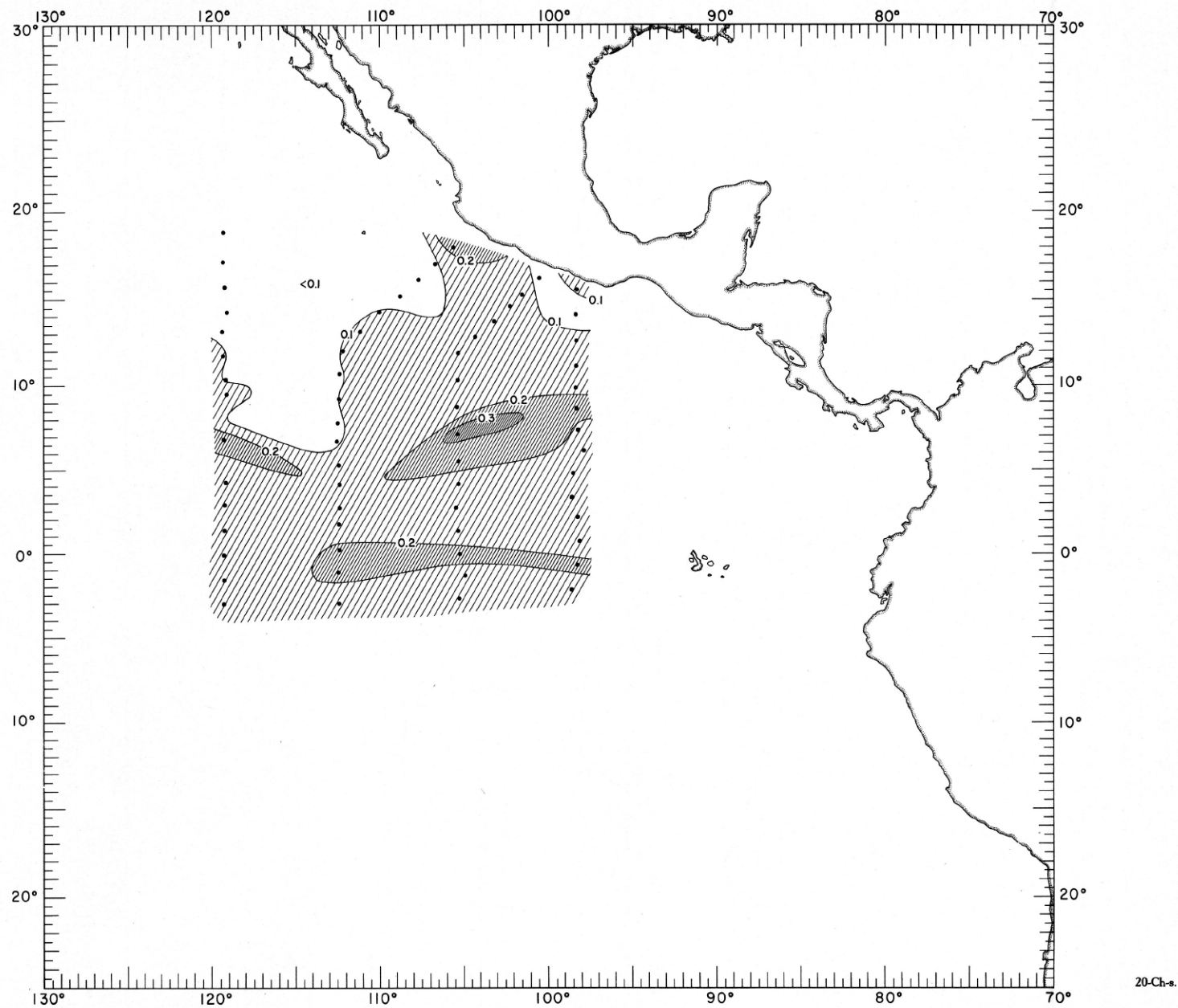
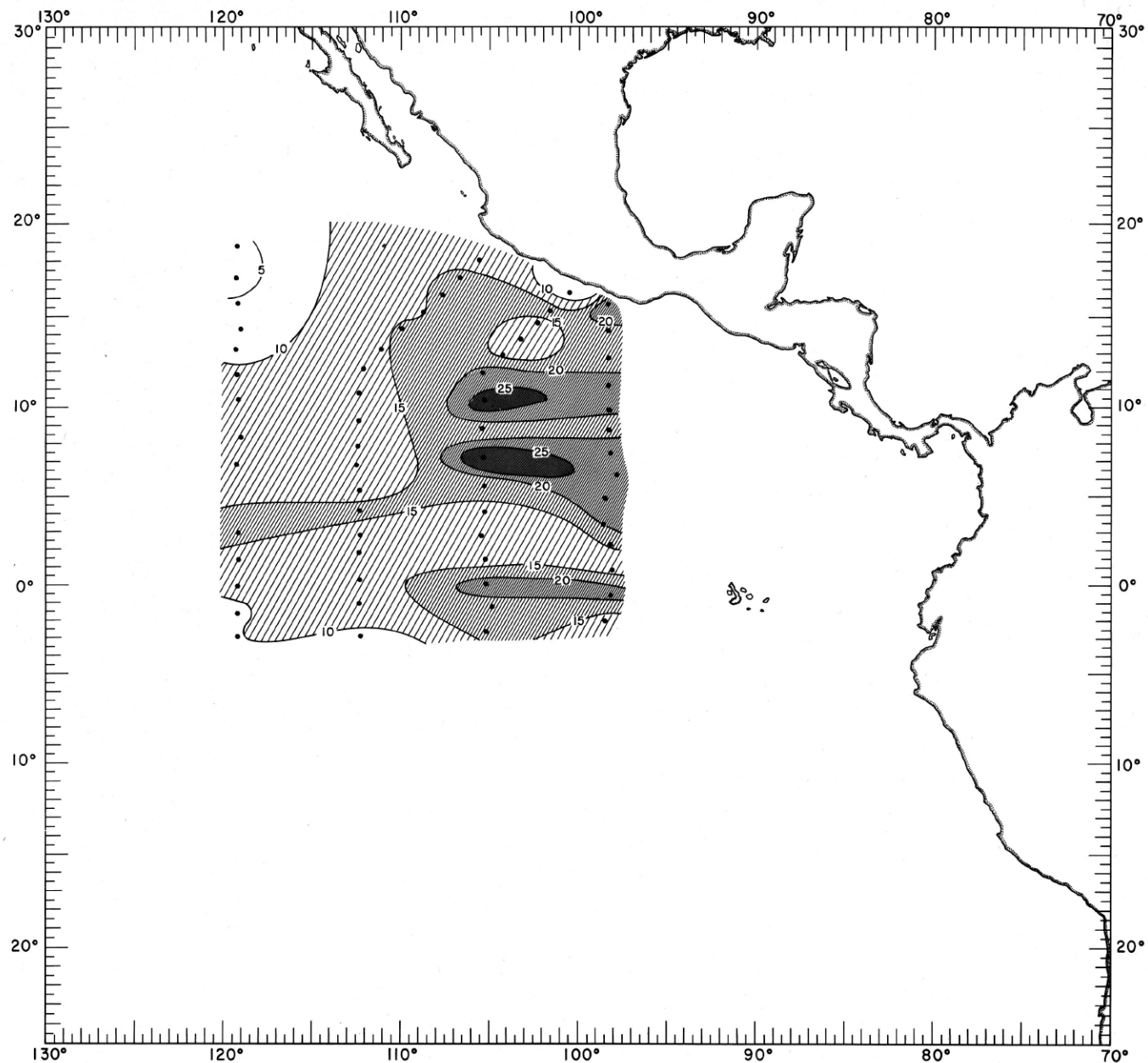
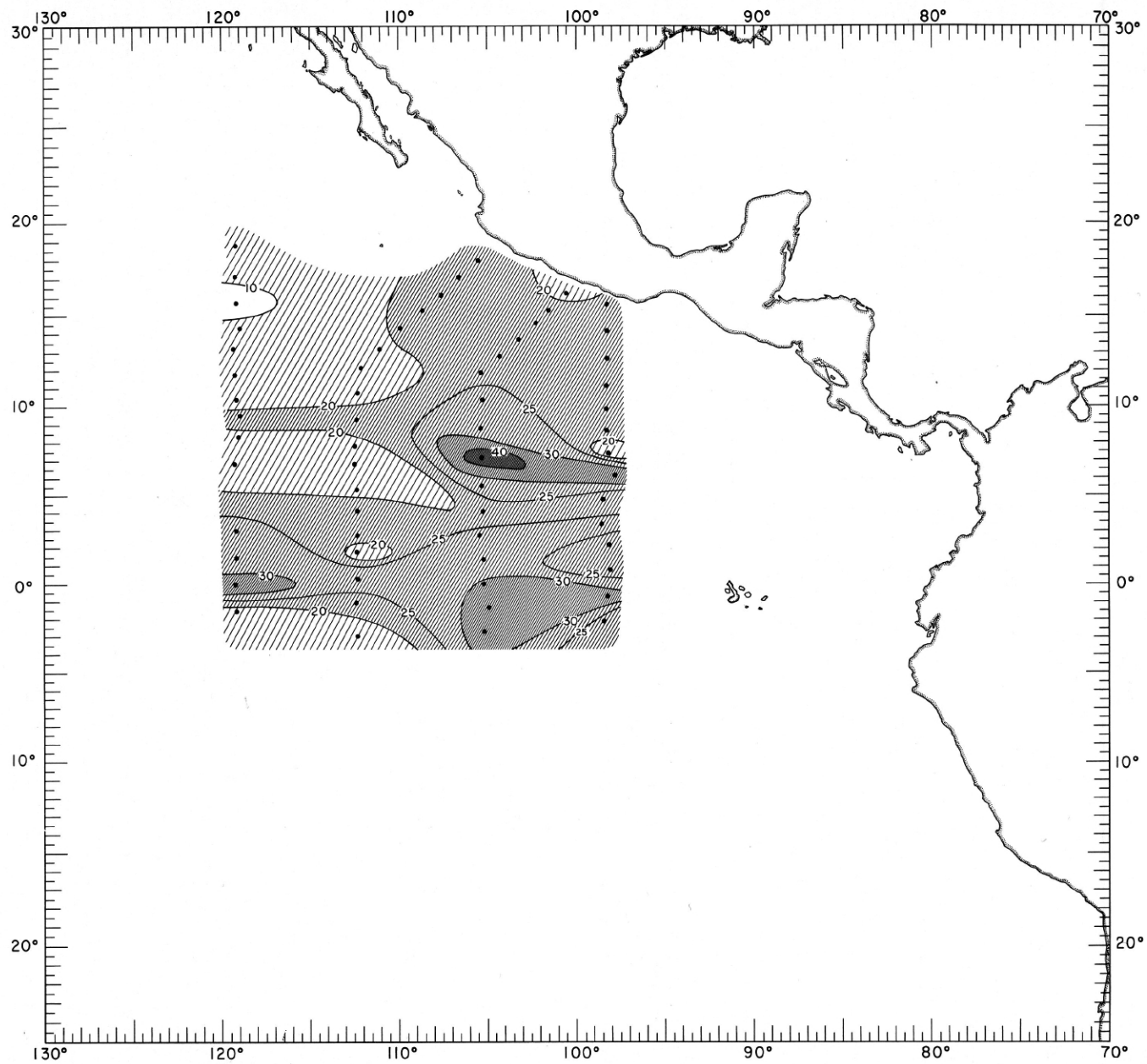


FIGURE 20-Ch-s. — Chlorophyll-a (mg./m.<sup>3</sup>) at the sea surface, April-May 1967.



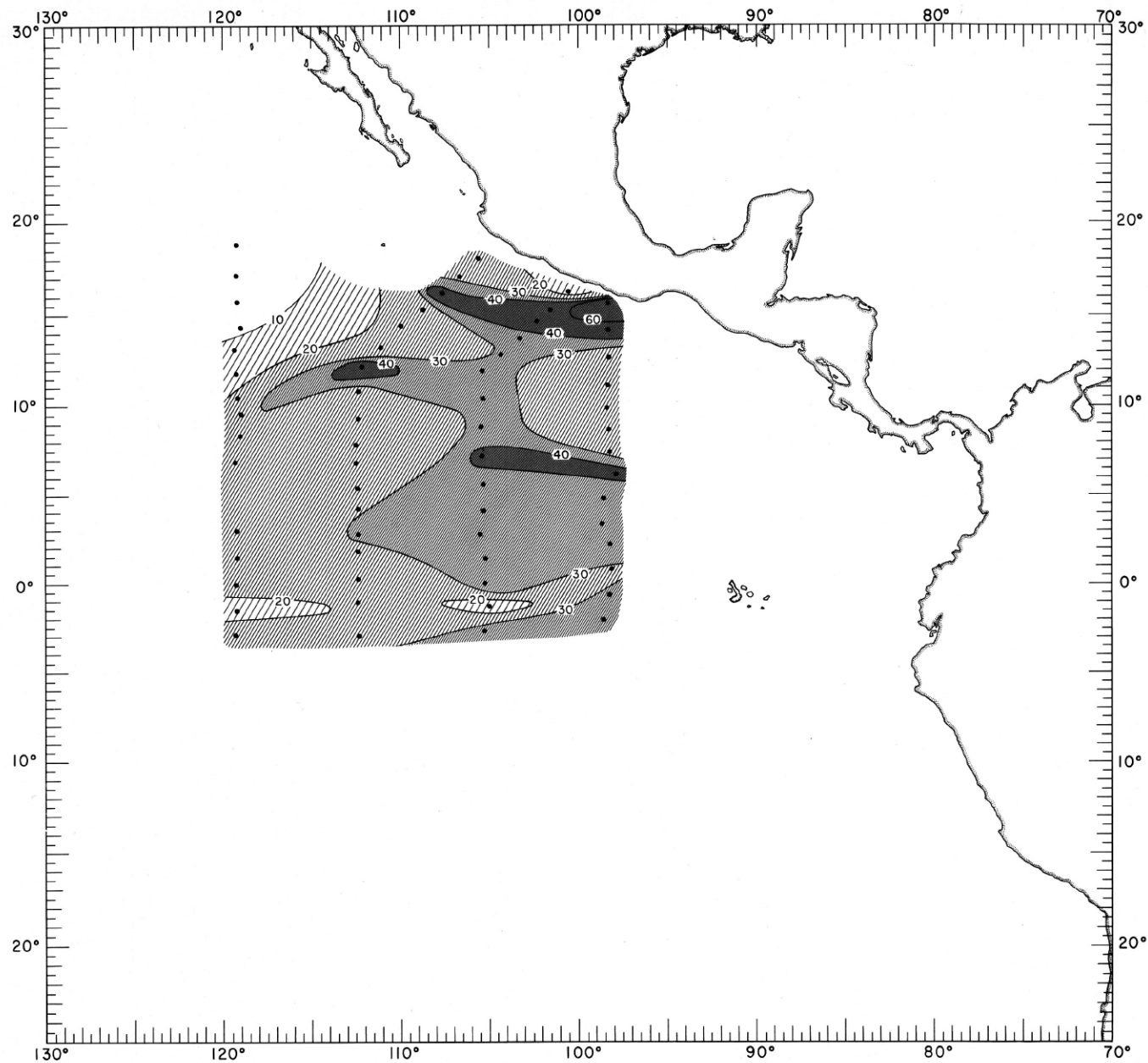
20-Ch-ei.

FIGURE 20-Ch-ei. — Chlorophyll-a (mg./m.<sup>2</sup>) integrated over the euphotic layer, April-May 1967.



20-Ch-150i.

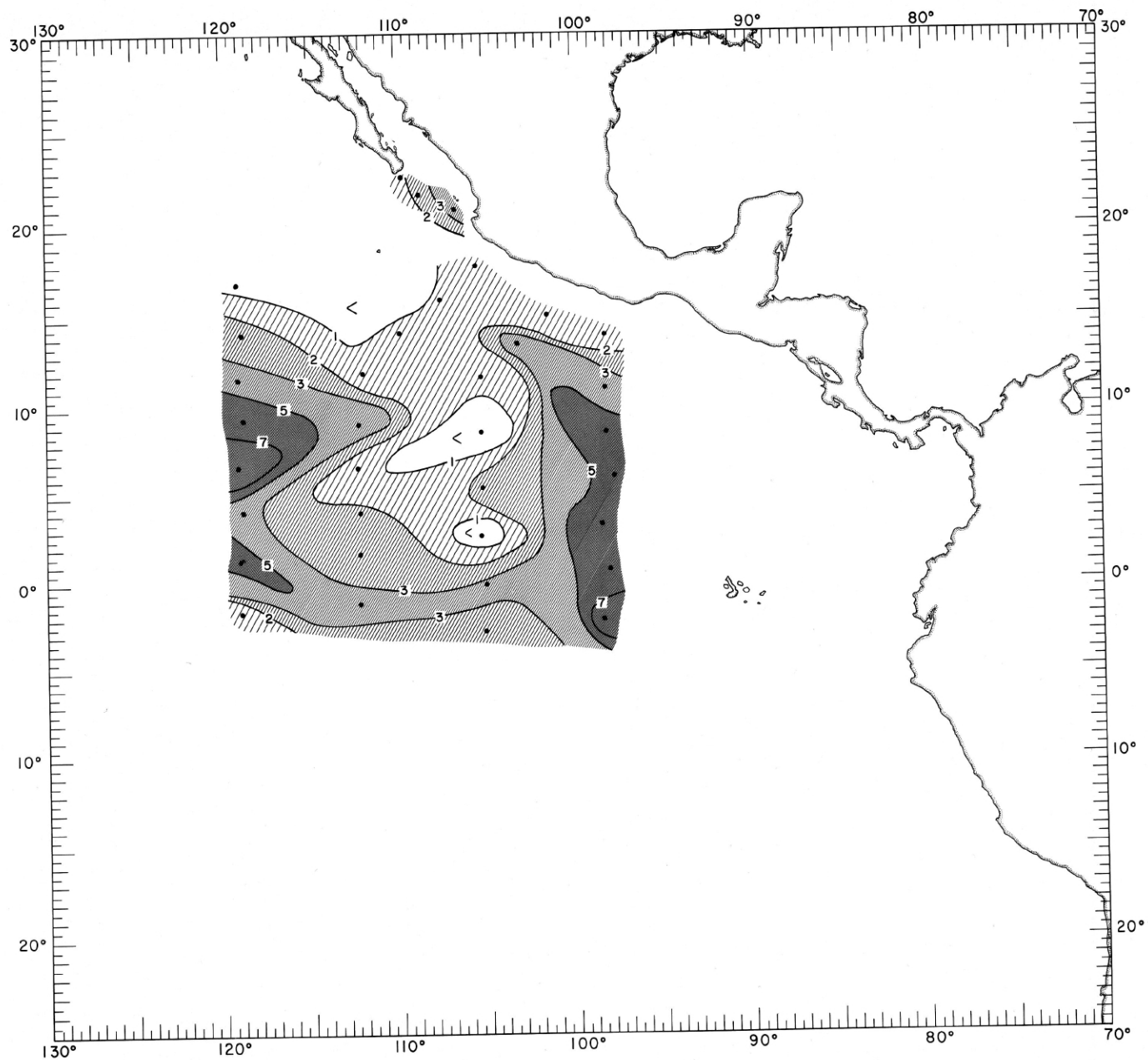
FIGURE 20-Ch-150i. — Chlorophyll-a (mg./m.<sup>2</sup>) integrated from the sea surface to 150 meters depth, April-May 1967.



20-Ph-150i.

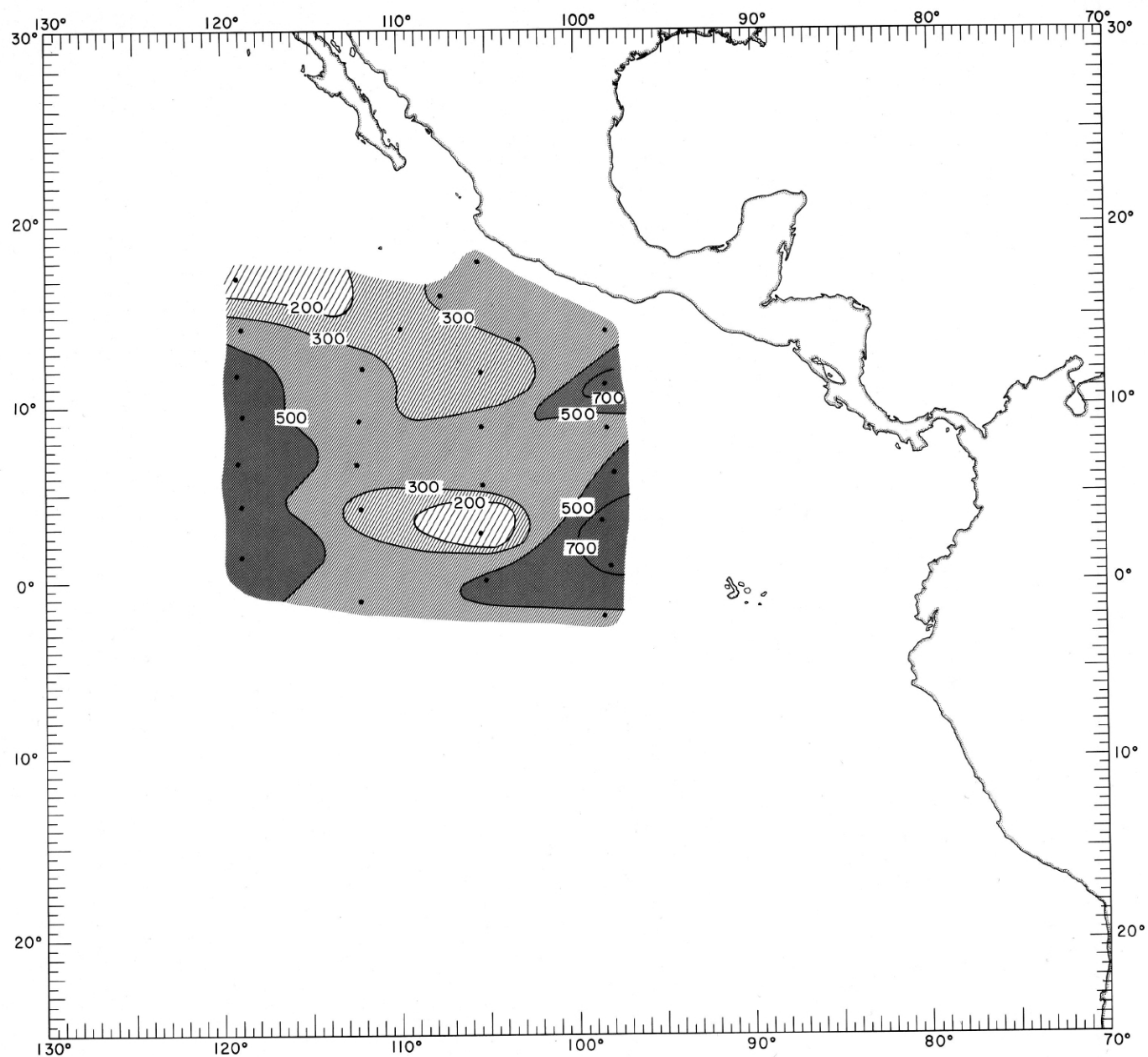
FIGURE 20-Ph-150i. — Phaeophytin (mg./m.<sup>3</sup>) integrated from the sea surface to 150 meters depth, April-May 1967.





20-PP-s.

FIGURE 20-PP-s. — Primary production (mg C/m<sup>3</sup>/day) at the sea surface, April-May 1967.



20-PP-ei.

FIGURE 20-PP-ei. — Primary production (mg.C/m.<sup>2</sup>/day) integrated over the euphotic layer, April-May 1967.

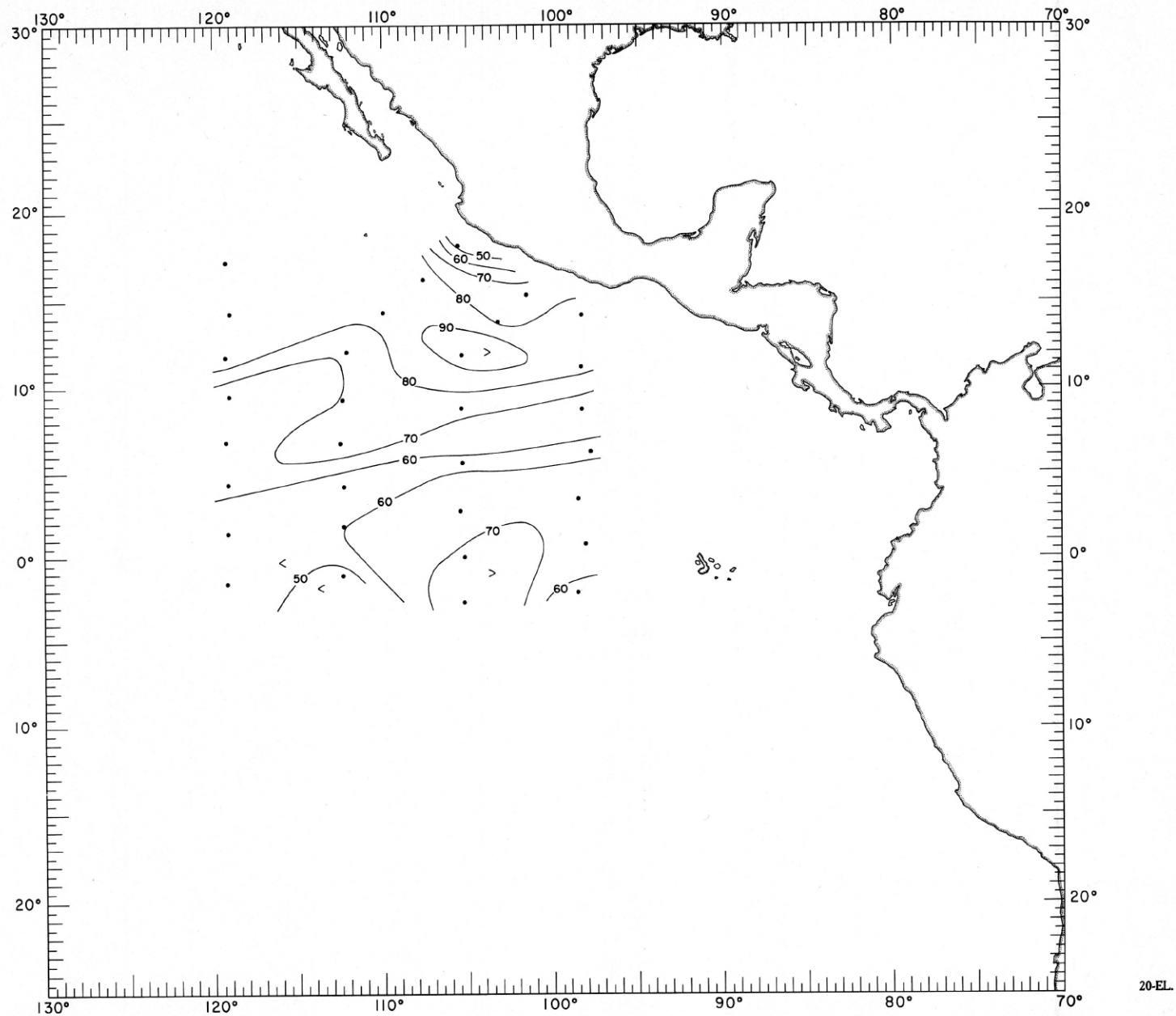
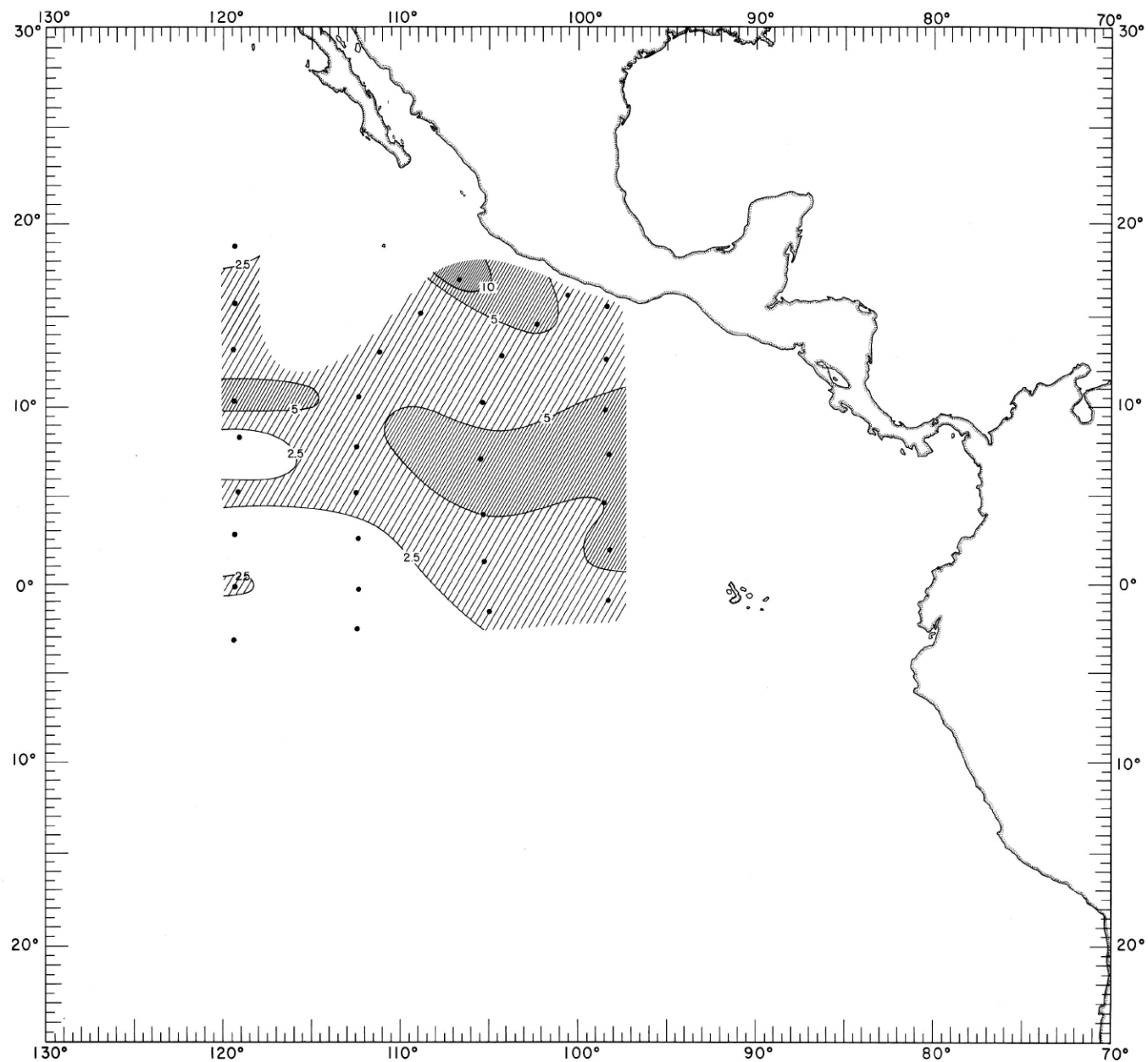
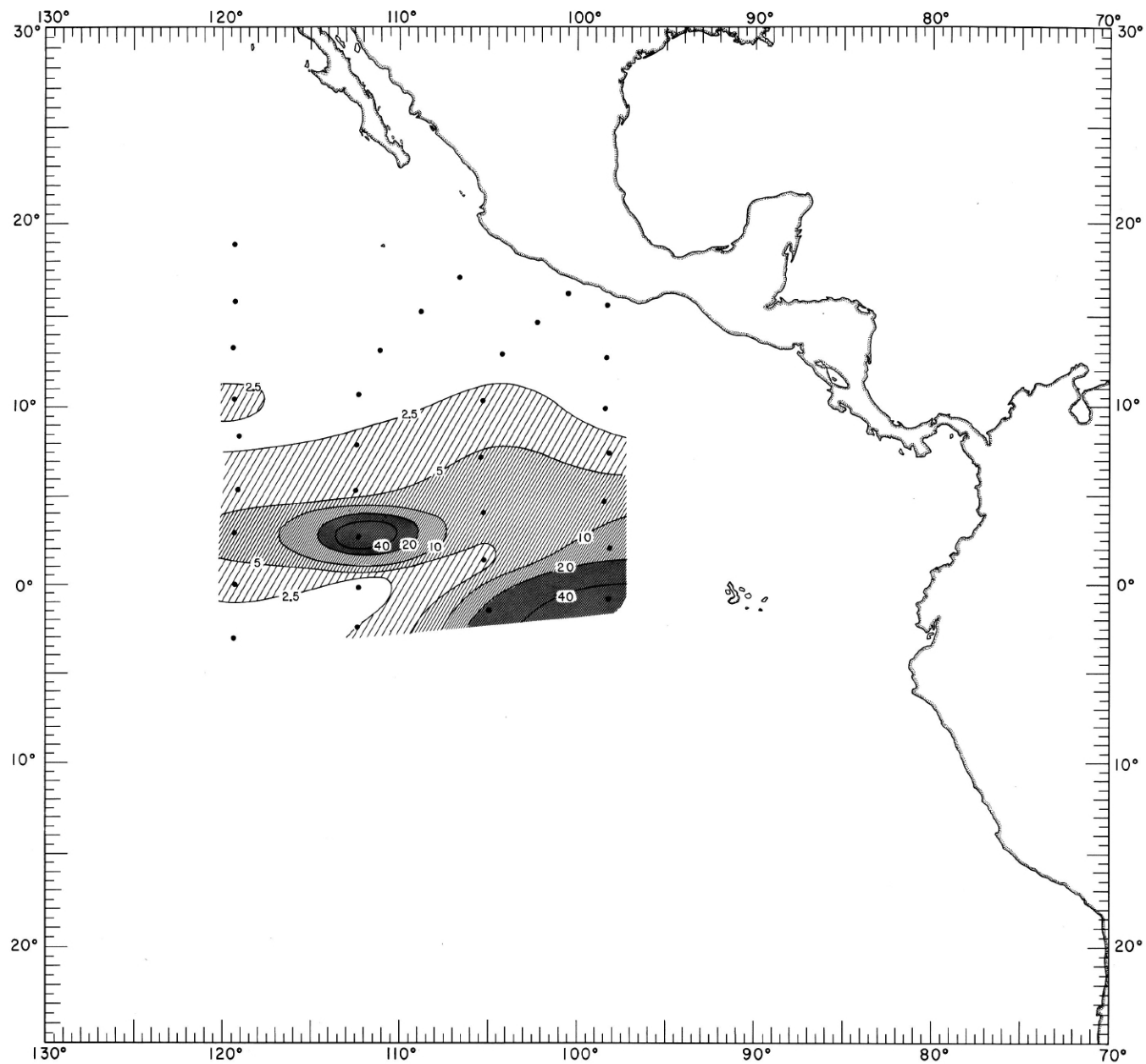


FIGURE 20-EL. — Thickness of the euphotic layer in meters, April-May 1967.



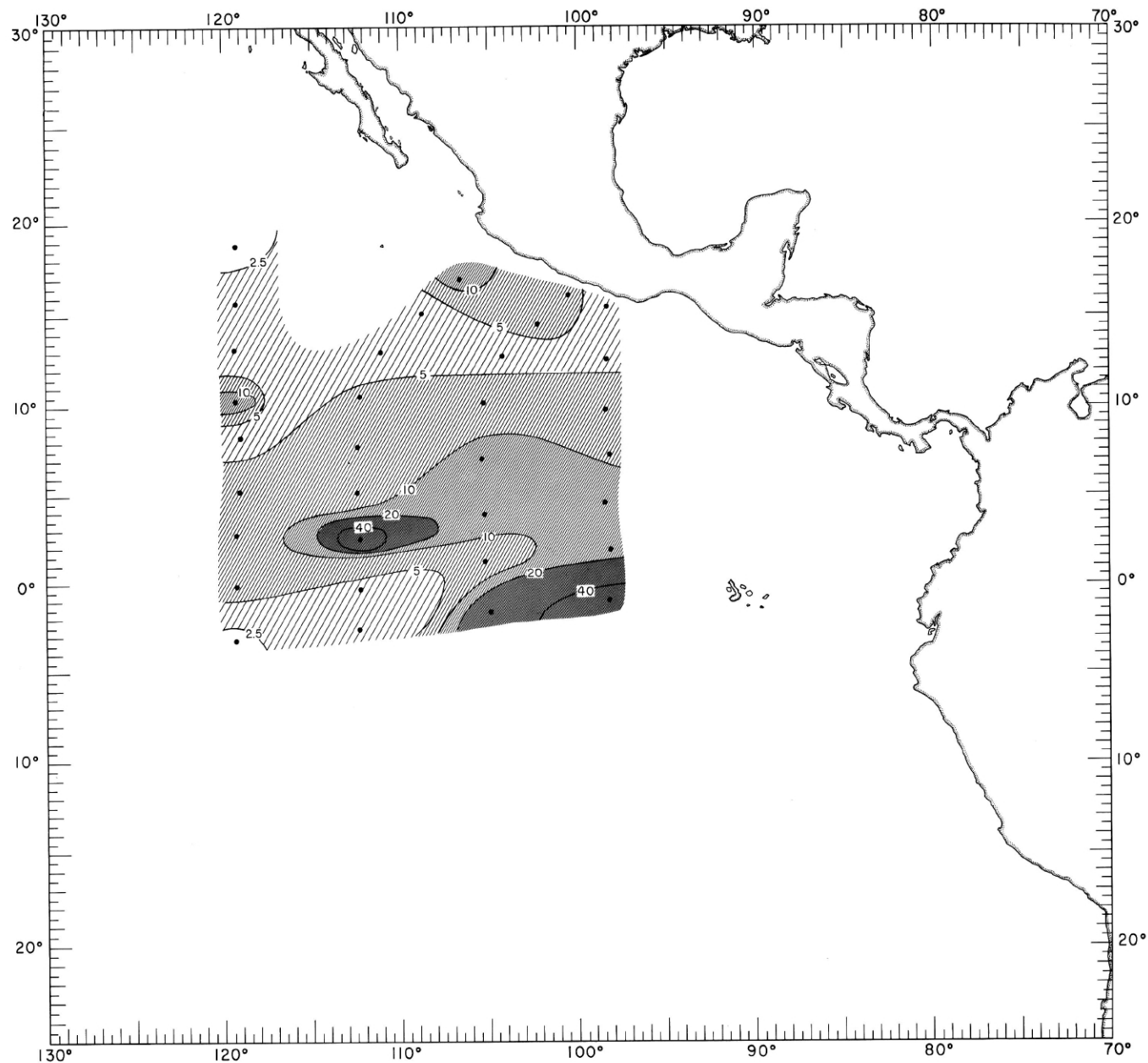
20-FCp.

FIGURE 20-FCp. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of total fish and cephalopods taken in night micronekton hauls during April-May 1967.



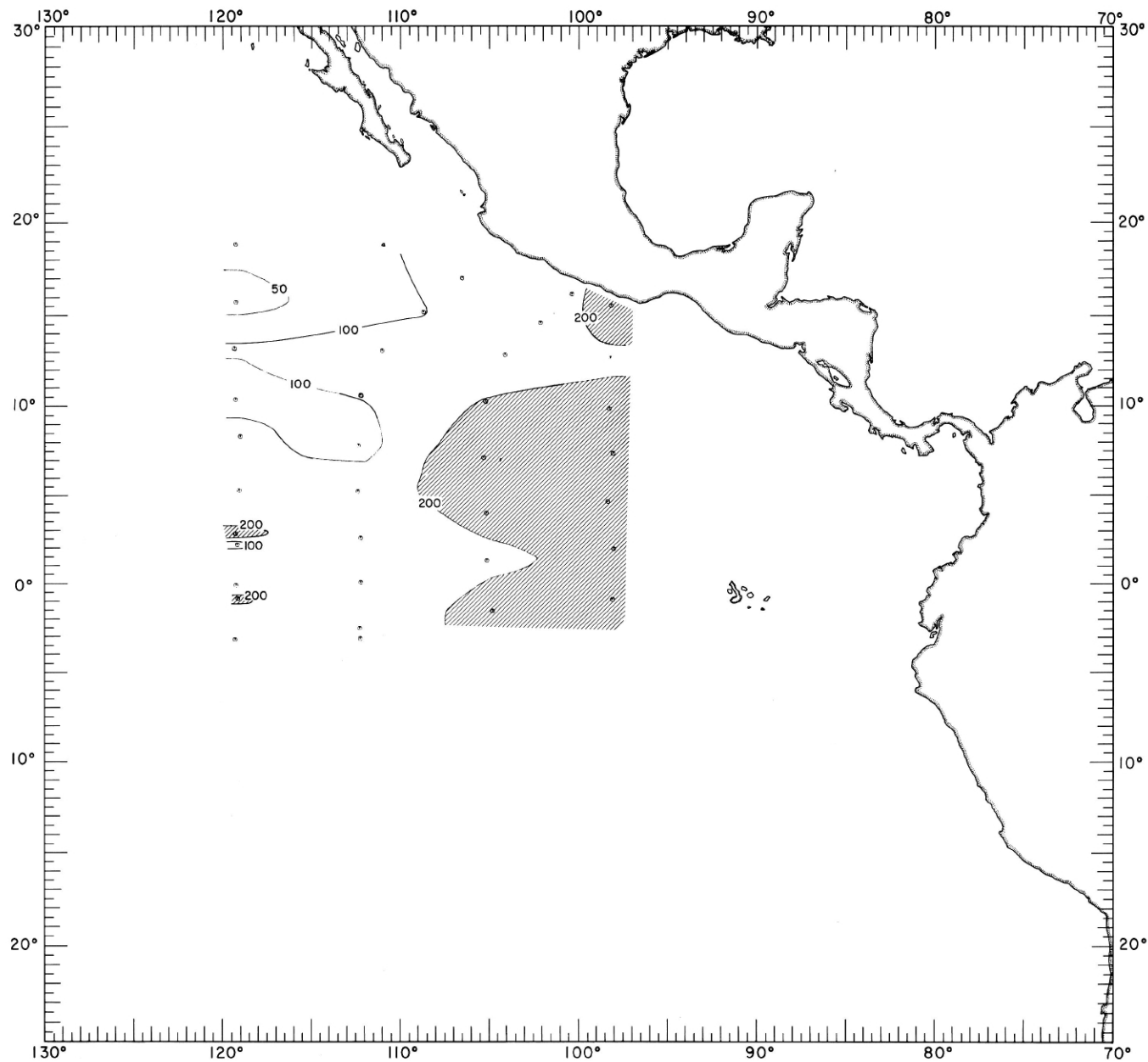
20-Cr.

FIGURE 20-Cr. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of total crustaceans taken in night micronekton hauls during April-May 1967.



20-Nk.

FIGURE 20-Nk. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of total micronekton taken in night micronekton hauls during April-May 1967.



20-ZhN.

FIGURE 20-ZhN. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 50-cm. net hauls at night, April-May 1967.

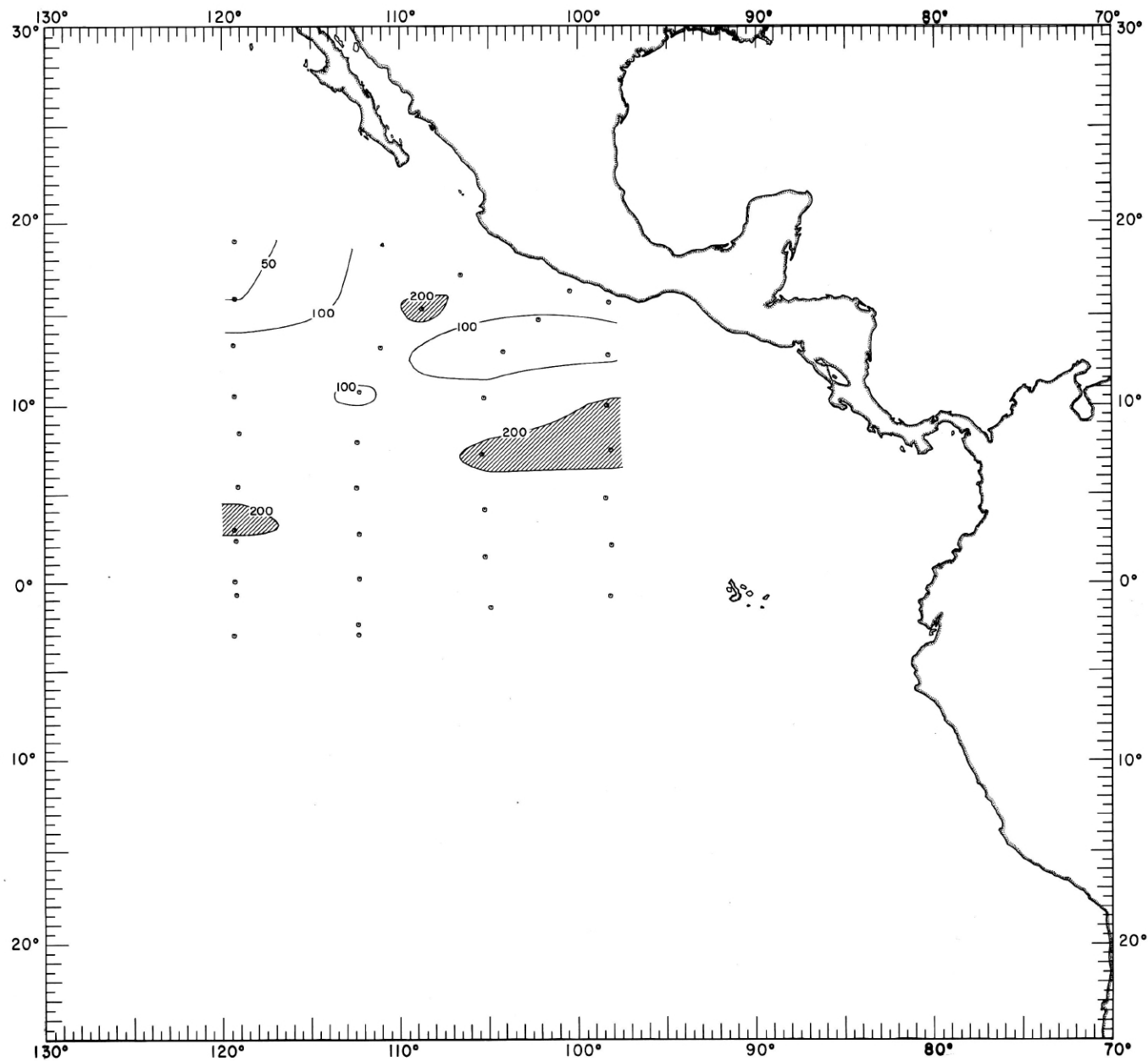
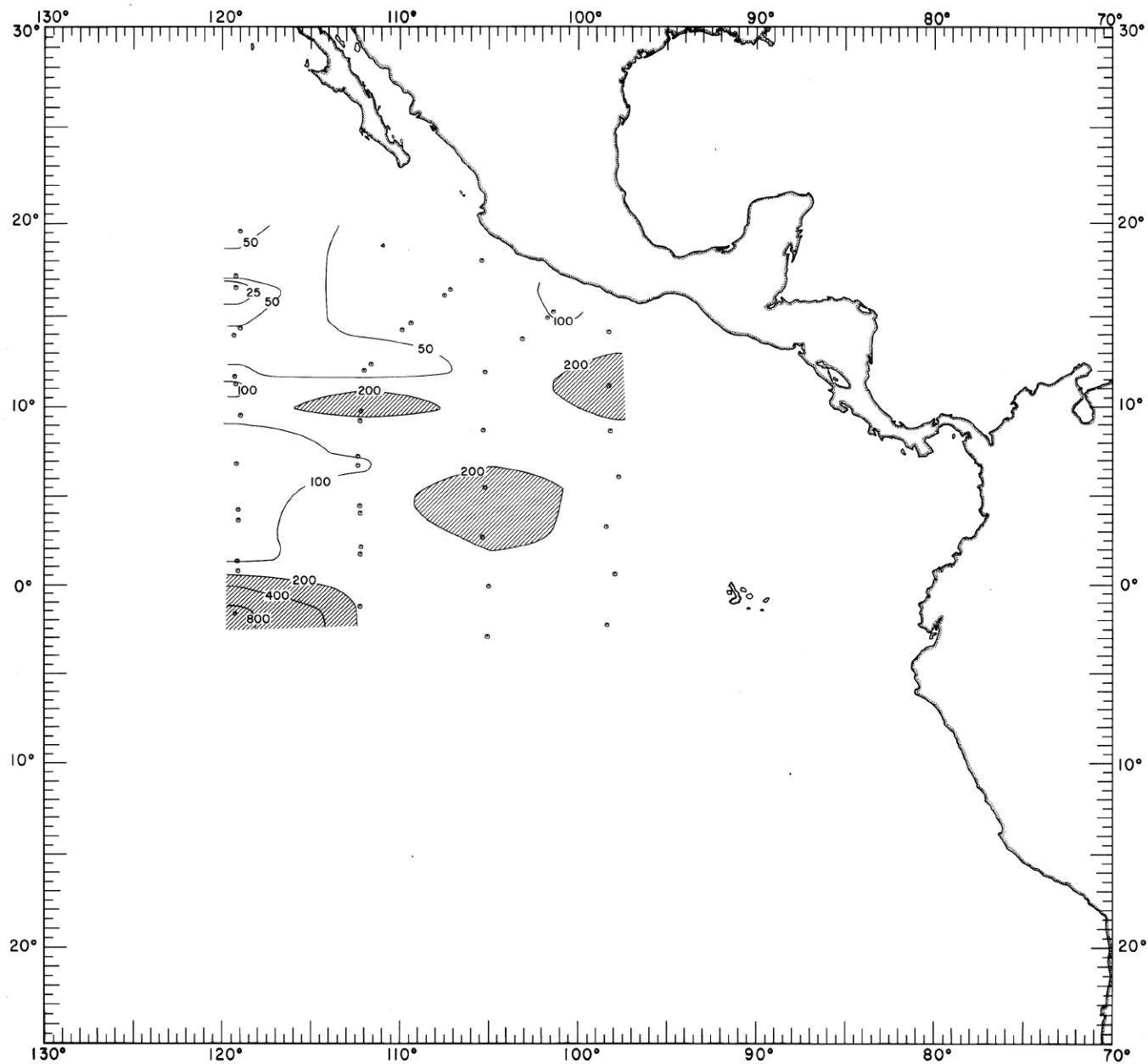


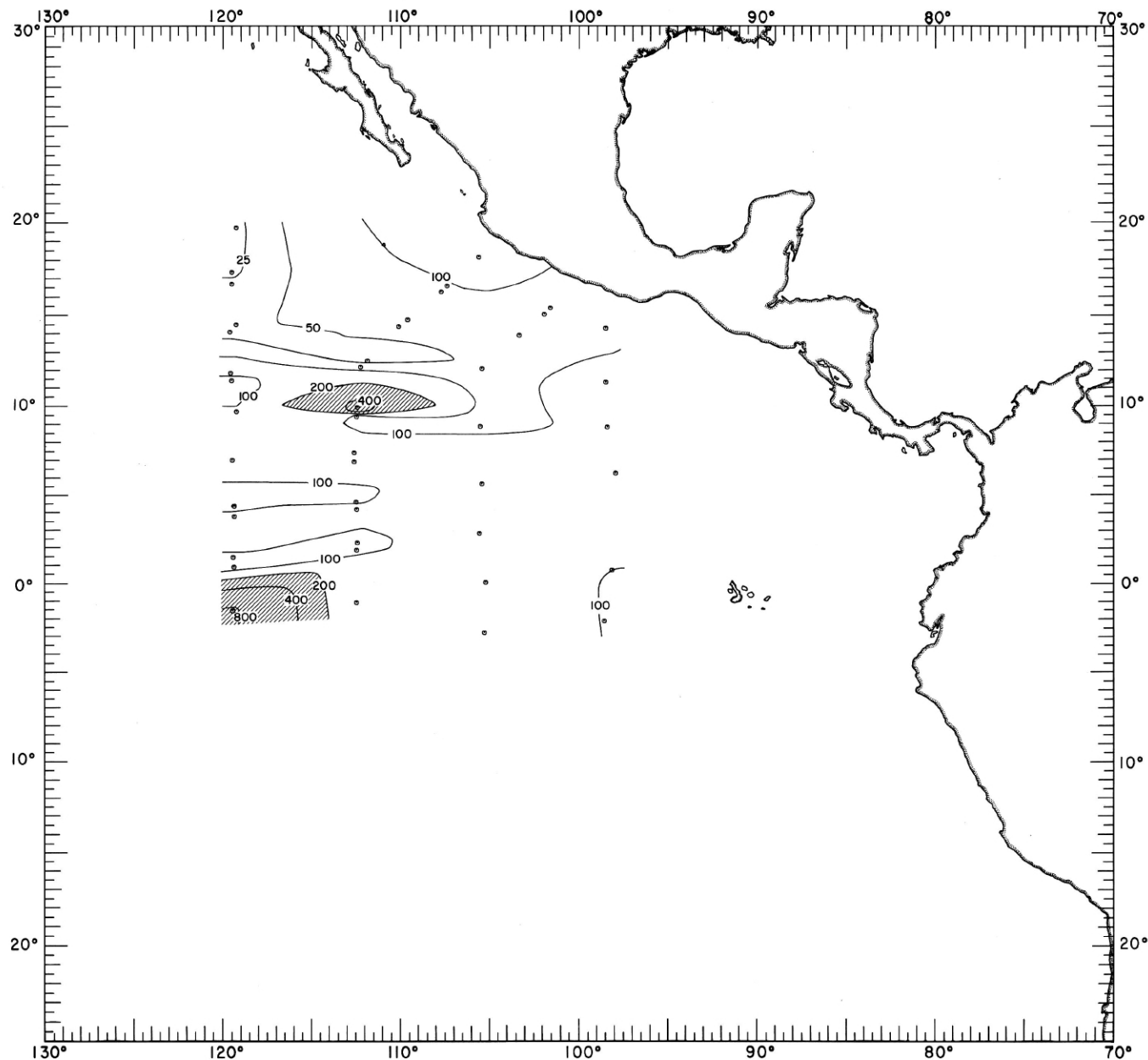
FIGURE 20-Z1N. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 1-m. net hauls at night, April-May 1967.





20-ZhD.

FIGURE 20-ZhD. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 50-cm. net hauls during the day, April-May 1967.



20-Z1D.

FIGURE 20-Z1D. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 1-m. net hauls during the day, April-May 1967.

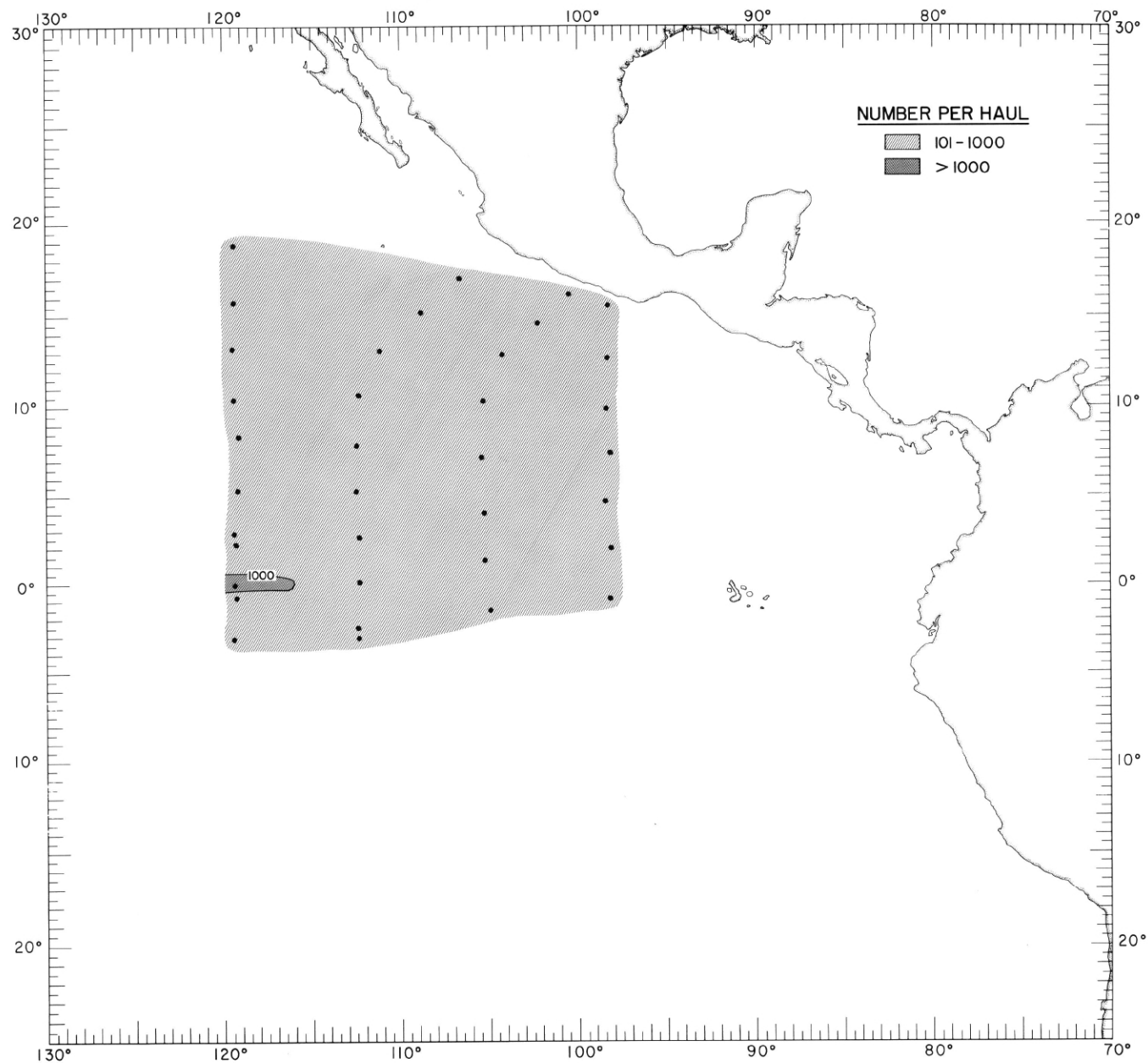
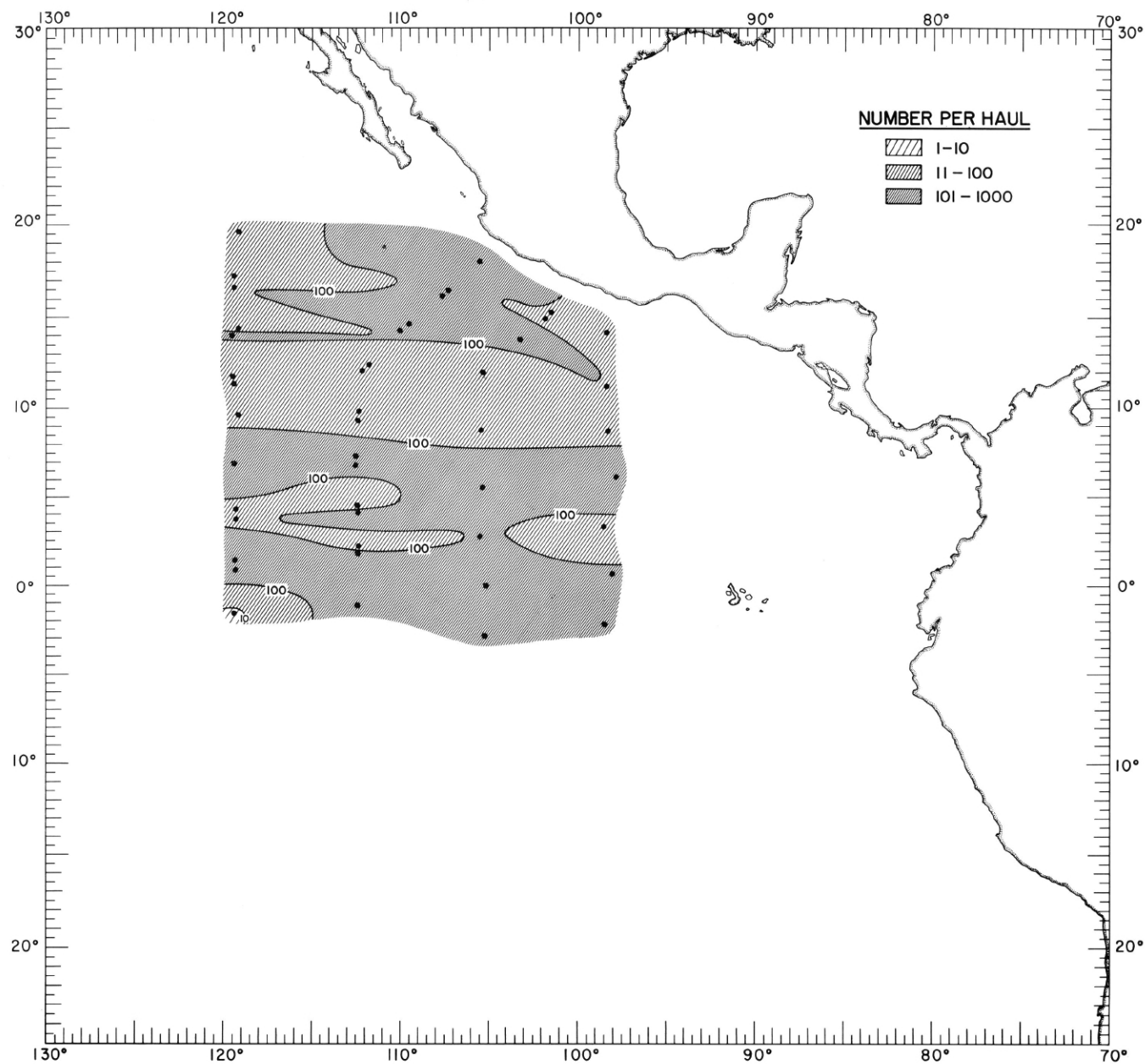
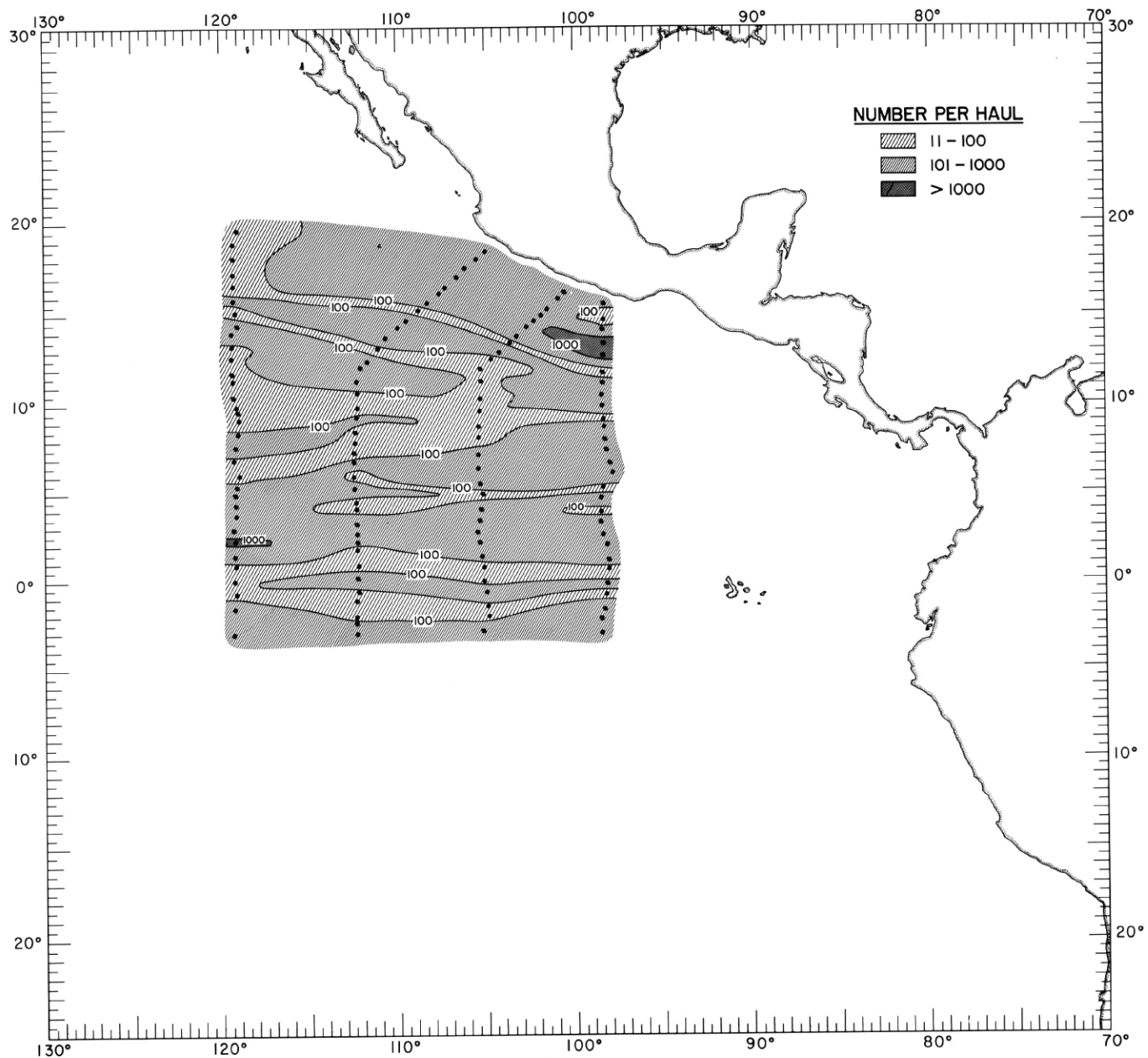


FIGURE 20-FLN. — Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls at night during April-May 1967.



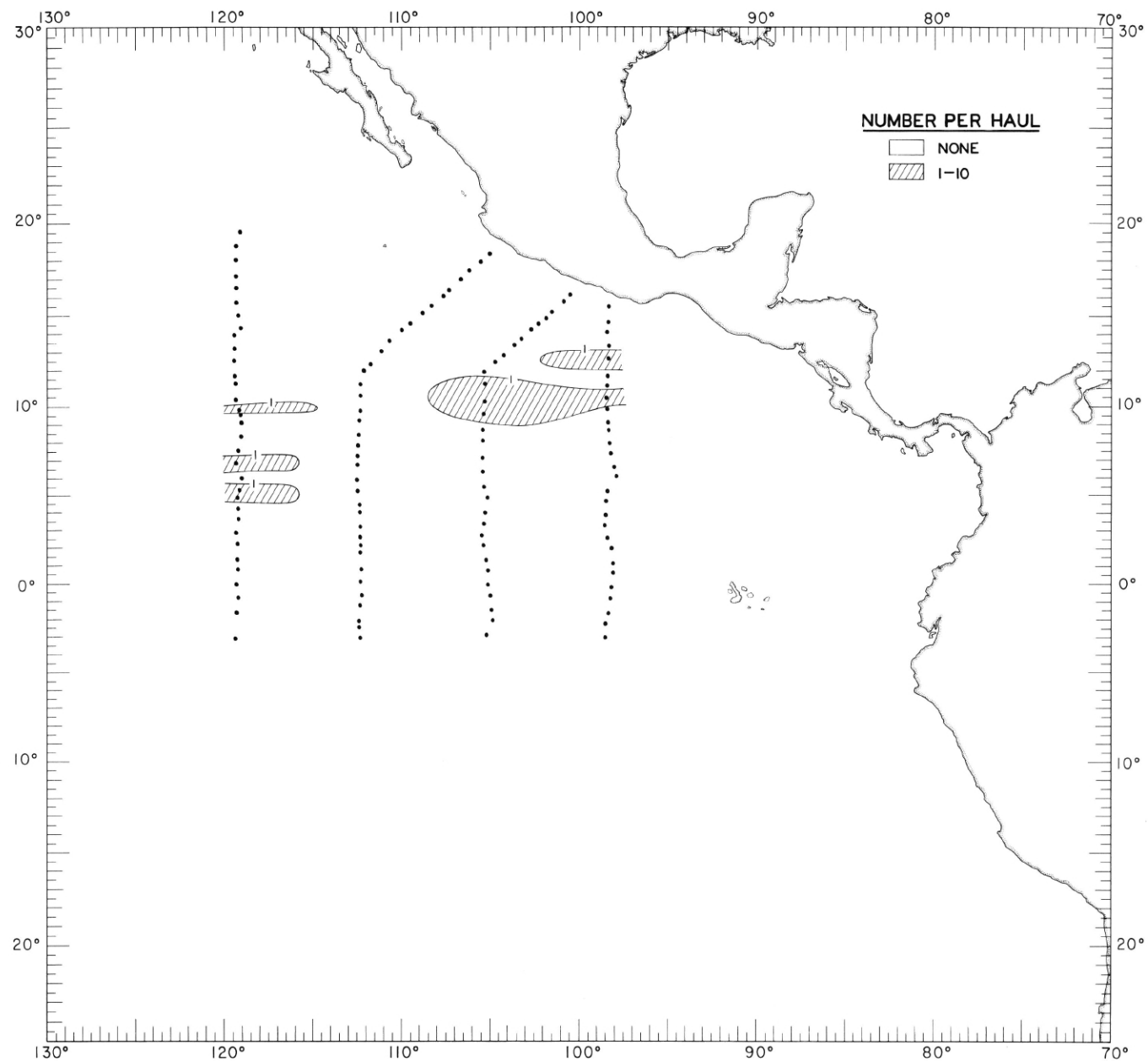
20-FLD.

FIGURE 20-FLD. — Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, April-May 1967.



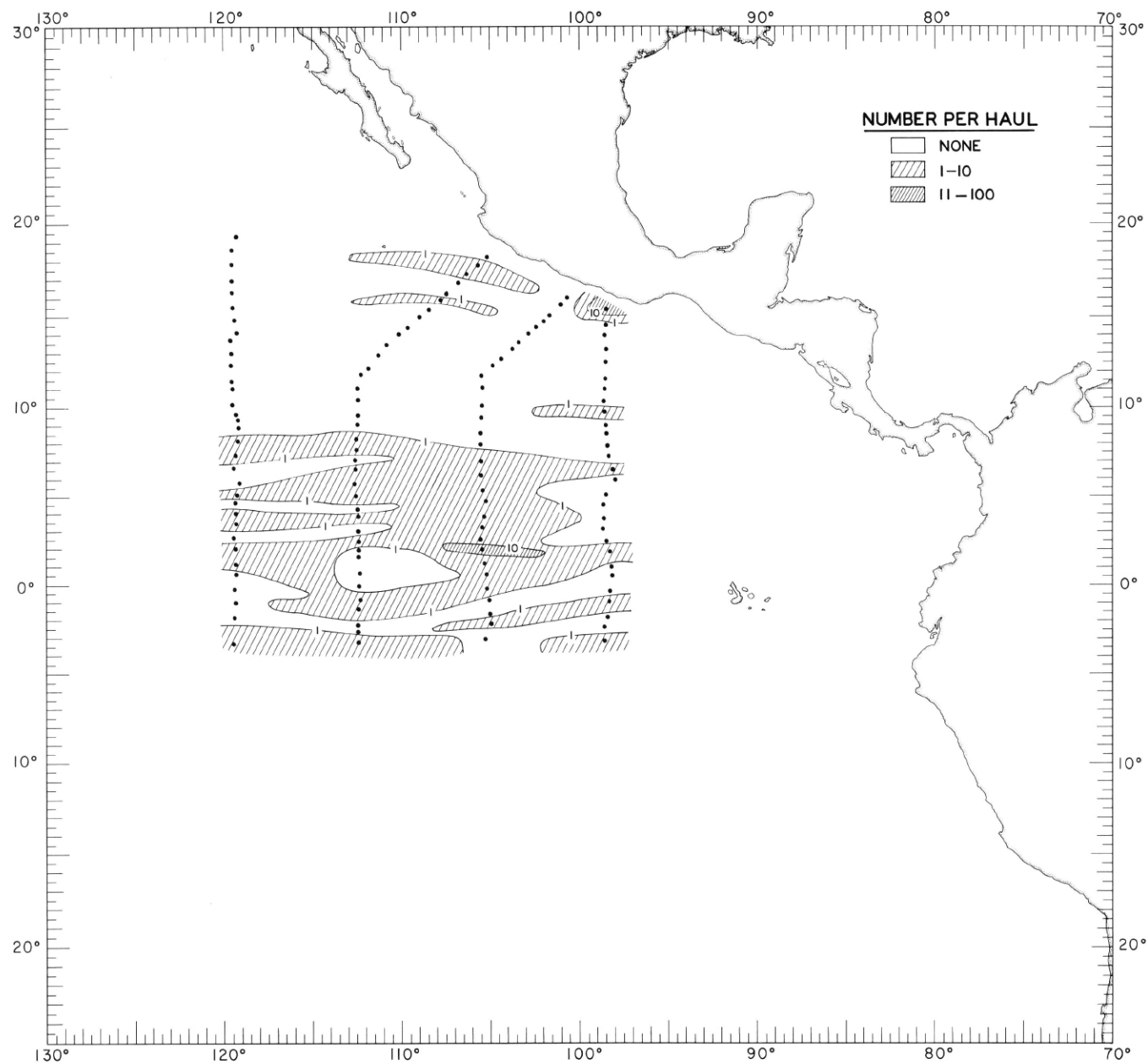
20-FE.

FIGURE 20-FE. — Total fish eggs (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.



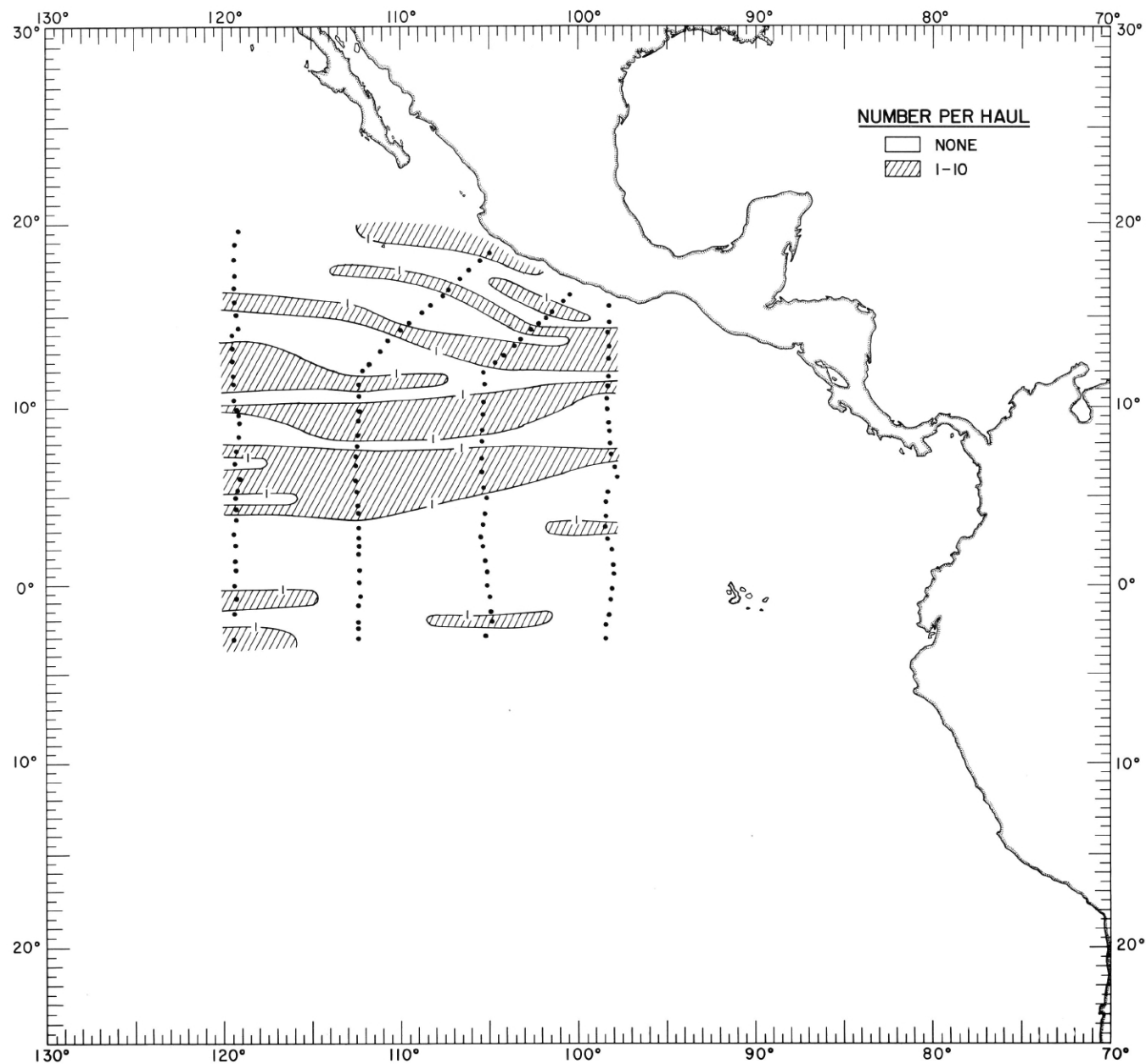
20-FS.

FIGURE 20-FS. — Total skipjack tuna, *Katsuwonus pelamis*, larvae (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.



20-FA.

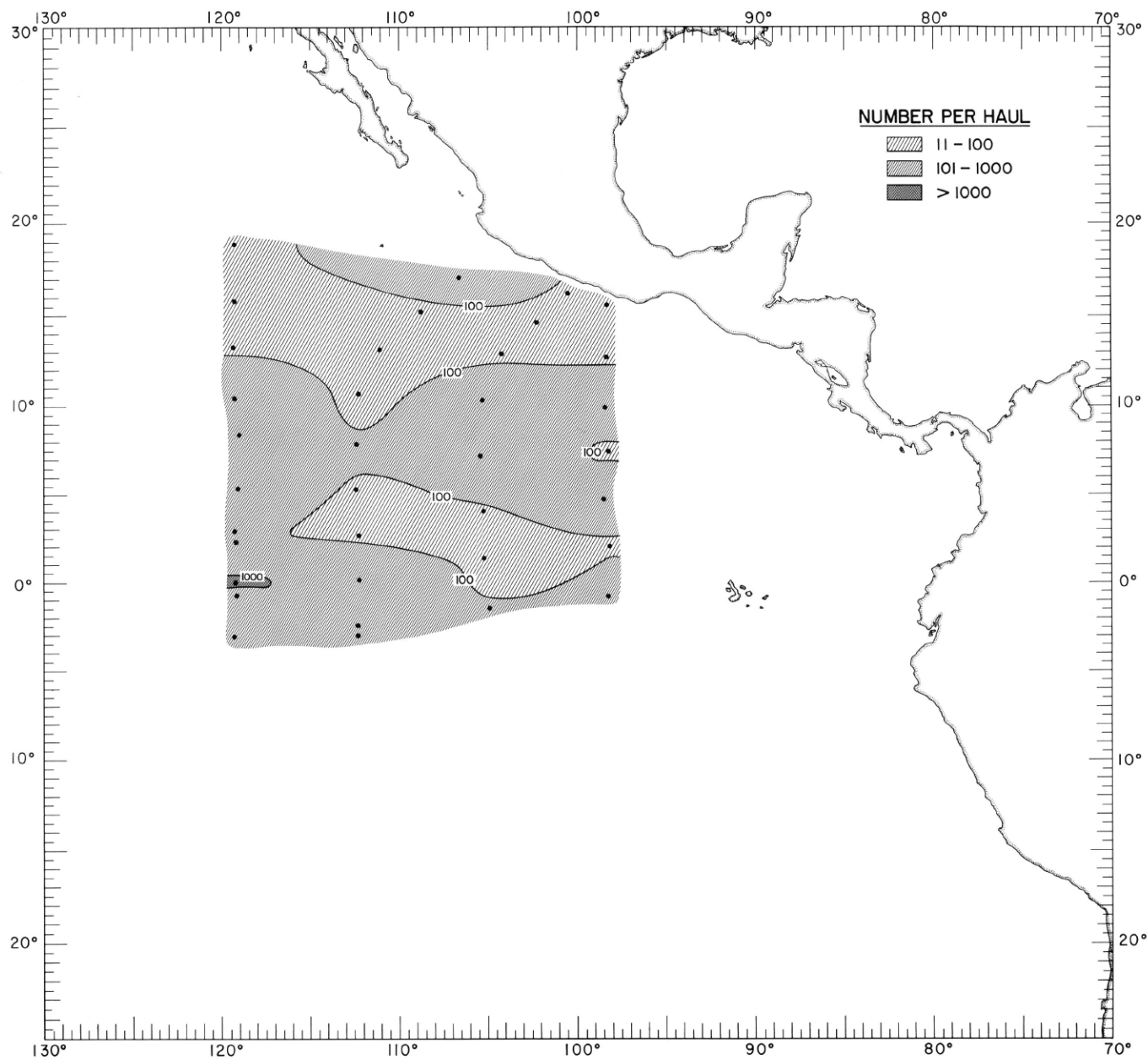
FIGURE 20-FA. — Total frigate mackerel, *Auxis*, larvae (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.



20-FC.

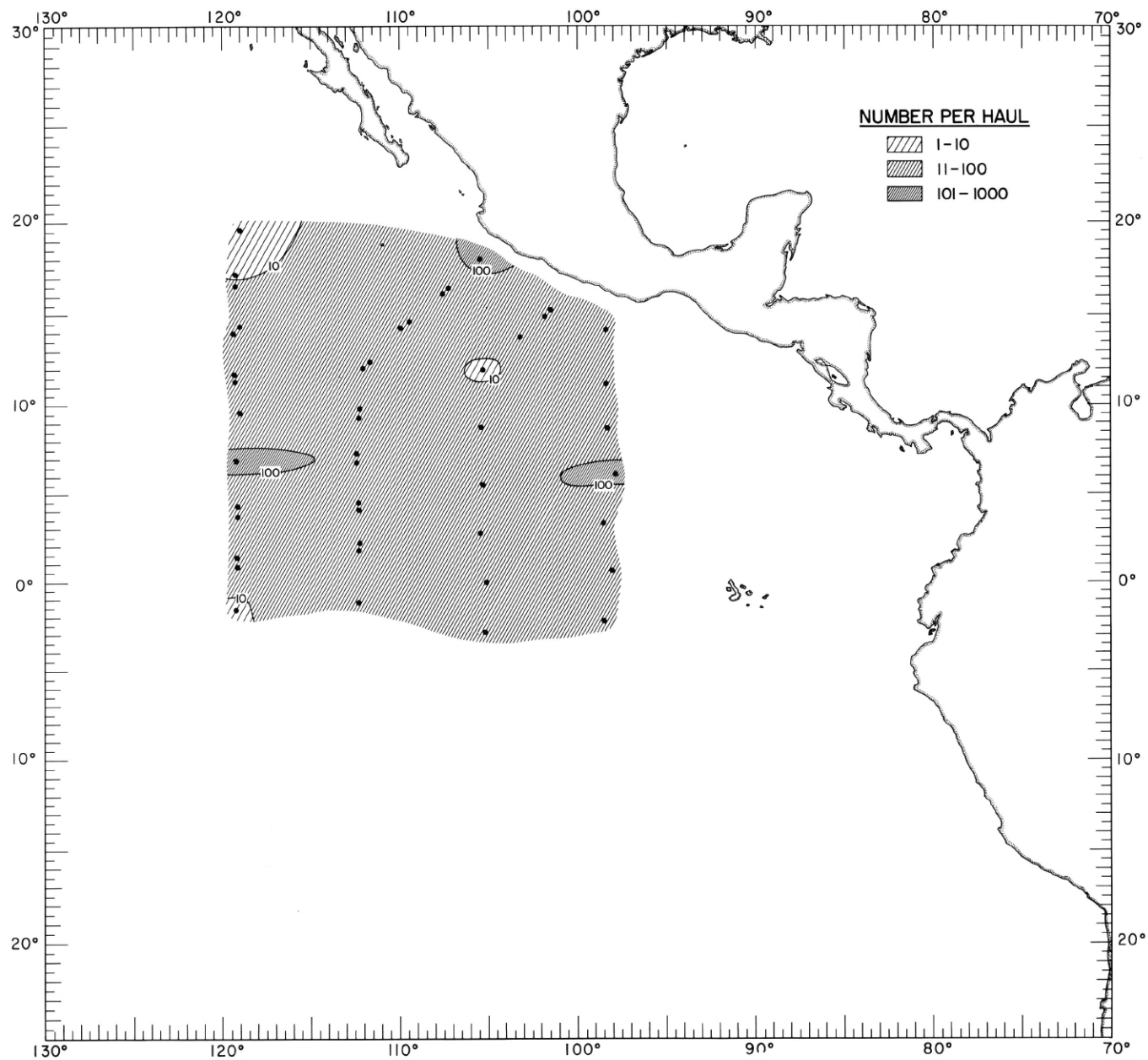
FIGURE 20-FC. — Total dolphin (fish), *Coryphaena*, larvae (number/haul) taken in 1-m. oblique plankton hauls during April-May 1967.





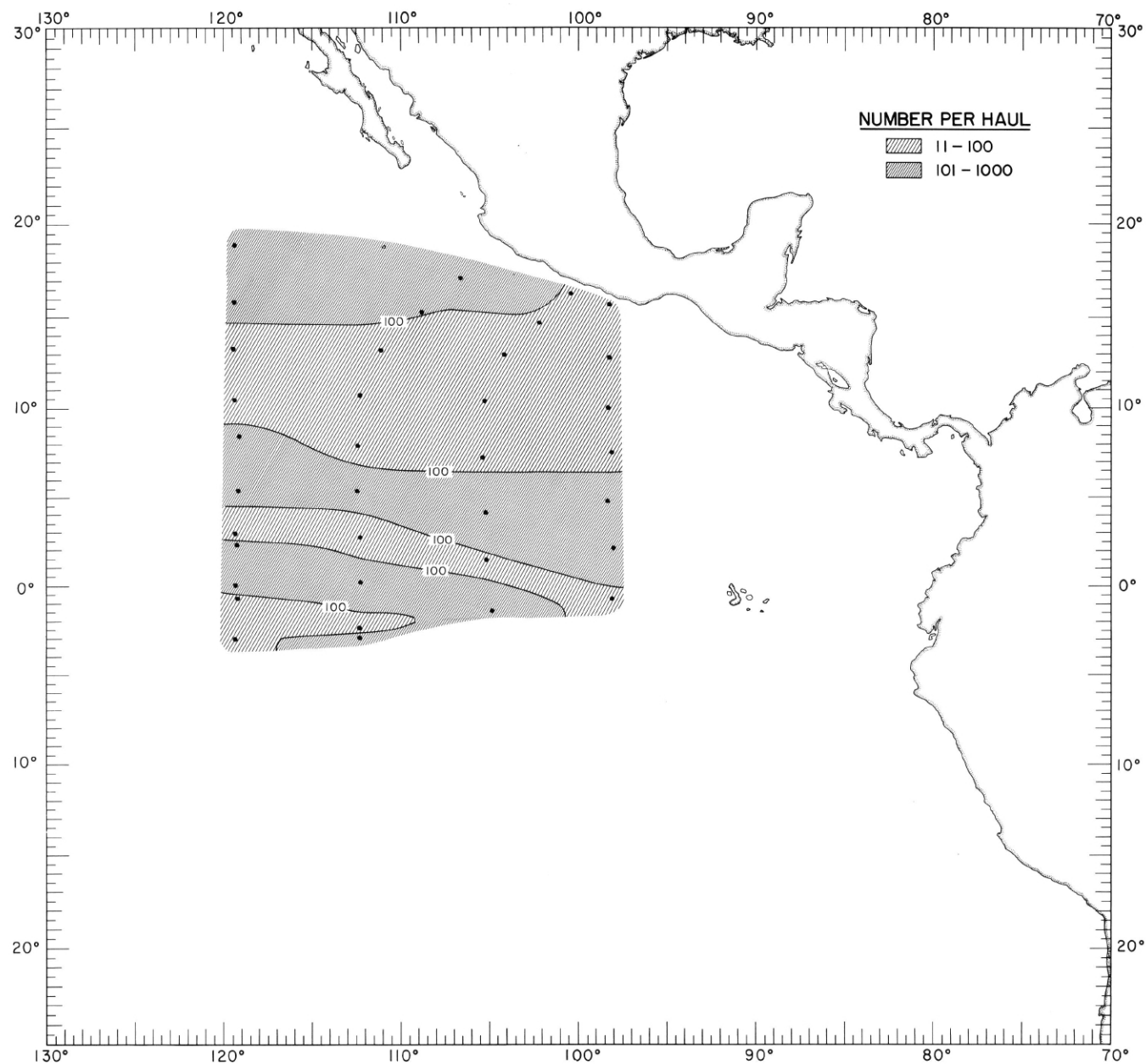
20-FMN.

FIGURE 20-FMN. — Total *Myctophid* larvae (number/haul) taken in 1-m. oblique plankton hauls at night during April-May 1967.



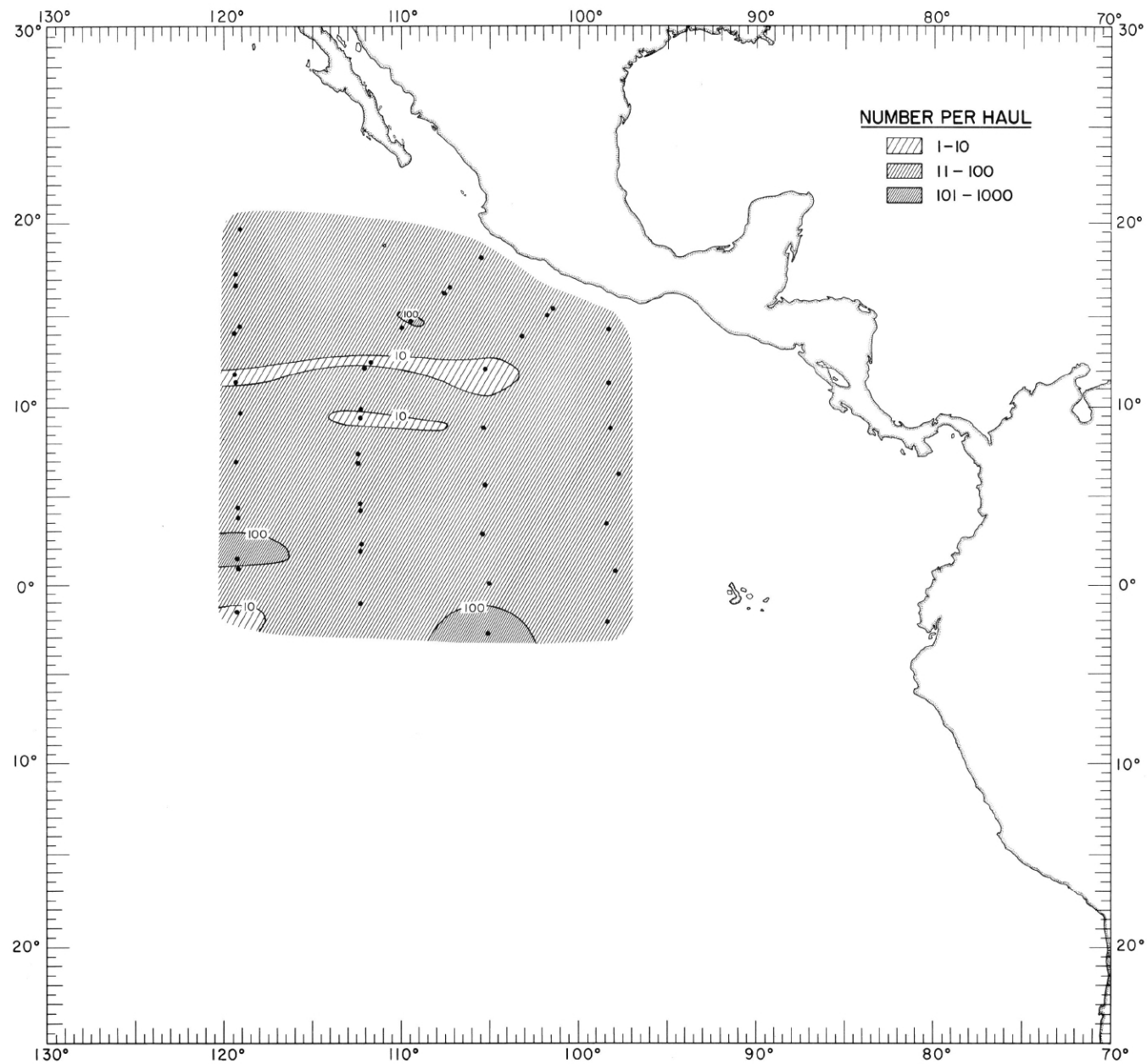
20-FMD.

FIGURE 20-FMD. — Total *Myctophid* larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, April-May 1967.



20-FGN.

FIGURE 20-FGN. — Total *Gonostomatid* and *Sternoptychid* larvae (number/haul) taken in 1-m. oblique plankton hauls at night during April-May 1967.



20-FGD.

FIGURE 20-FGD. — Total *Gonostomatid* and *Sternoptychid* larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, April-May 1967.

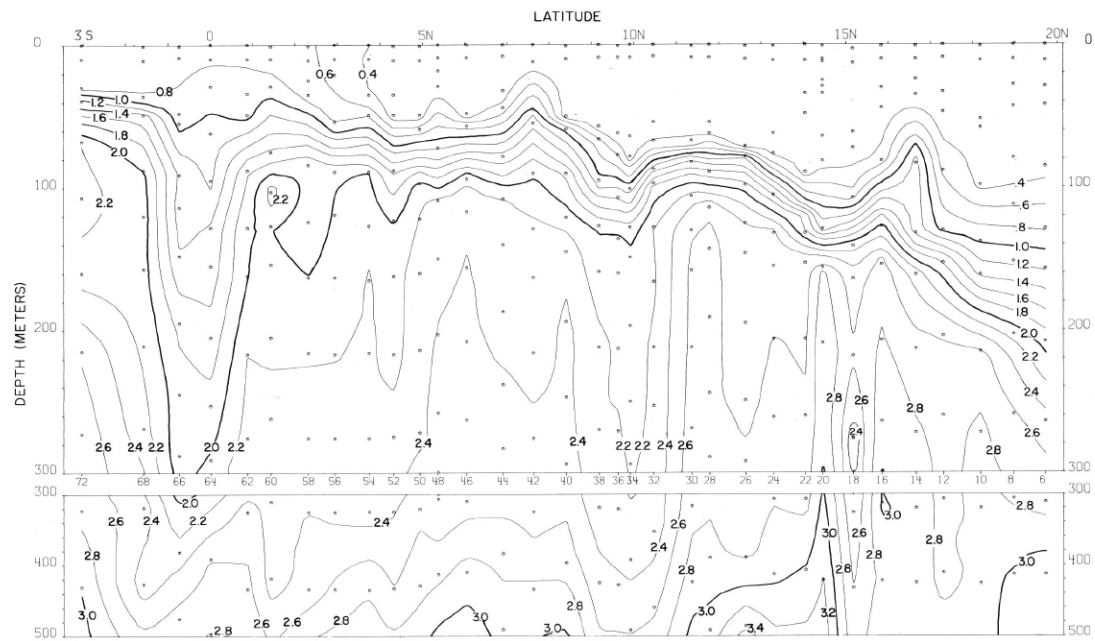
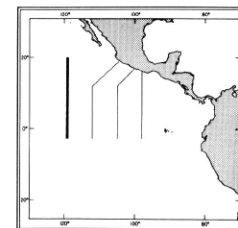


FIGURE 20-P-v1. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along 119°20' W., April 13-21, 1967.



20-P-v1.

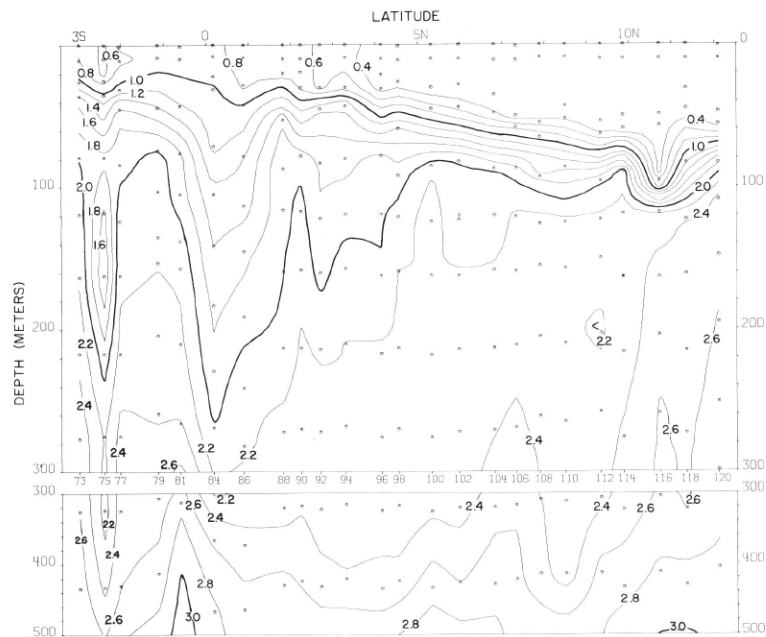


FIGURE 20-P-v2. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $112^{\circ}20'$  W., April 23-29, 1967.

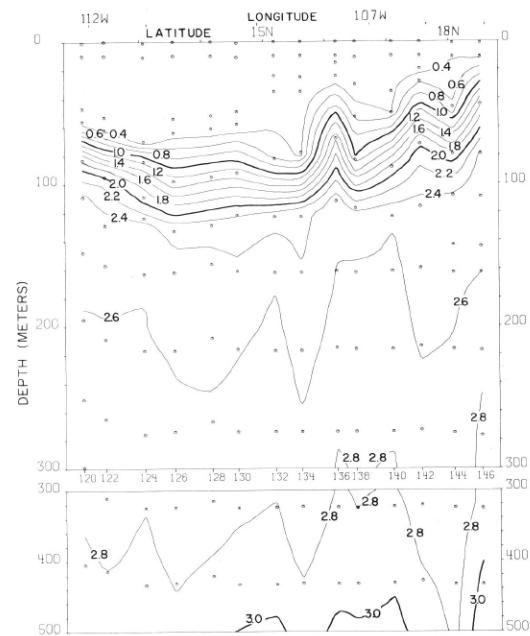
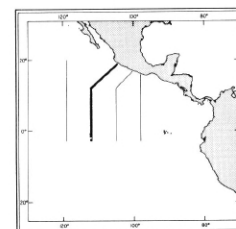


FIGURE 20-P-v3. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ}\text{N}$ ,  $112^{\circ}20'$  W. to Manzanillo, April 29-May 2, 1967.



20-P-v2.

20-P-v3.

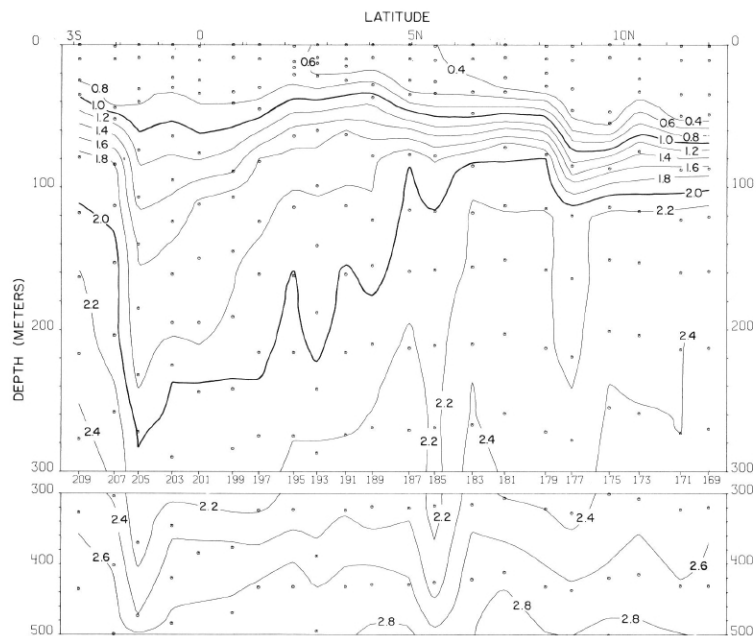


FIGURE 20-P-v5. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

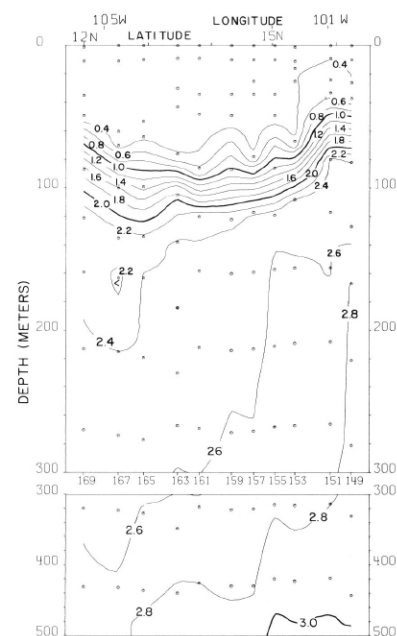
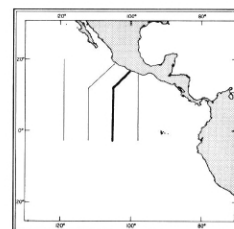


FIGURE 20-P-v4. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.



20-P-v5.

20-P-v4.

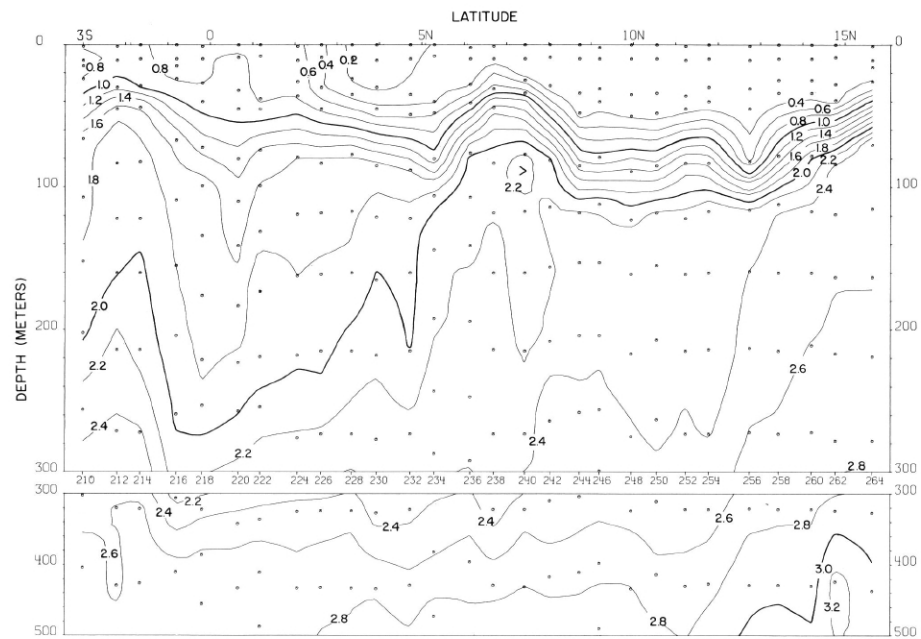
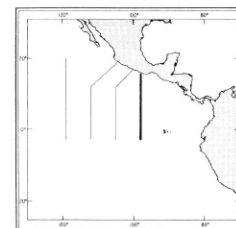


FIGURE 20-P-v6. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $98^{\circ}20'$  W., May 17-24, 1967.



20-P-v6.



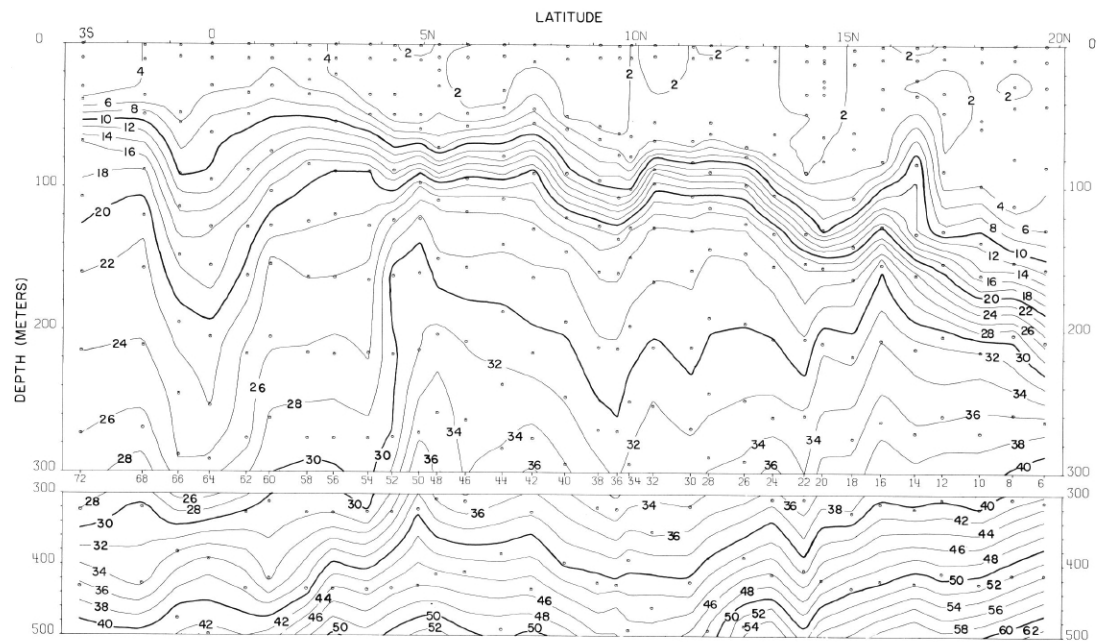
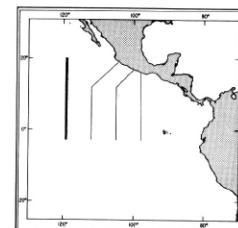


FIGURE 20-Si-v1. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $119^{\circ}20'$  W., April 13-21, 1967.



20-Si-v1.

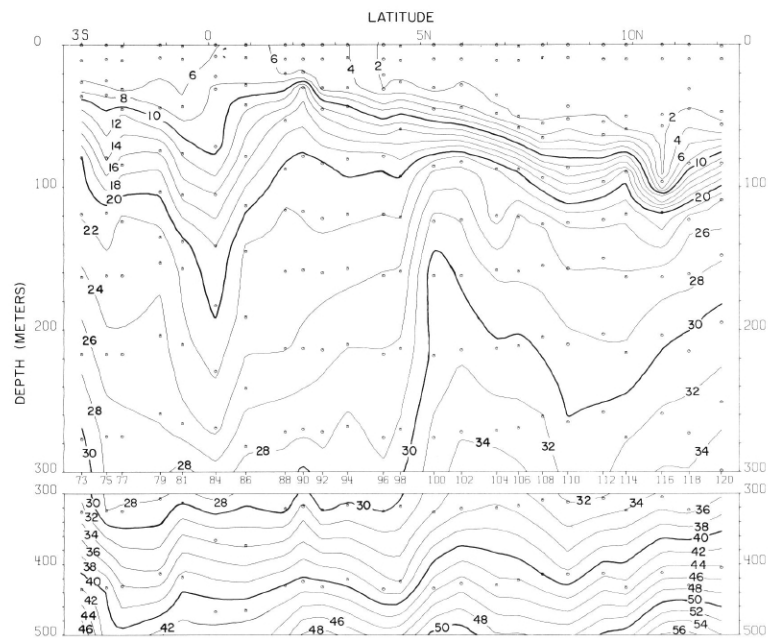


FIGURE 20-Si-v2. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $112^{\circ}20' \text{ W.}$ , April 23-29, 1967.

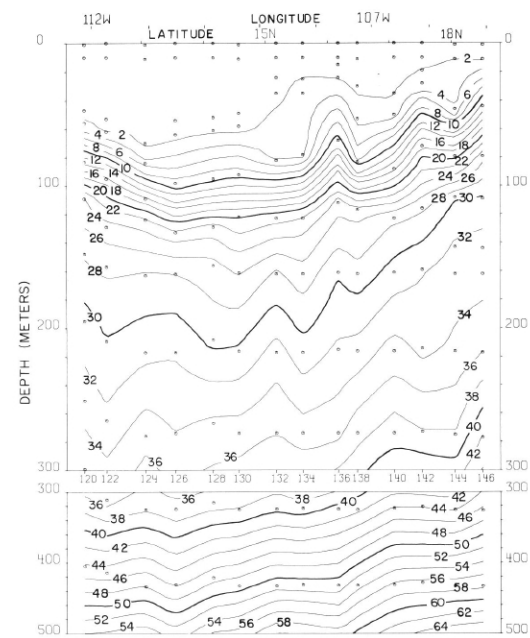
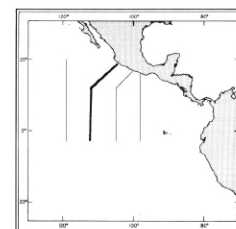


FIGURE 20-Si-v3. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ}20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.



20-Si-v2.

20-Si-v3.

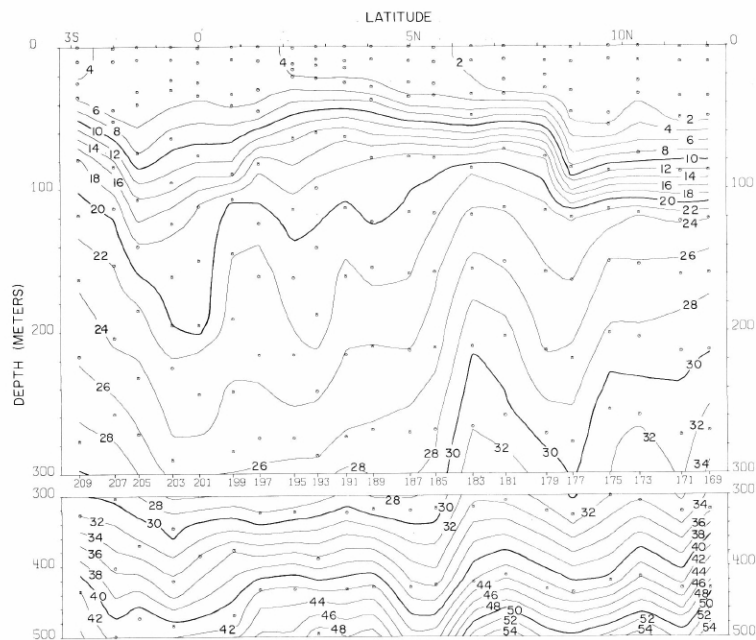


FIGURE 20-Si-v5. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $105^{\circ}20'$  W., May 10-15, 1967.

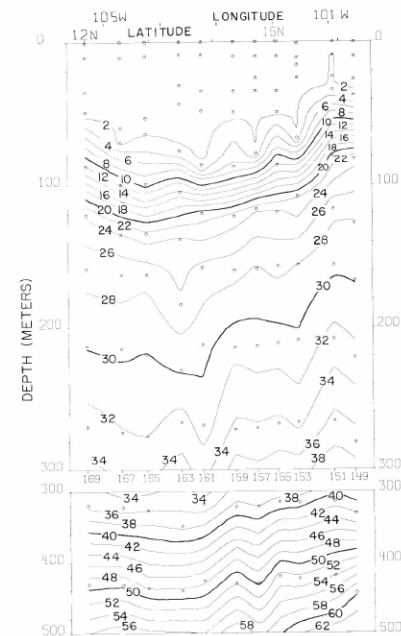
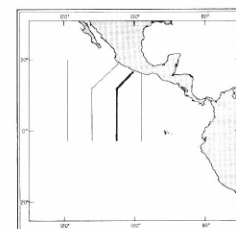


FIGURE 20-Si-v4. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ}$  N.,  $105^{\circ}20'$  W., May 7-10, 1967.



20-Si-v5.

20-Si-v4.

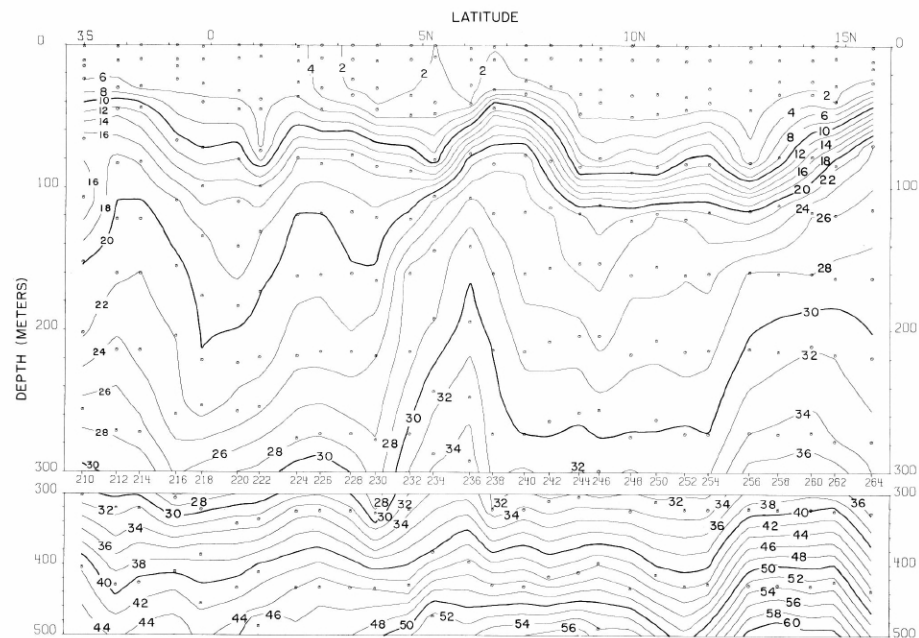
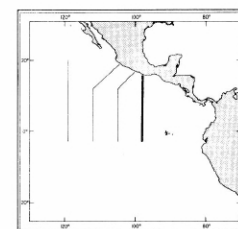
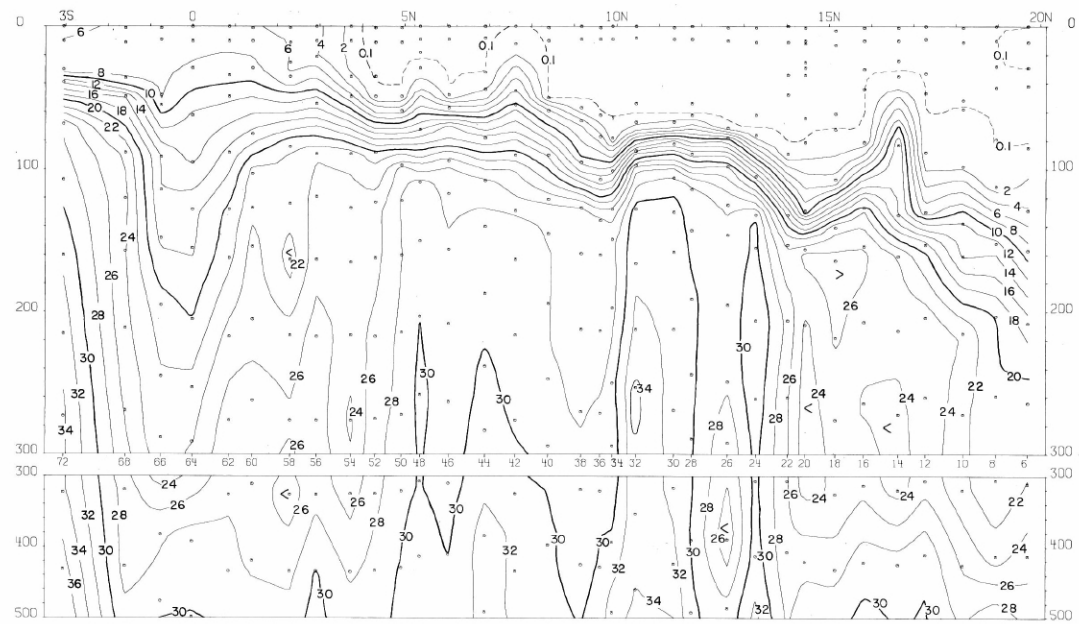


FIGURE 20-Si-v6. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $98^{\circ}20' \text{ W.}$ , May 17-24, 1967.



20-Si-v6.



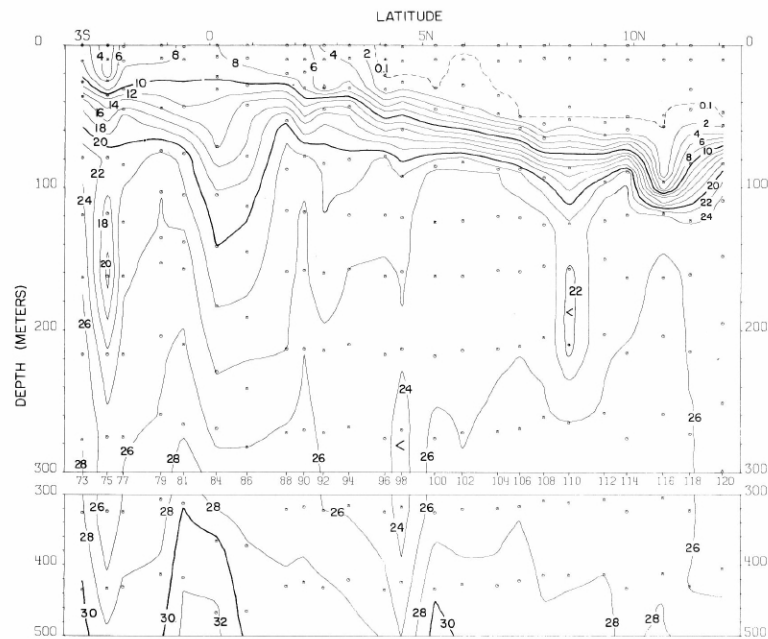


FIGURE 20-NO<sub>3</sub>-v2.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along  $112^{\circ} 20' \text{ W.}$ , April 23-29, 1967.

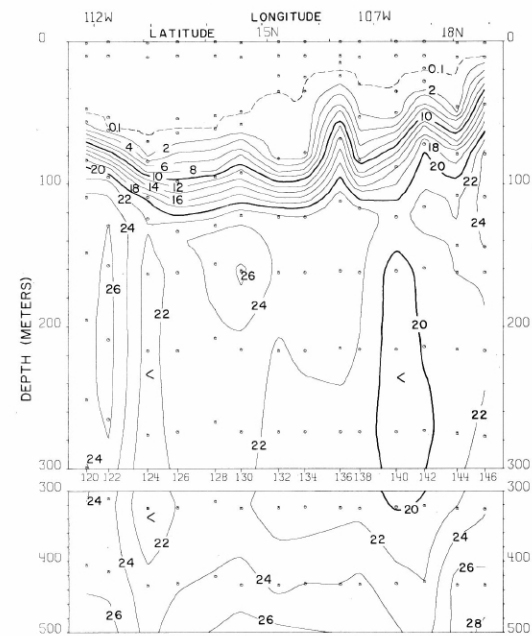
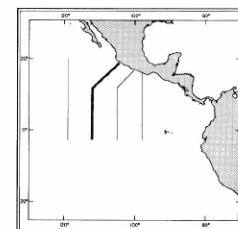


FIGURE 20-NO<sub>3</sub>-v3.—Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $112^{\circ} 20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.



20-NO<sub>3</sub>-v2.

20-NO<sub>3</sub>-v3.

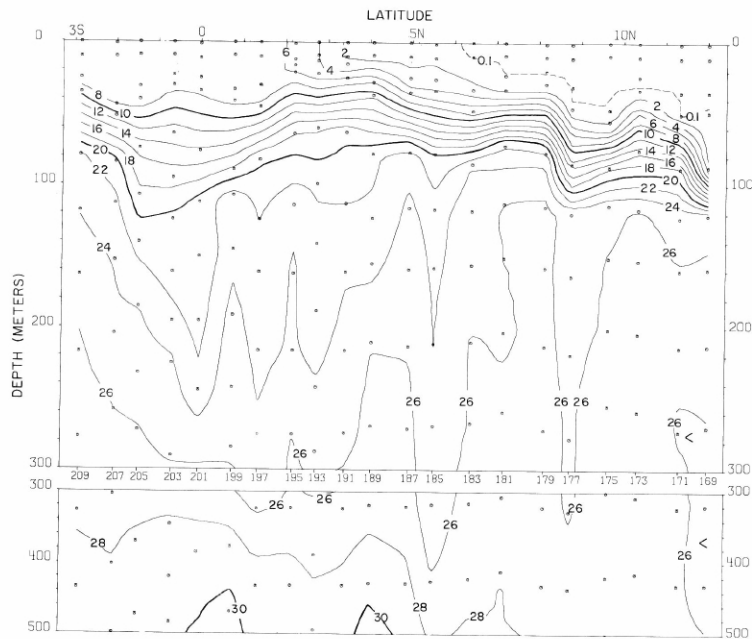


FIGURE 20-NO<sub>3</sub>-v5. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

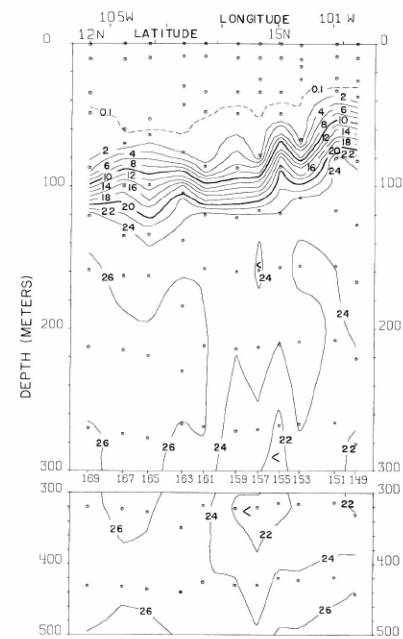
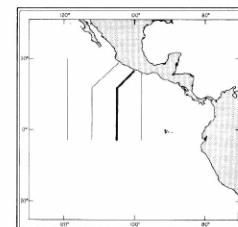


FIGURE 20-NO<sub>3</sub>-v4. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.



20-NO<sub>3</sub>-v4.

20-NO<sub>3</sub>-v5.

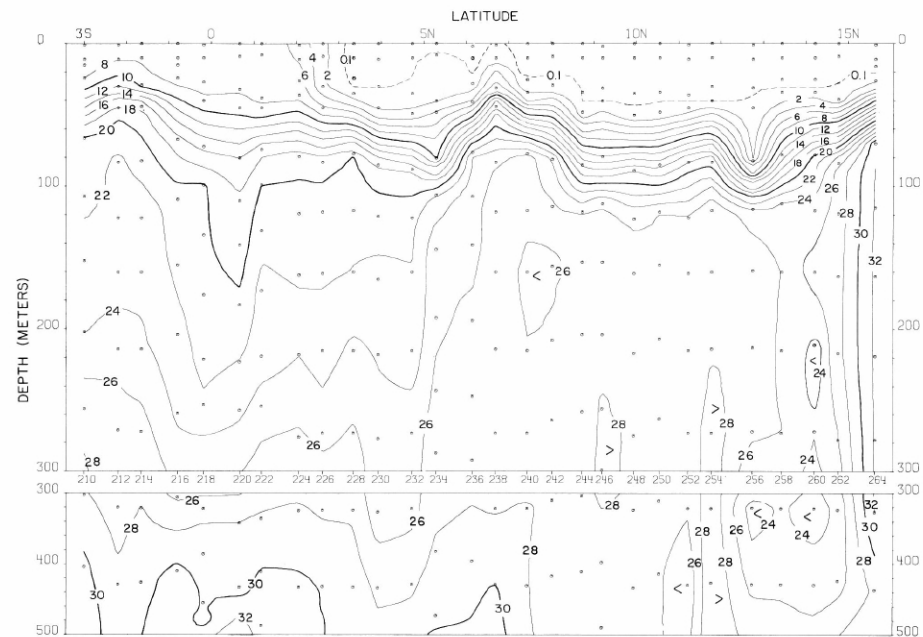
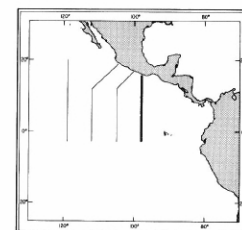


FIGURE 20-NO<sub>3</sub>-v6. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along  $98^{\circ}20'$  W., May 17-24, 1967.



20-NO<sub>3</sub>-v6.



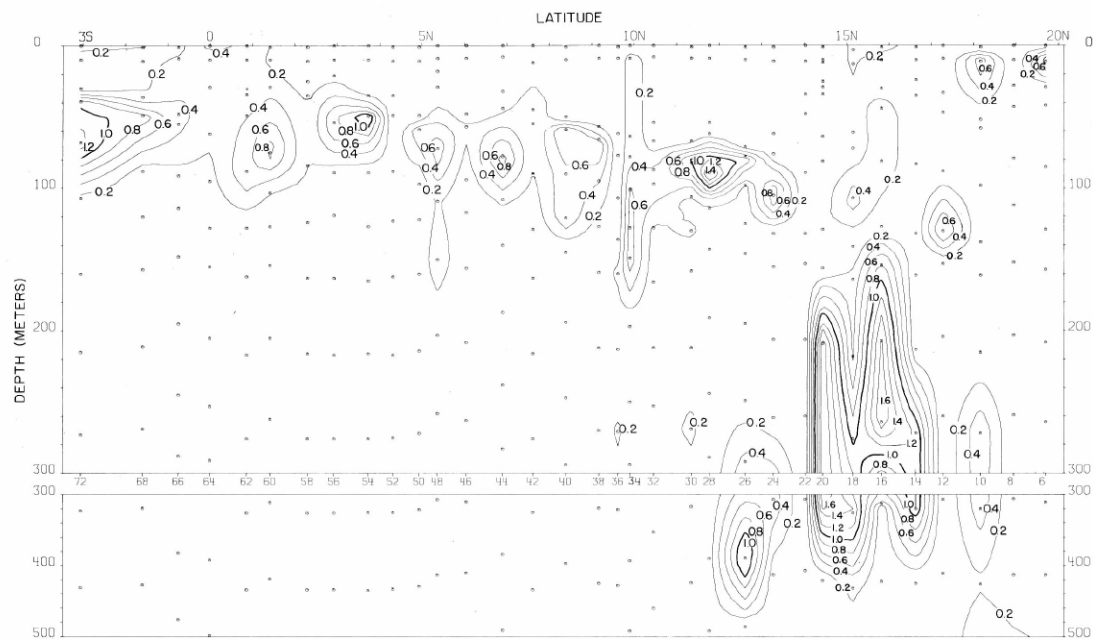
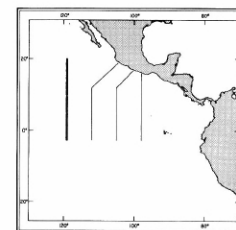


FIGURE 20- $\text{NO}_2\text{v1}$ . — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along  $119^{\circ}20' \text{ W.}$ , April 13-21, 1967.



20- $\text{NO}_2\text{v1}$ .

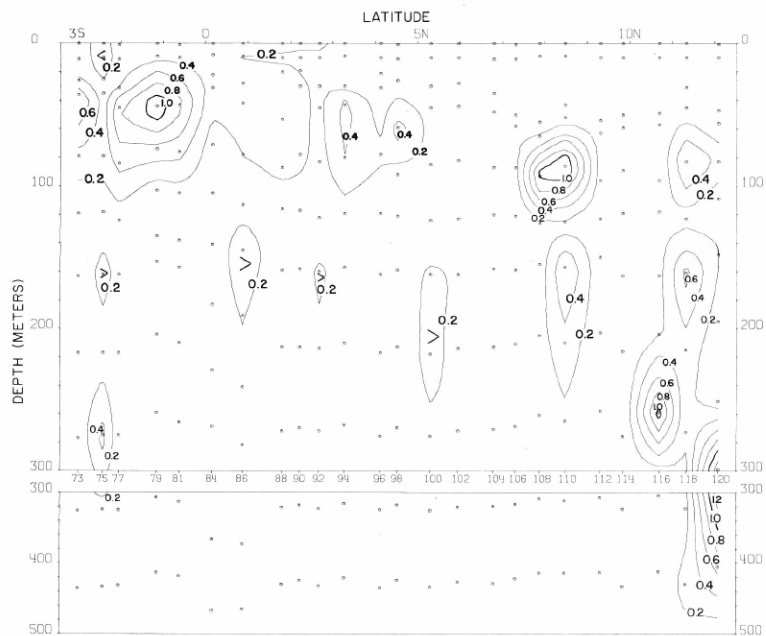


FIGURE 20-NO<sub>2</sub>-v2. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along  $112^{\circ}20'$  W., April 23-29, 1967.

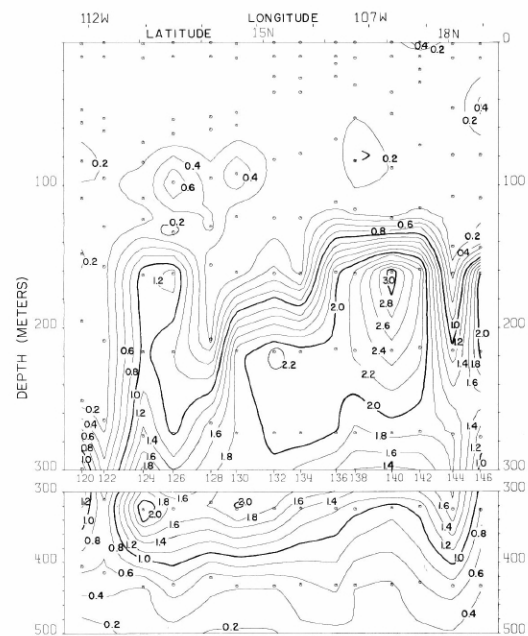
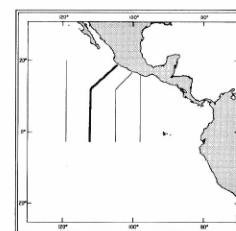


FIGURE 20-NO<sub>2</sub>-v3. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ}$  N.,  $112^{\circ}20'$  W. to Manzanillo, April 29-May 2, 1967.



20-NO<sub>2</sub>-v2.

20-NO<sub>2</sub>-v3.

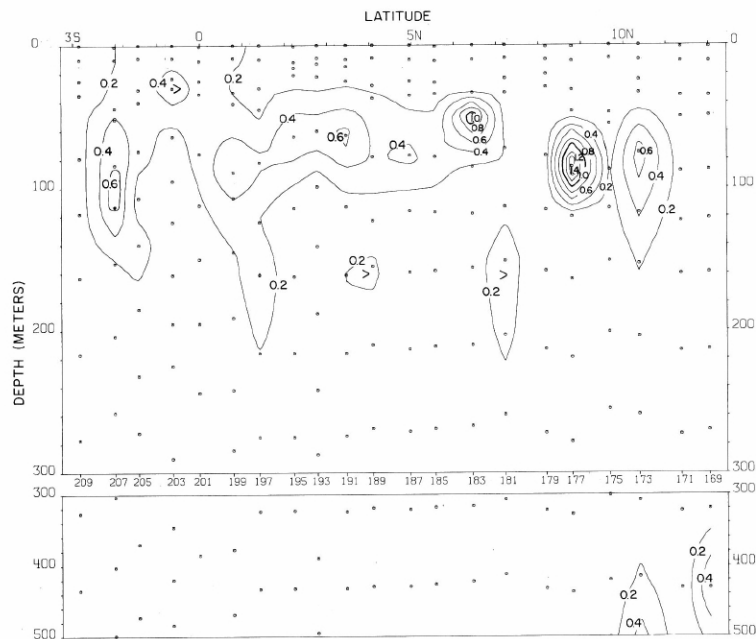


FIGURE 20-NO<sub>2</sub>-v5. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along  $105^{\circ}20' \text{ W.}$ , May 10-15, 1967.

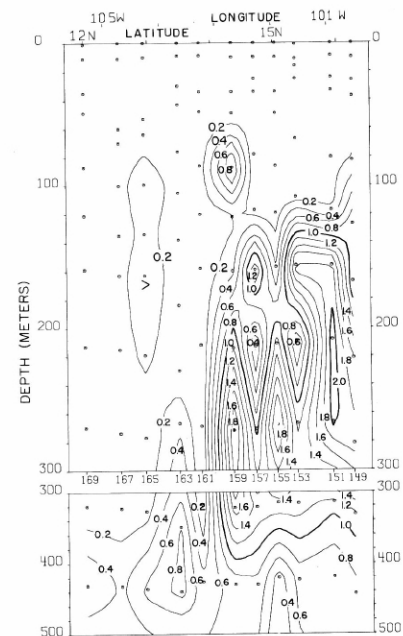
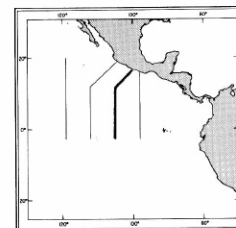


FIGURE 20-NO<sub>2</sub>-v4. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $105^{\circ}20' \text{ W.}$ , May 7-10, 1967.



20-NO<sub>2</sub>-v5.

20-NO<sub>2</sub>-v4.

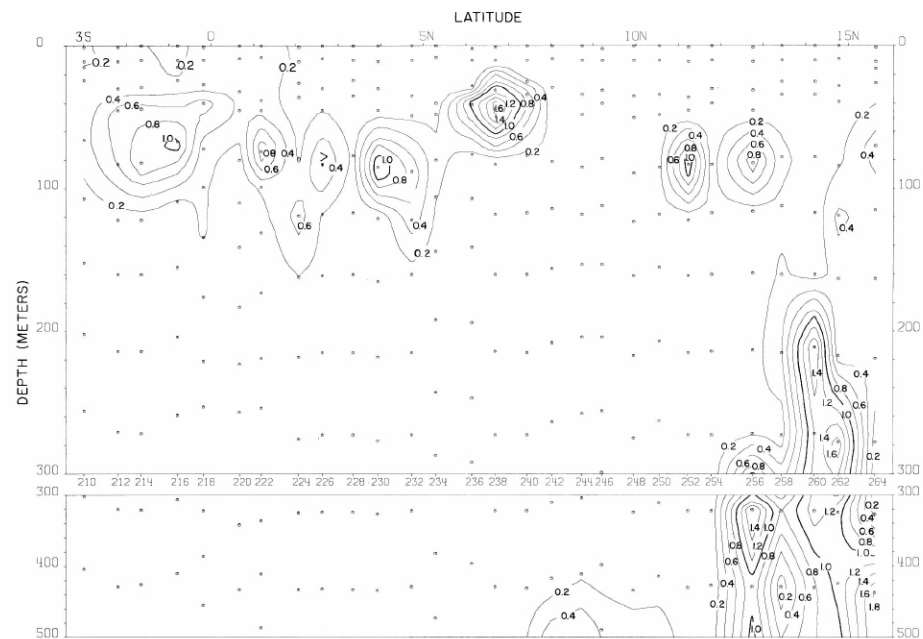
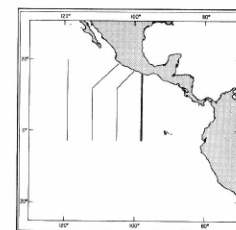


FIGURE 20-NO<sub>2</sub>-v6. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along  $96^{\circ}20' \text{ W.}$ , May 17-24, 1967.



20-NO<sub>2</sub>-v6.

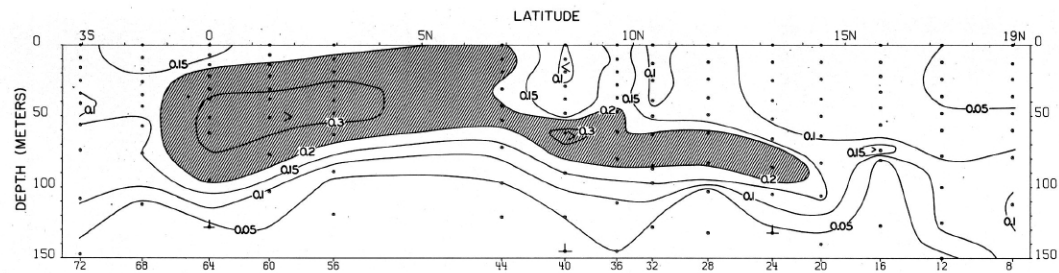


FIGURE 20-Ch-v1. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 119°20' W., April 13-21, 1967.

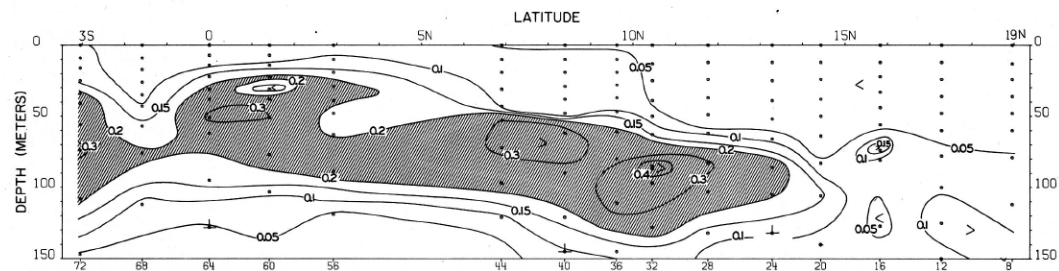


FIGURE 20-Ph-v1. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 119°20' W., April 13-21, 1967.

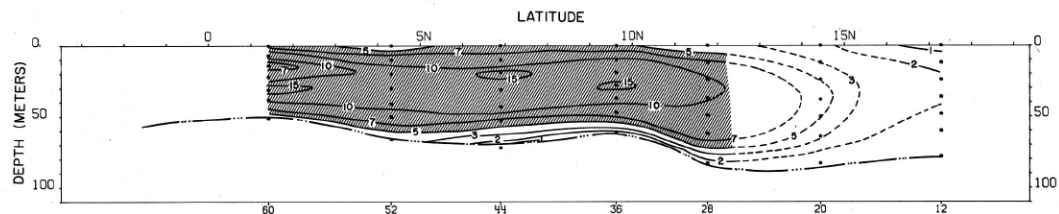
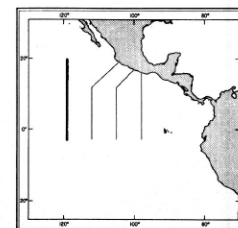


FIGURE 20-PP-v1. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along 119°20' W., April 13-21, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



20-Ch-v1.

20-Ph-v1.

20-PP-v1.

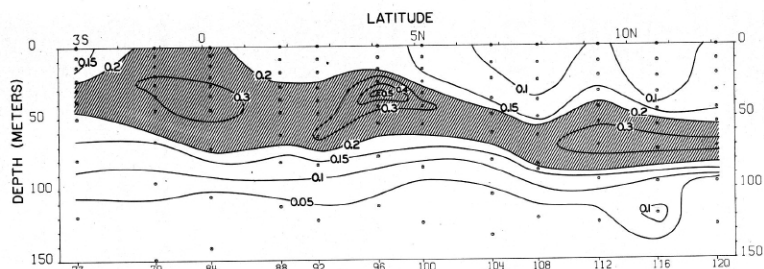


FIGURE 20-Ch-v2. — Vertical distribution of chlorophyll-a ( $\text{mg./m}^3$ ) along  $112^\circ 20' \text{ W.}$ , April 23-29, 1967.

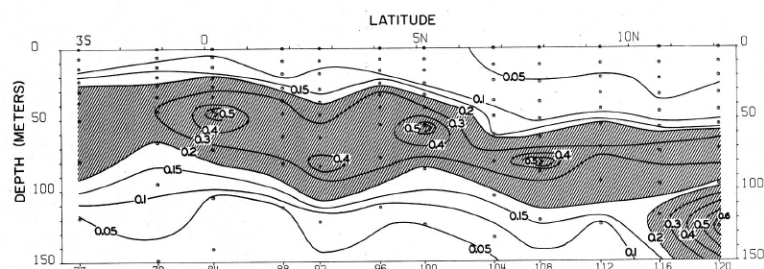


FIGURE 20-Ph-v2. — Vertical distribution of phaeophytin ( $\text{mg./m}^3$ ) along  $112^\circ 20' \text{ W.}$ , April 23-29, 1967.

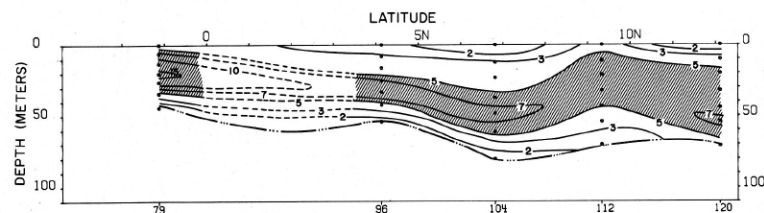


FIGURE 20-PP-v2. — Vertical distribution of primary production ( $\text{mg.C/m}^3/\text{day}$ ) along  $112^\circ 20' \text{ W.}$ , April 23-29, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

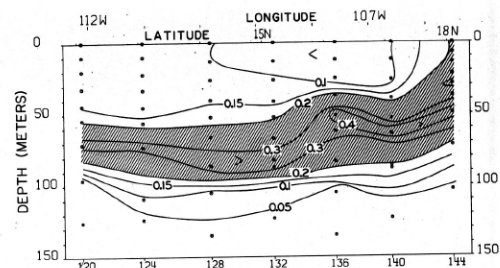


FIGURE 20-Ch-v3. — Vertical distribution of chlorophyll-a ( $\text{mg./m}^3$ ) along a section from  $12^\circ \text{ N.}$ ,  $112^\circ 20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

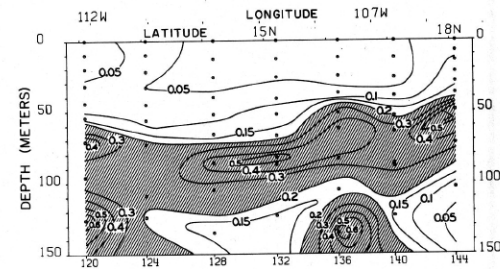


FIGURE 20-Ph-v3. — Vertical distribution of phaeophytin ( $\text{mg./m}^3$ ) along a section from  $12^\circ \text{ N.}$ ,  $112^\circ 20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967.

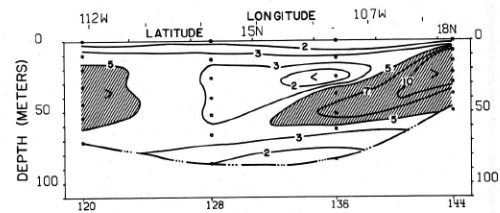
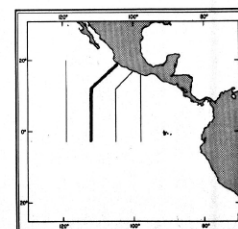


FIGURE 20-PP-v3. — Vertical distribution of primary production ( $\text{mg.C/m}^3/\text{day}$ ) along a section from  $12^\circ \text{ N.}$ ,  $112^\circ 20' \text{ W.}$  to Manzanillo, April 29-May 2, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



20-Ch-v2.

20-Ph-v2.

20-PP-v2.

20-Ch-v3.

20-Ph-v3.

20-PP-v3.

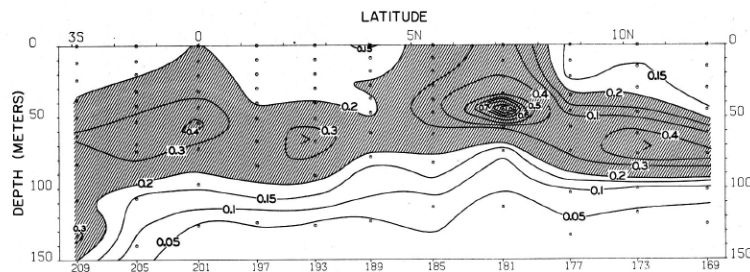


FIGURE 20-Ch-v5. — Vertical distribution of chlorophyll-a ( $\text{mg./m.}^3$ ) along  $105^\circ 20'$  W. May 10-15, 1967.

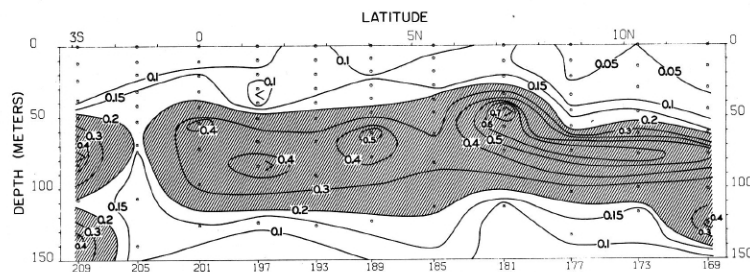


FIGURE 20-Ph-v5. — Vertical distribution of phaeophytin ( $\text{mg./m.}^3$ ) along  $105^\circ 20'$  W., May 10-15, 1967.

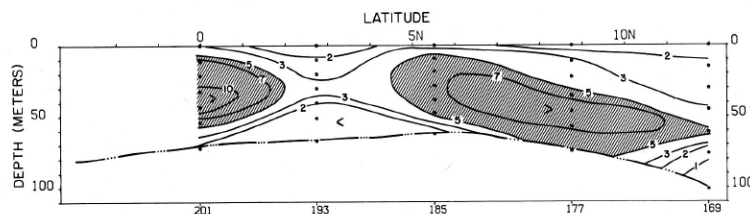


FIGURE 20-PP-v5. — Vertical distribution of primary production ( $\text{mg.C/m.}^2/\text{day}$ ) along  $105^\circ 20'$  W., May 10-15, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

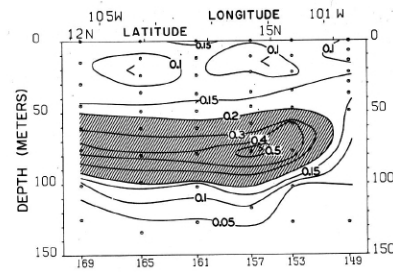


FIGURE 20-Ch-v4. — Vertical distribution of chlorophyll-a ( $\text{mg./m.}^3$ ) along a section from Acapulco to  $12^\circ \text{N}$ ,  $105^\circ 20'$  W., May 7-10, 1967.

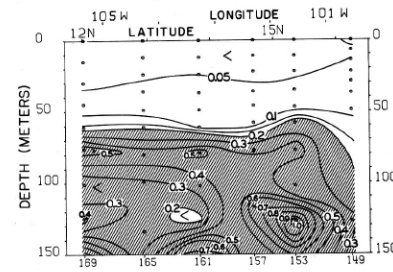


FIGURE 20-Ph-v4. — Vertical distribution of phaeophytin ( $\text{mg./m.}^3$ ) along a section from Acapulco to  $12^\circ \text{N}$ ,  $105^\circ 20'$  W., May 7-10, 1967.

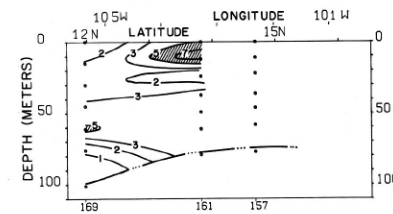
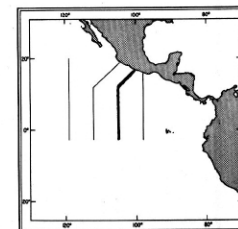


FIGURE 20-PP-v4. — Vertical distribution of primary production ( $\text{mg.C/m.}^2/\text{day}$ ) along a section from Acapulco to  $12^\circ \text{N}$ ,  $105^\circ 20'$  W., May 7-10, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



20-Ch-v4.  
20-Ph-v4.  
20-PP-v4.  
20-Ch-v5.  
20-Ph-v5.  
20-PP-v5.

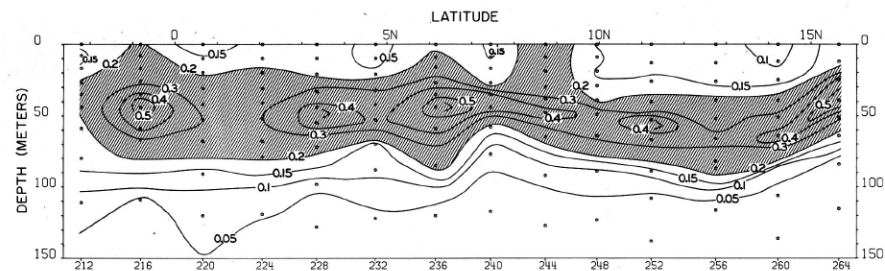


FIGURE 20-Ch-v6. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 98°20' W., May 17-24, 1967.

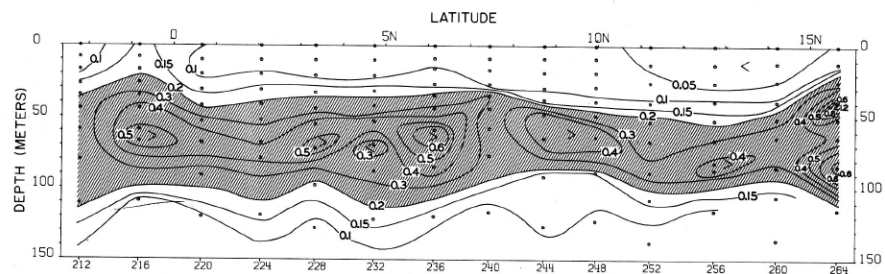


FIGURE 20-Ph-v6. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 98°20' W., May 17-24, 1967.

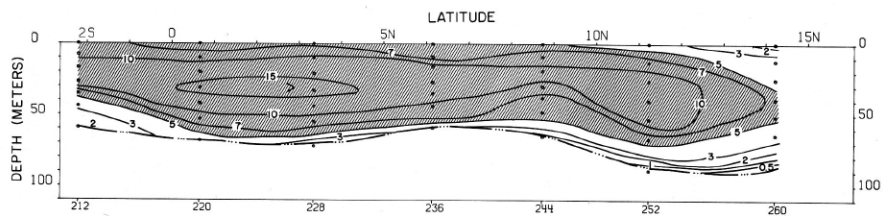
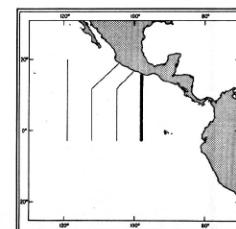


FIGURE 20-PP-v6. — Vertical distribution of primary production (mg.C/m.<sup>2</sup>/day) along 98°20' W., May 17-24, 1967.  
The heavy dash-dot line indicates the bottom of the euphotic layer.

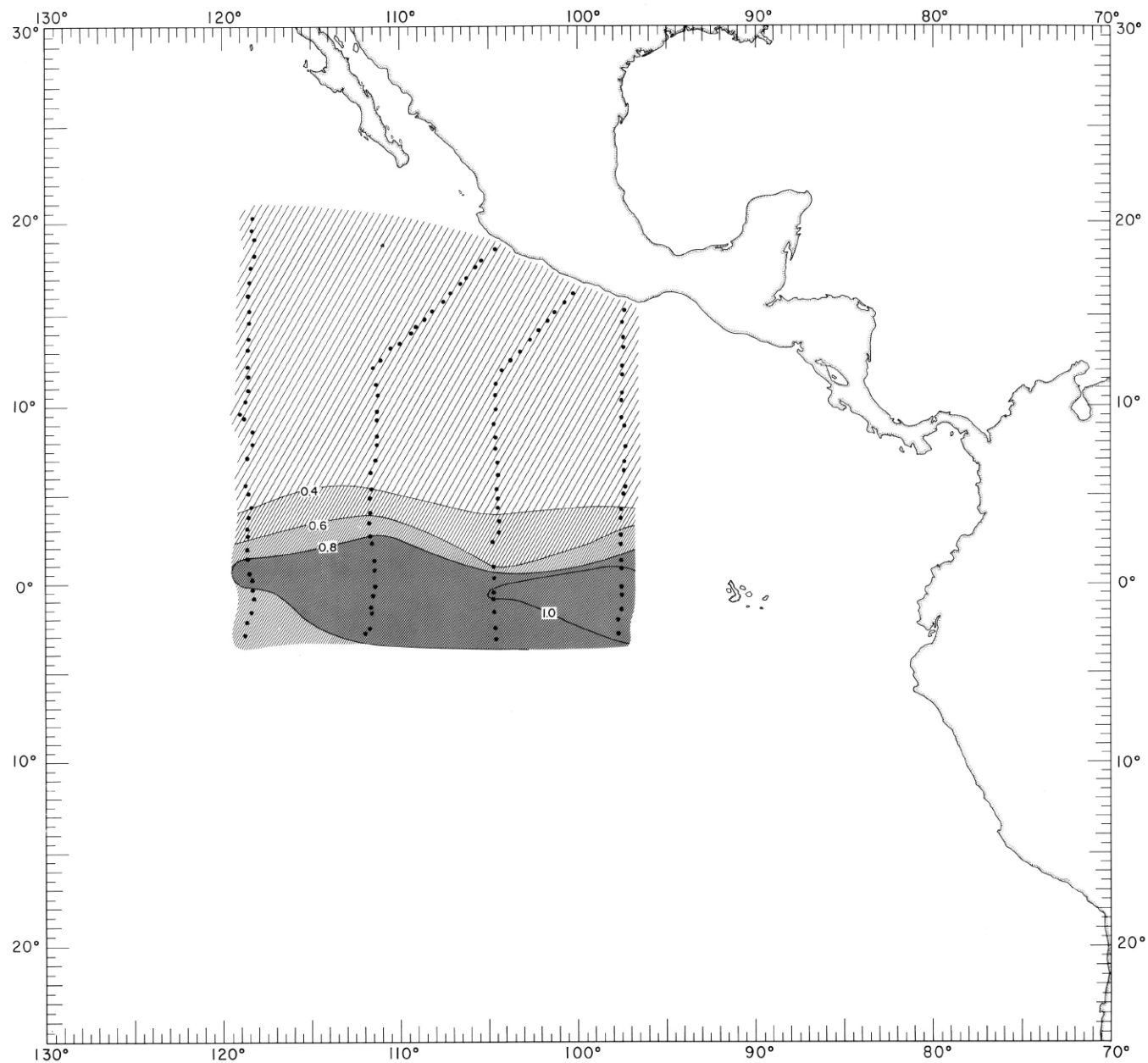


20-Ch-v6.

20-Ph-v6.

20-PP-v6.





30-P-10.

FIGURE 30-P-10. — Phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) at 10 meters, June-July 1967.

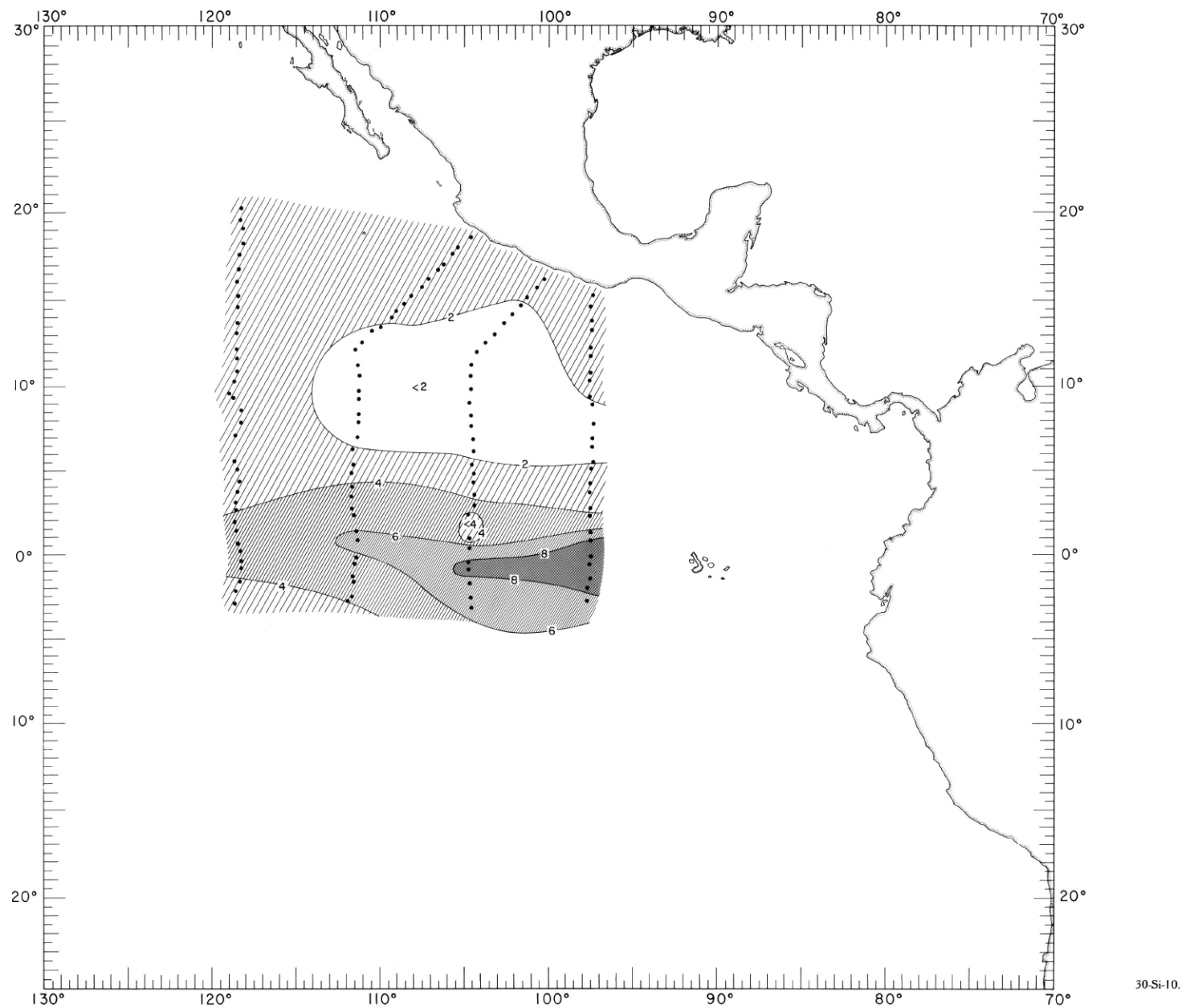
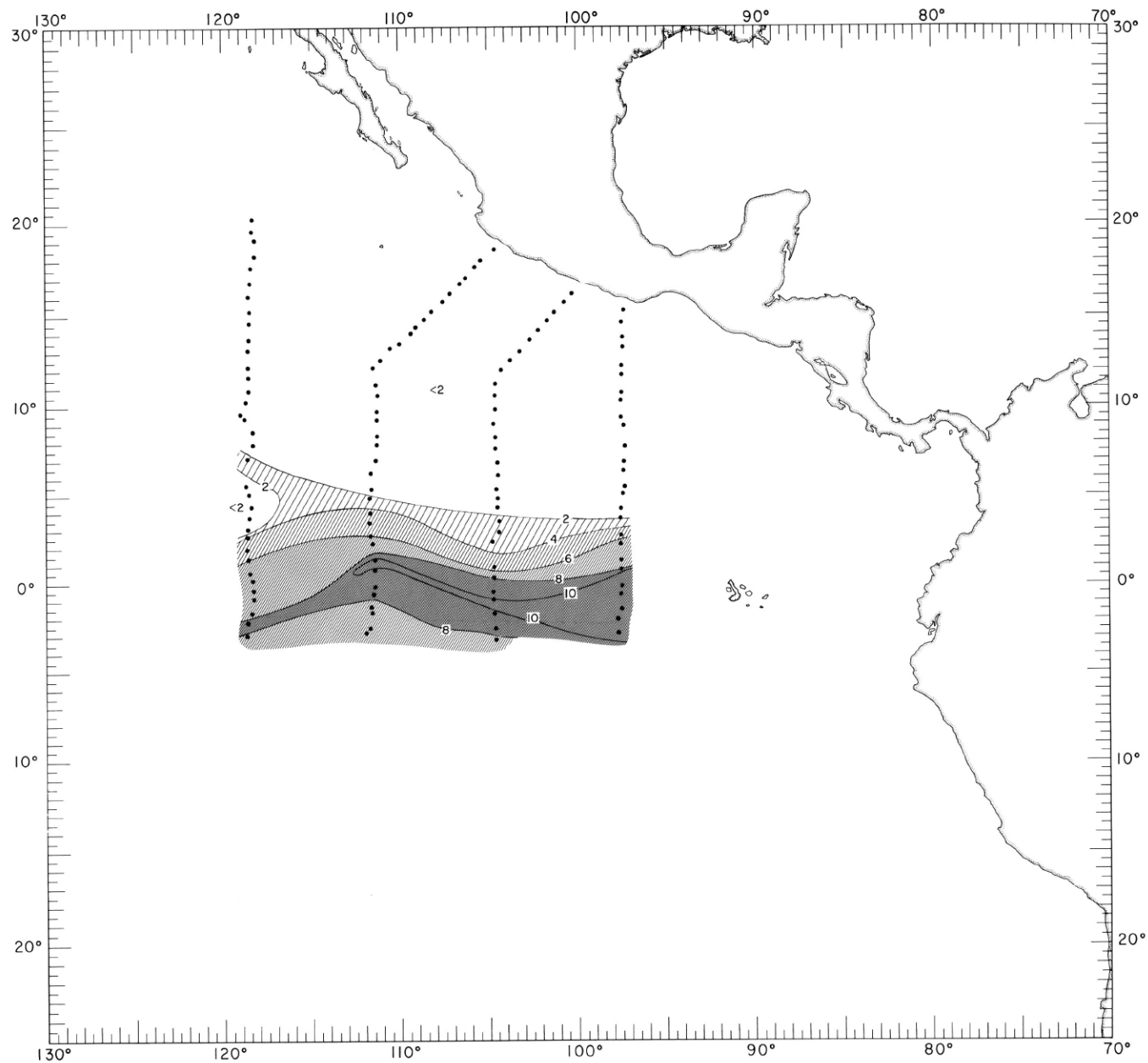


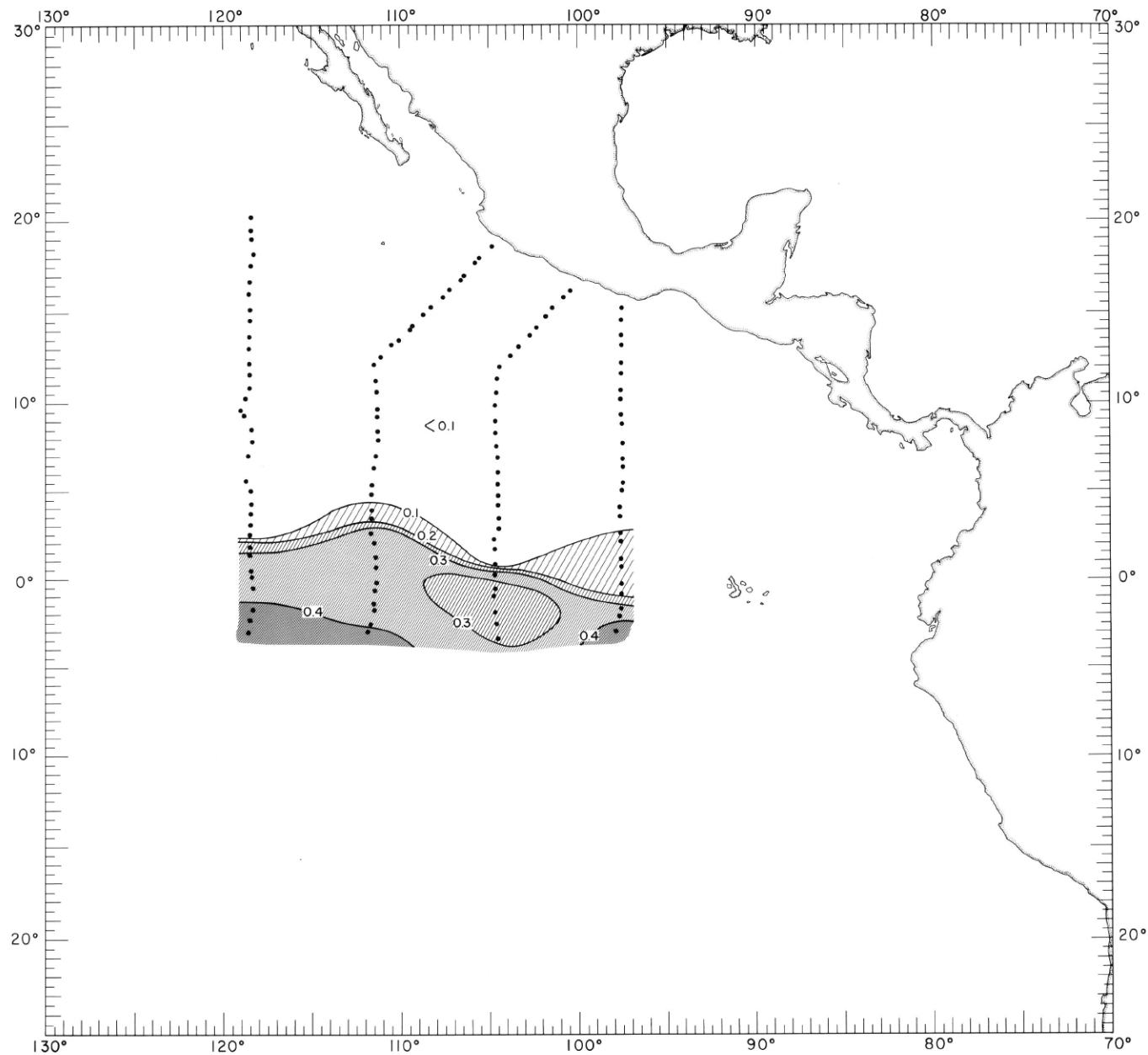
FIGURE 30-Si-10. — Silicate-silicon ( $\mu\text{g-at./l.}$ ) at 10 meters, June-July 1967.

30-Si-10.



30-NO<sub>2</sub>-10.

FIGURE 30-NO<sub>2</sub>-10. — Nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, June-July 1967.



30-NO<sub>2</sub>-10.

FIGURE 30-NO<sub>2</sub>-10. — Nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, June-July 1967.

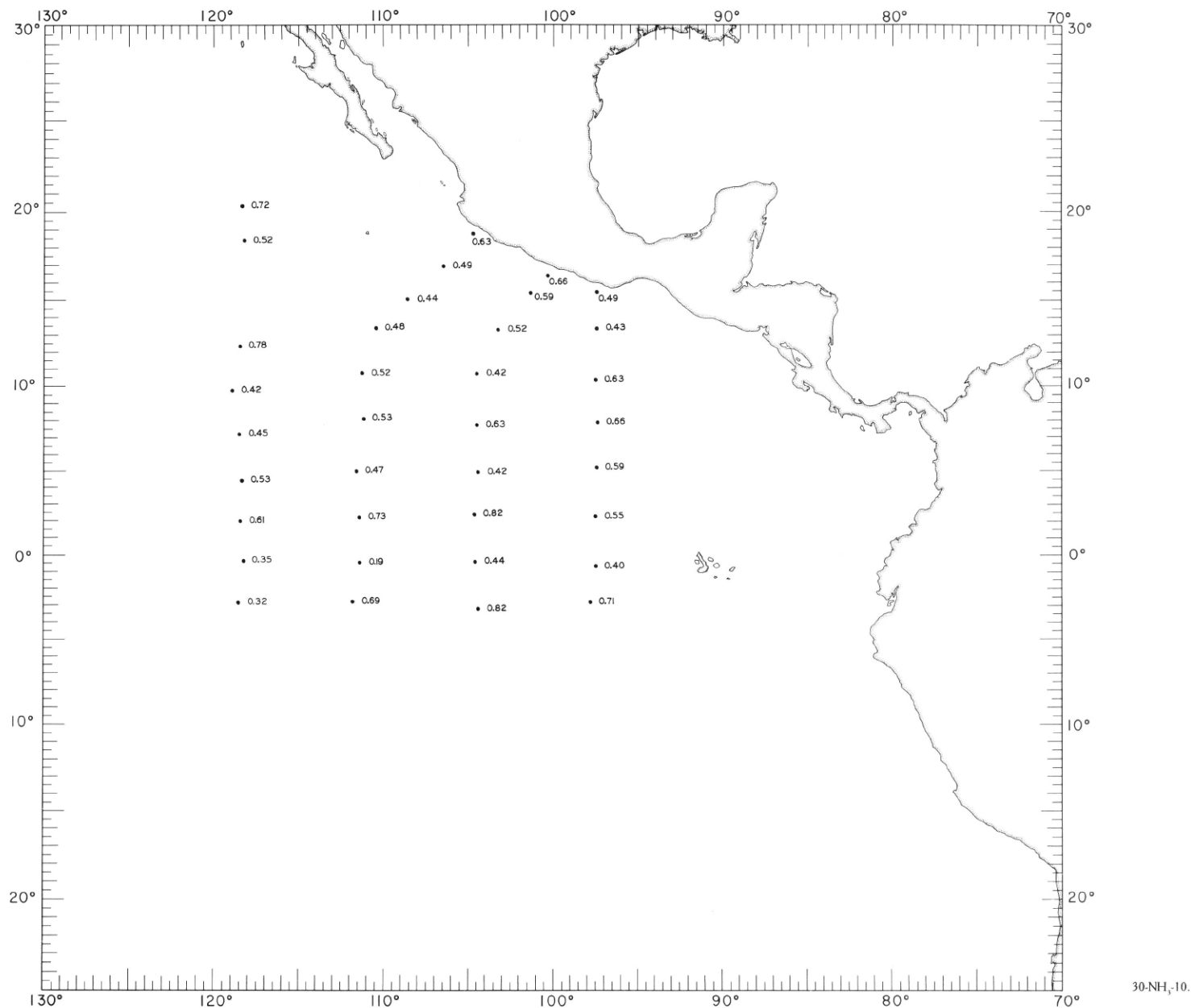
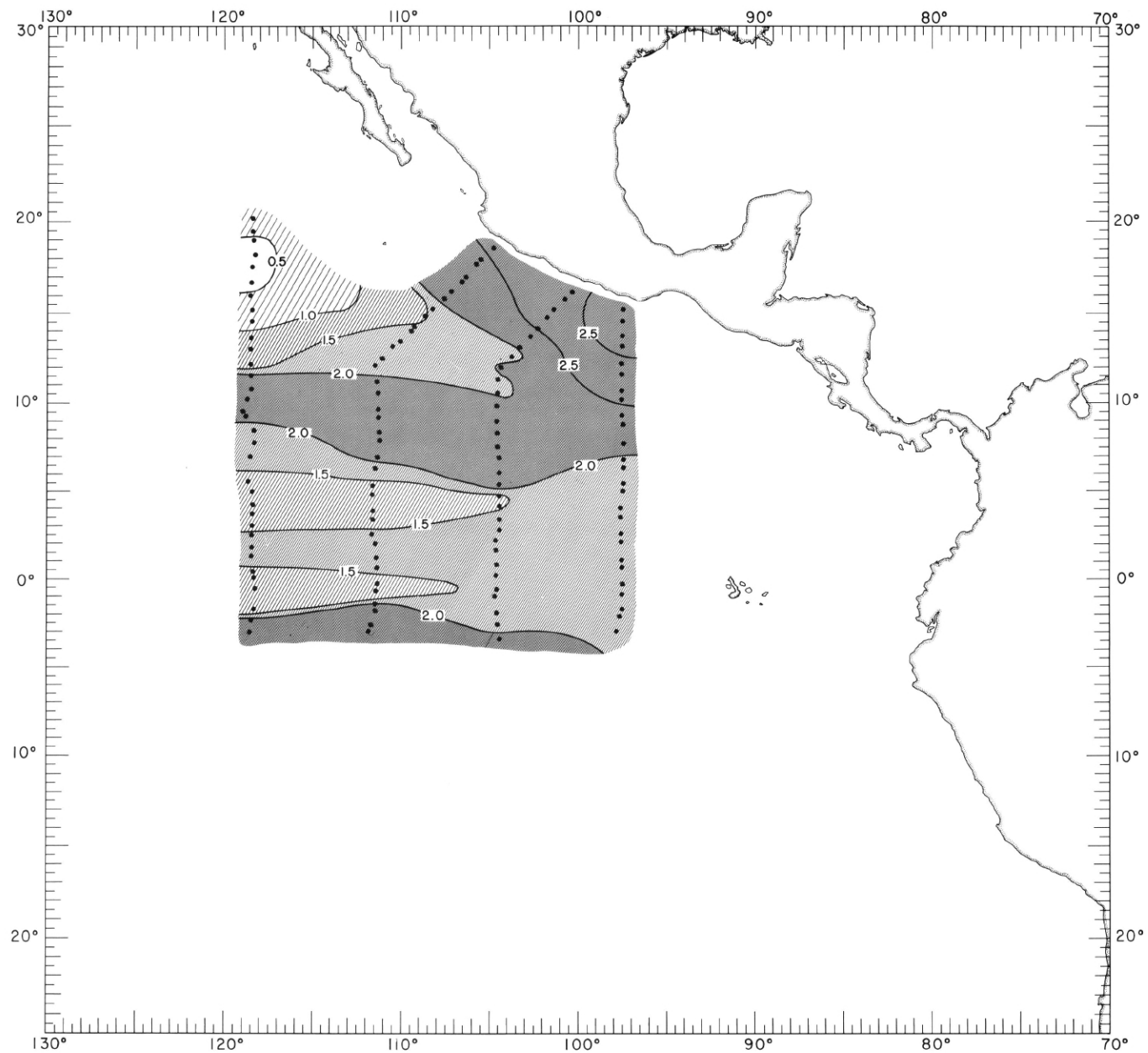


FIGURE 30-NH<sub>3</sub>-10. — Ammonia-nitrogen ( $\mu\text{g-at./l.}$ ) at 10 meters, June-July 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.



30-P-100.

FIGURE 30-P-100. — Phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) at 100 meters, June-July 1967.



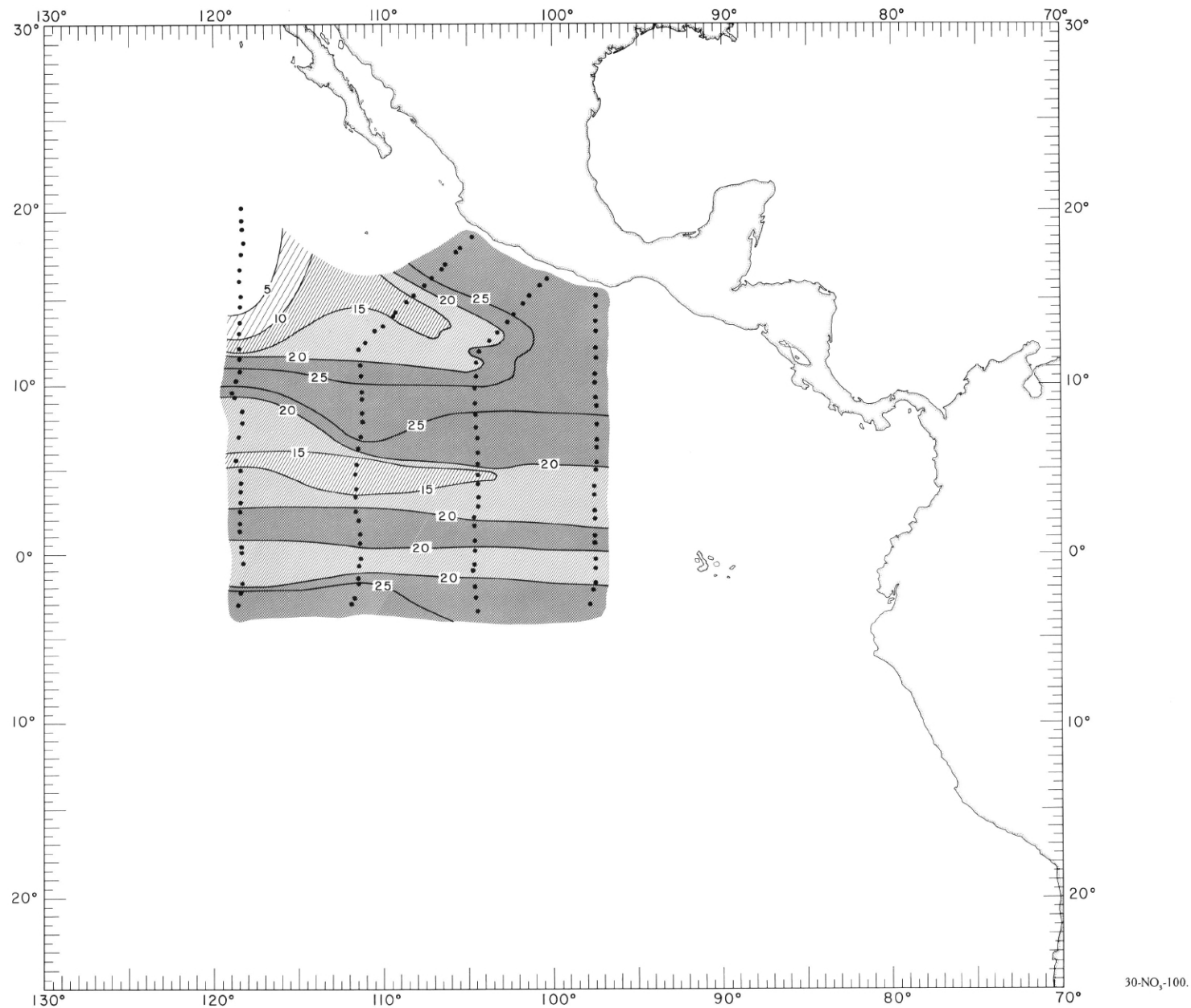


FIGURE 30-NO<sub>3</sub>-100. — Nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) at 100 meters, June-July 1967.



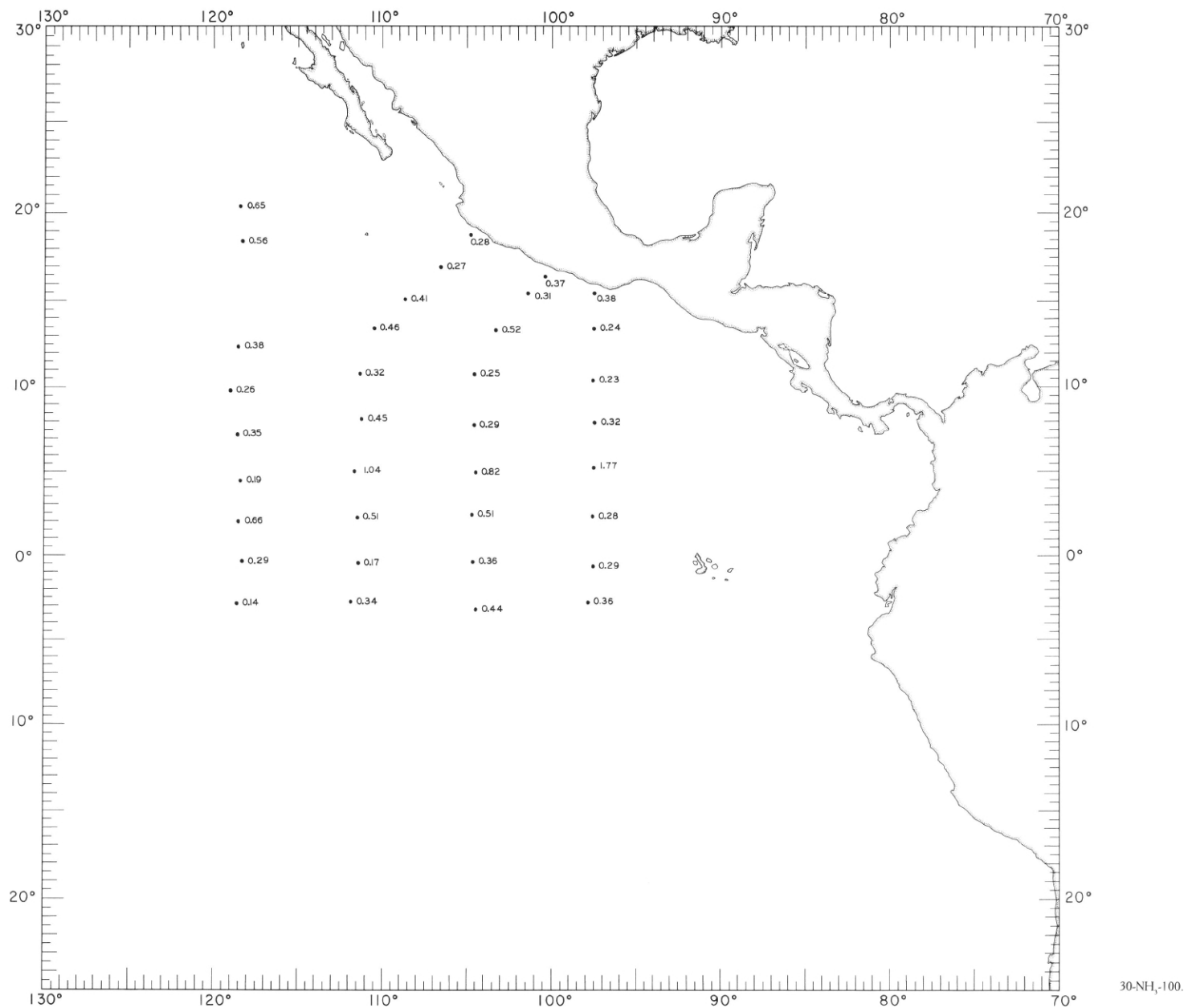
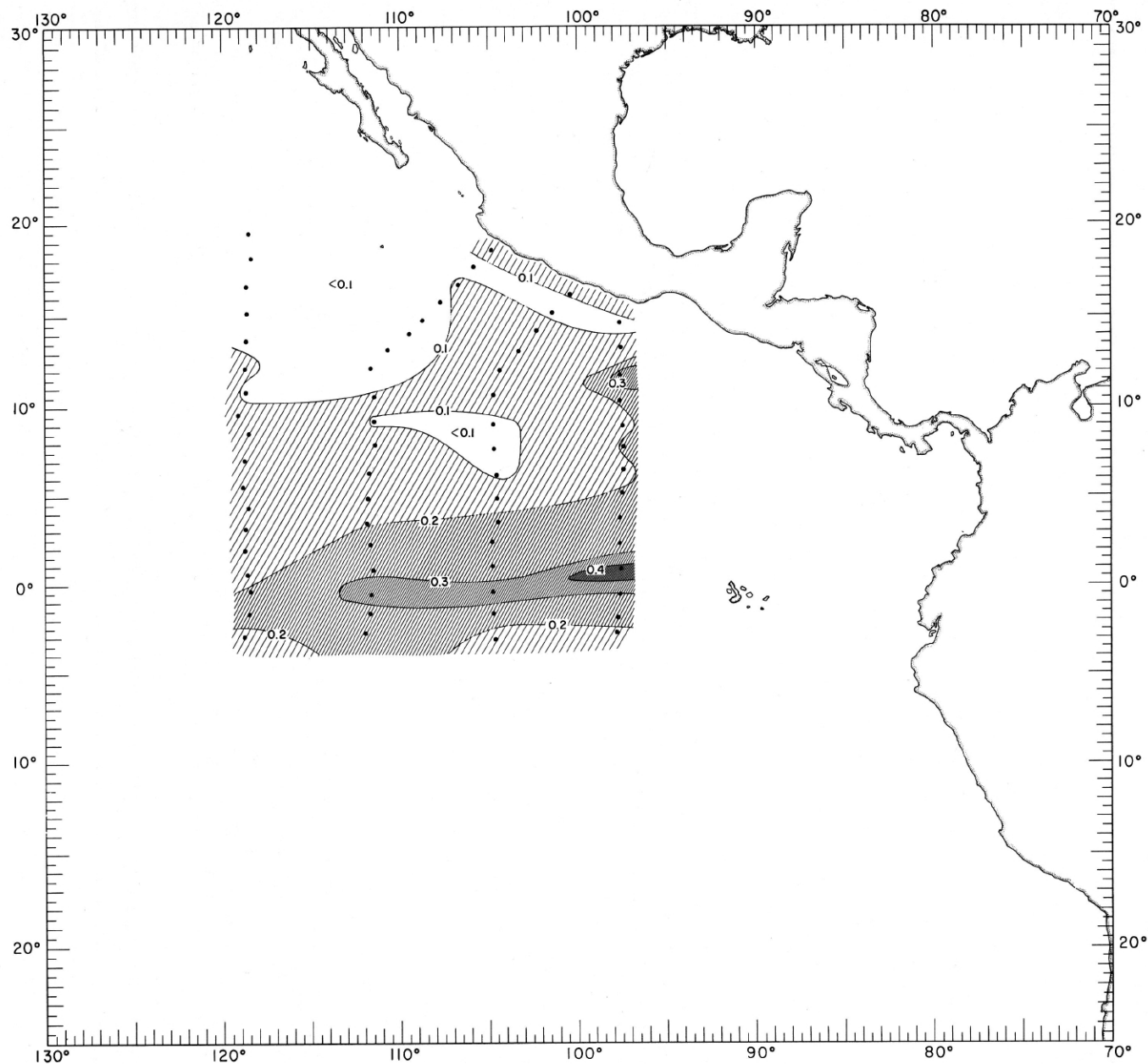
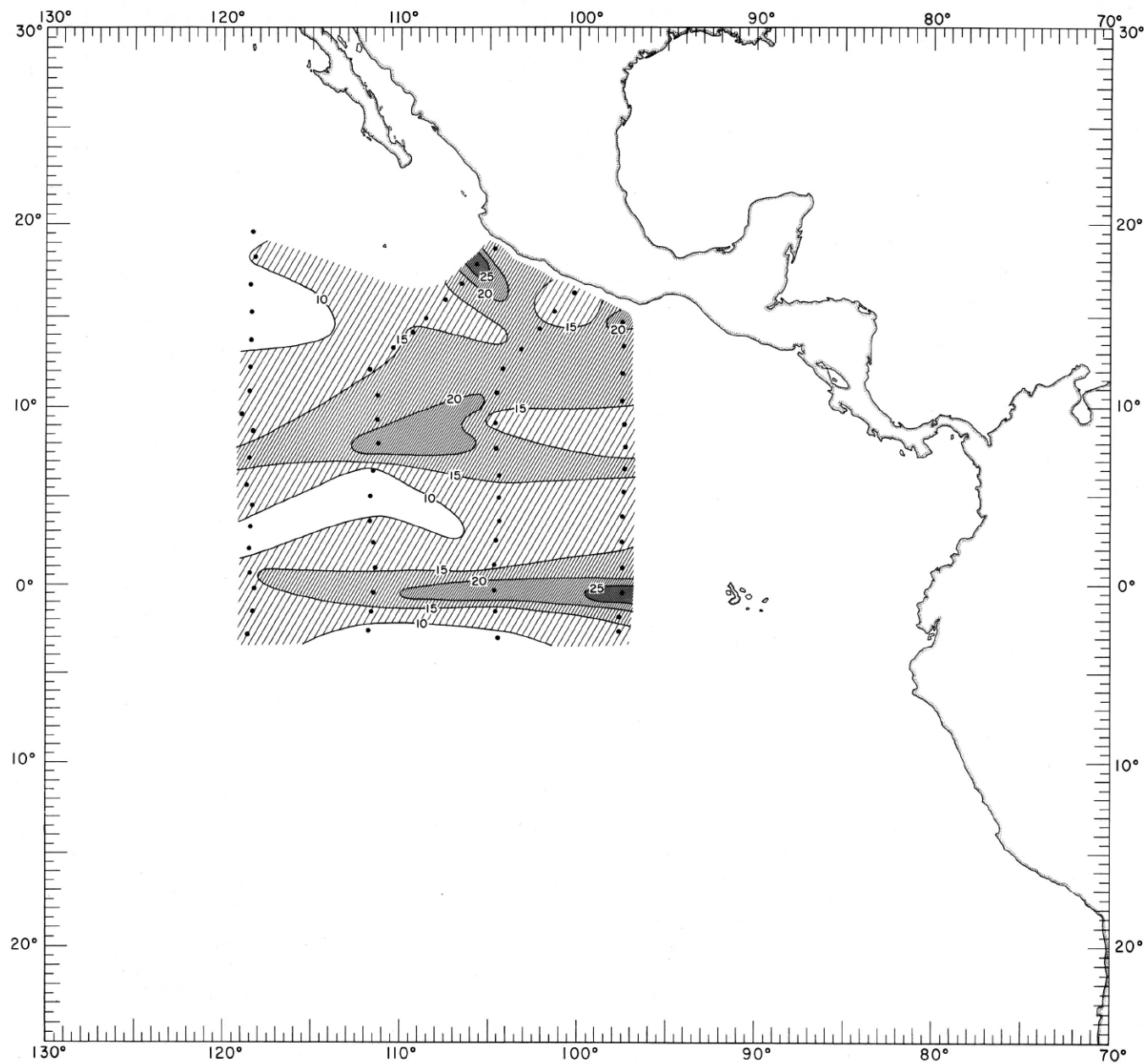


FIGURE 30-NH<sub>3</sub>-100. — Ammonia-nitrogen ( $\mu\text{g-at./l.}$ ) at 100 meters, June-July 1967. Because the distribution is so irregular no contours have been drawn. Instead, the concentration at each station is shown.



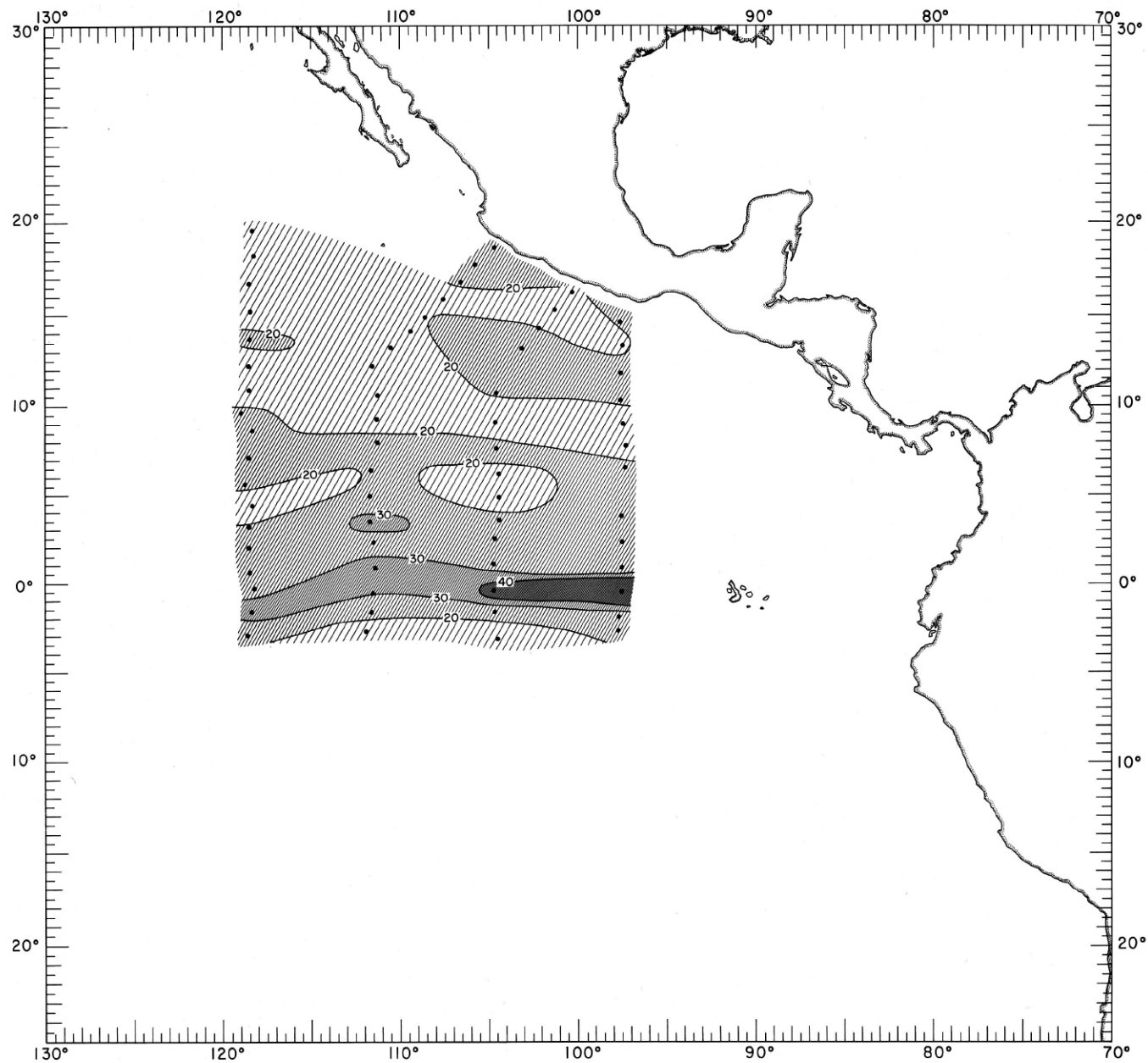
30-Ch-s.

FIGURE 30-Ch-s. — Chlorophyll-a (mg./m.<sup>3</sup>) at the sea surface, June-July 1967.



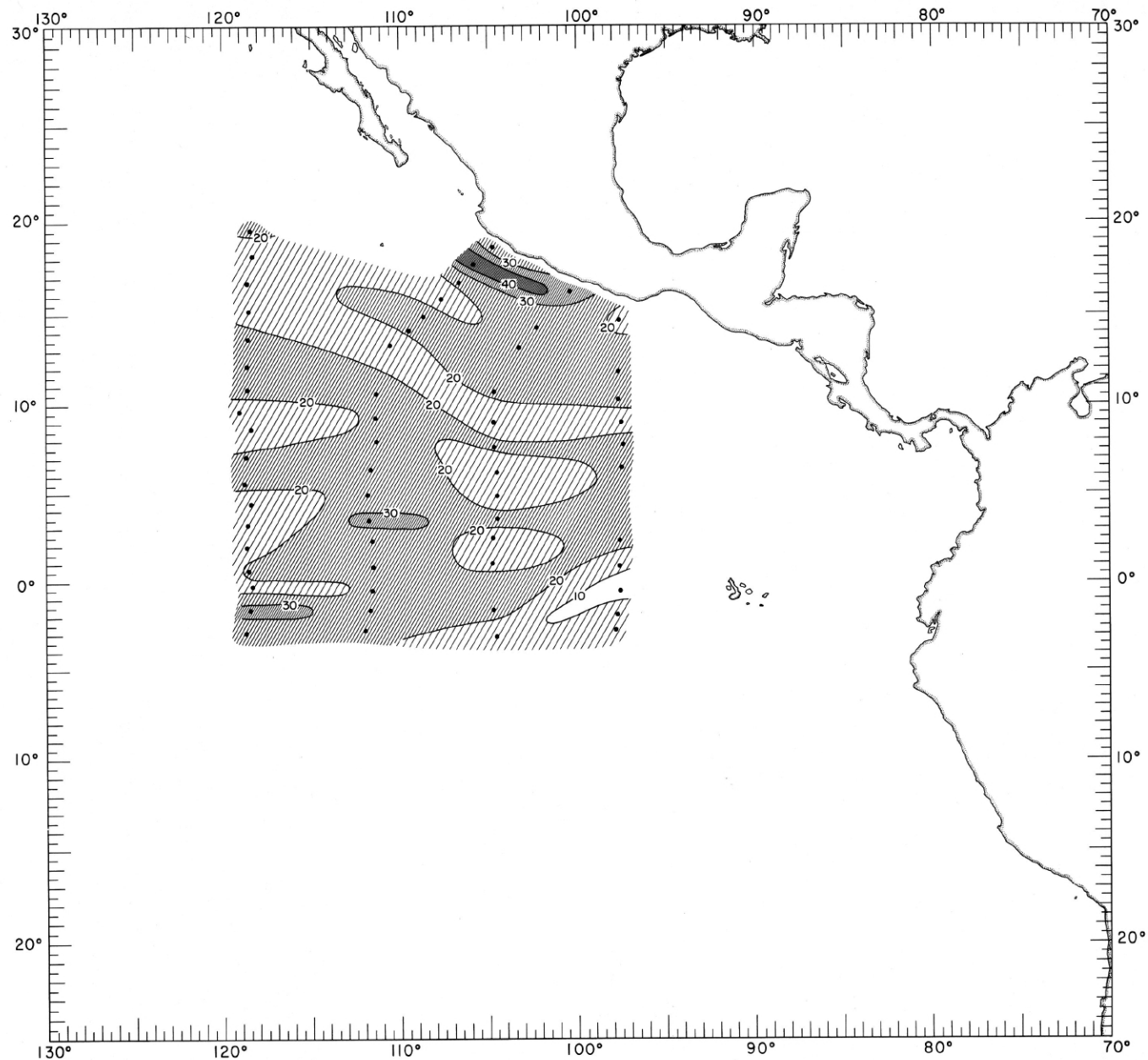
30-Ch-ei.

FIGURE 30-Ch-ei. — Chlorophyll-a (mg./m.<sup>3</sup>) integrated over the euphotic layer, June-July 1967.



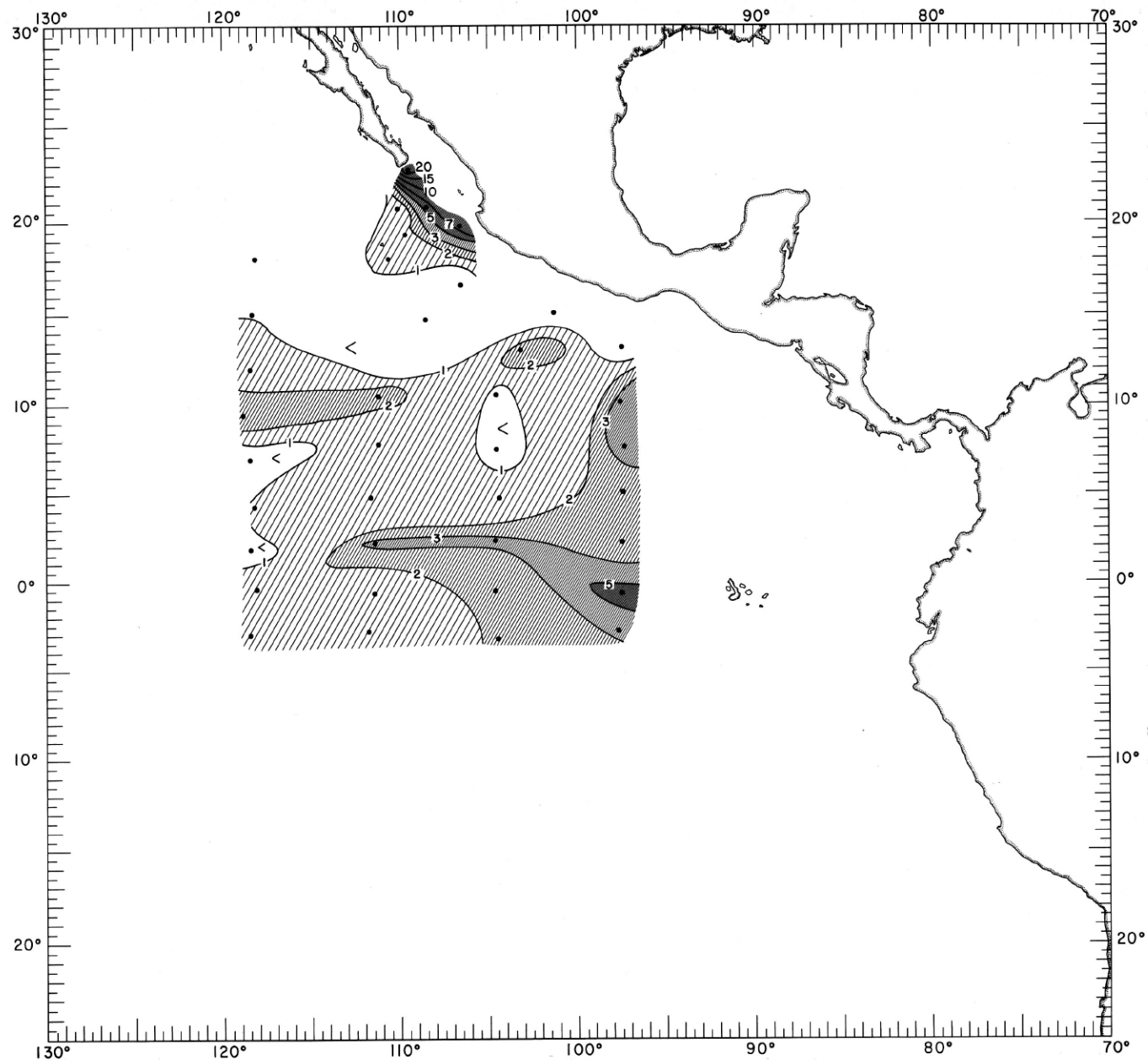
30-Ch-150i.

FIGURE 30-Ch-150i. — Chlorophyll-a (mg./m.²) integrated from the sea surface to 150 meters depth, June-July 1967.



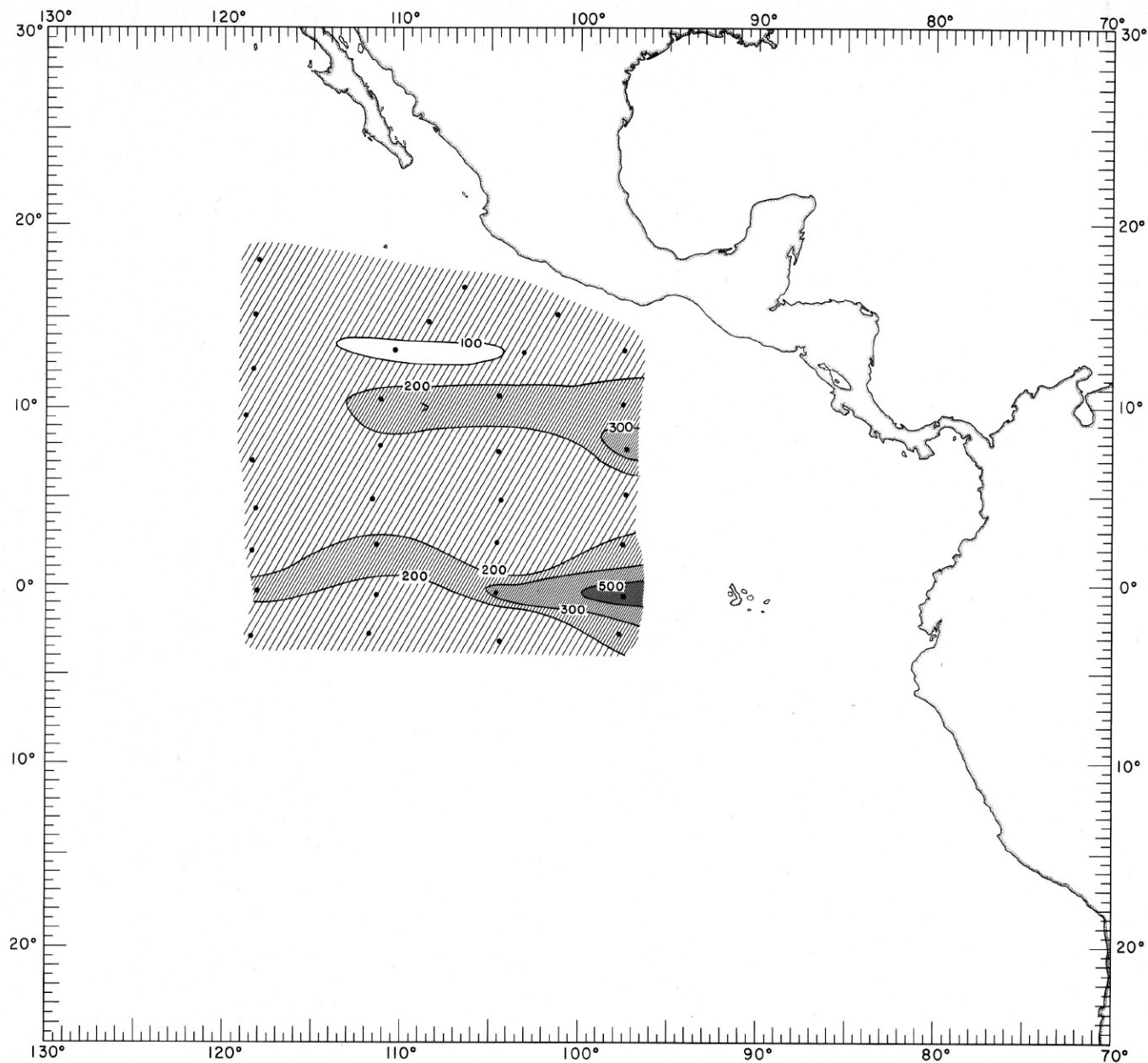
30-Ph-150i.

FIGURE 30-Ph-150i. — Phaeophytin (mg./m.²) integrated from the sea surface to 150 meters depth, June-July 1967.



30-PP-s.

FIGURE 30-PP-s. — Primary production (mg.C/m.<sup>2</sup>/day) at the sea surface, June-July 1967.



30-PP-ei.

FIGURE 30-PP-ei. — Primary production (mg.C/m.<sup>2</sup>/day) integrated over the euphotic layer, June-July 1967.

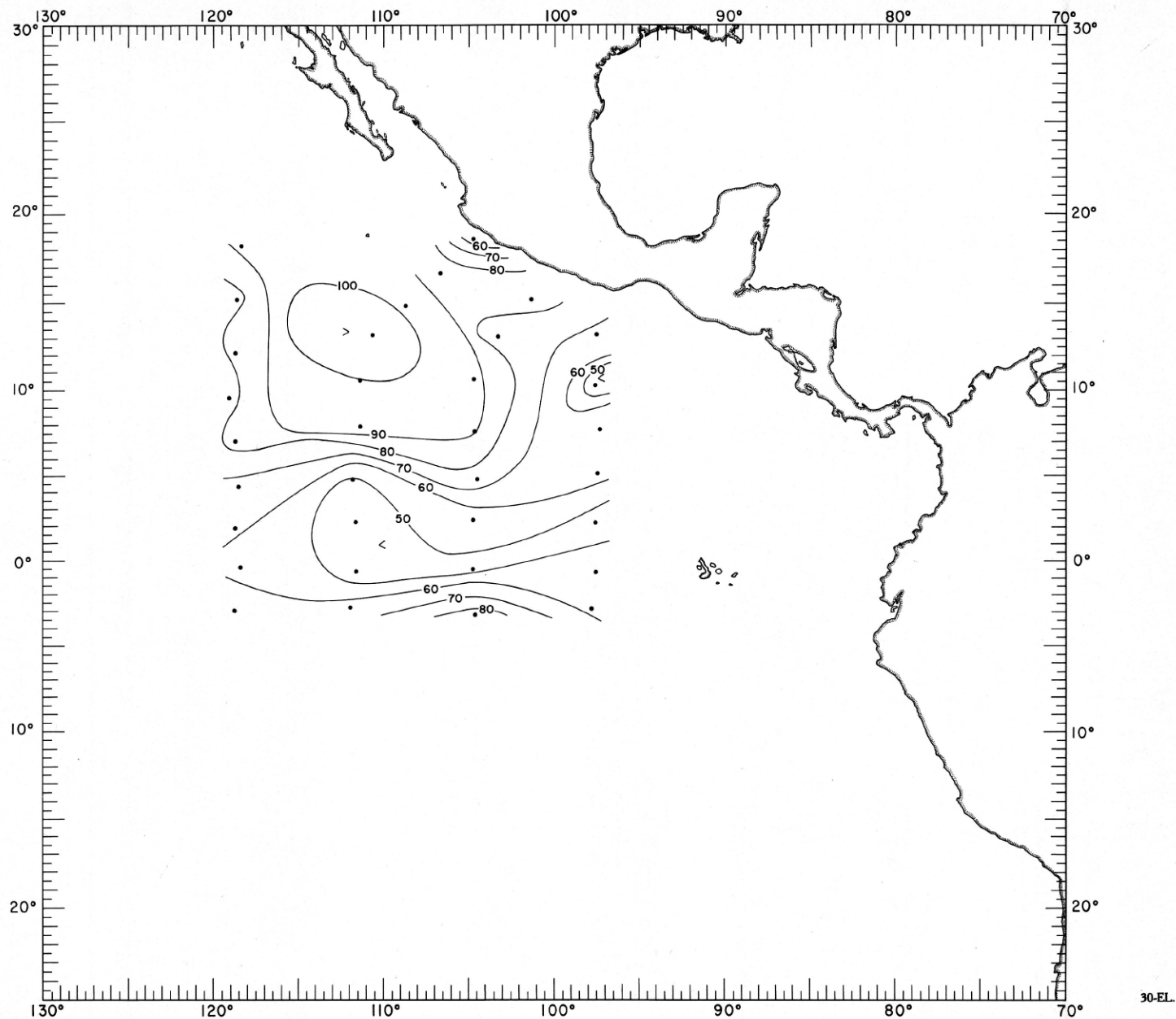
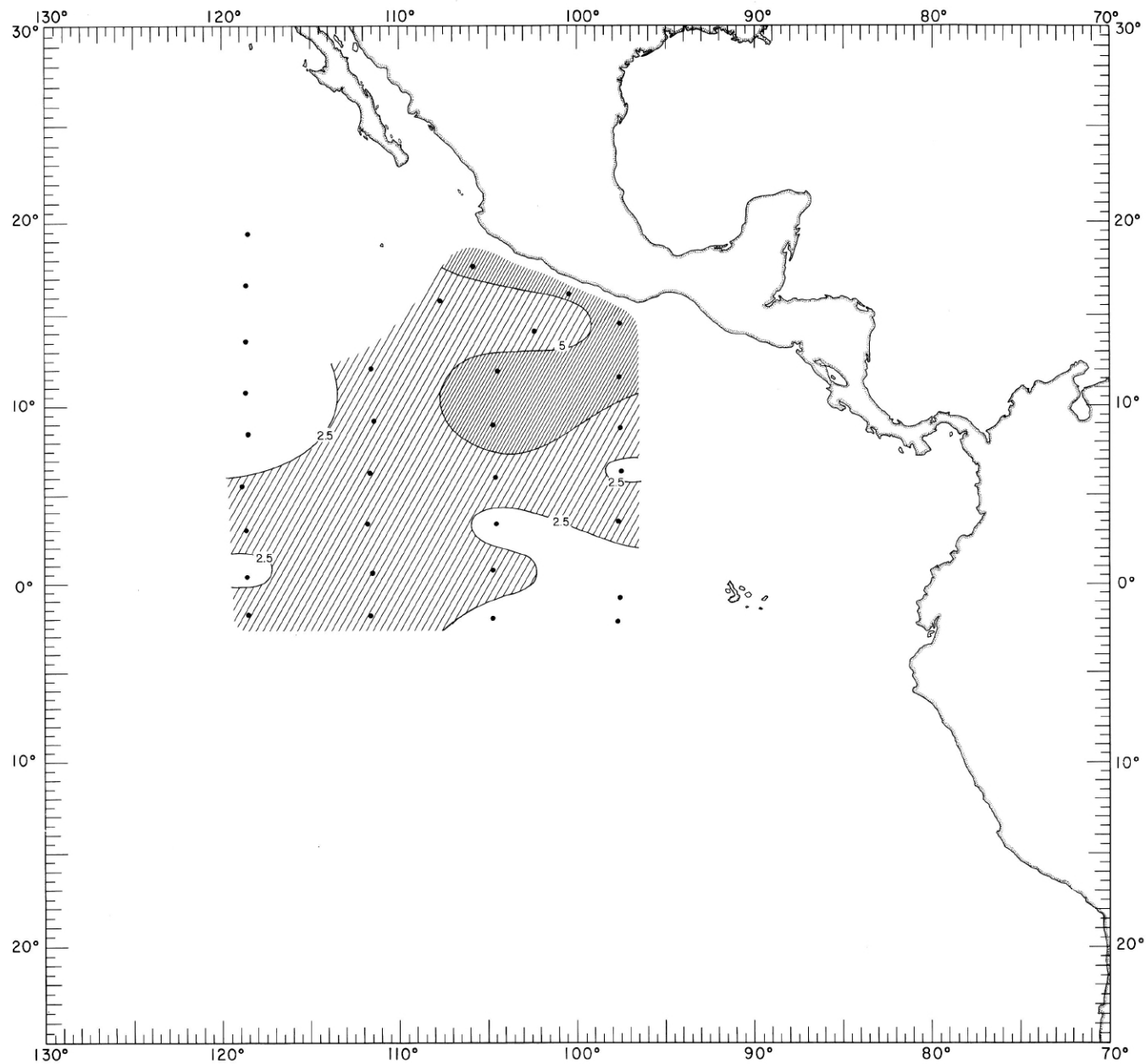


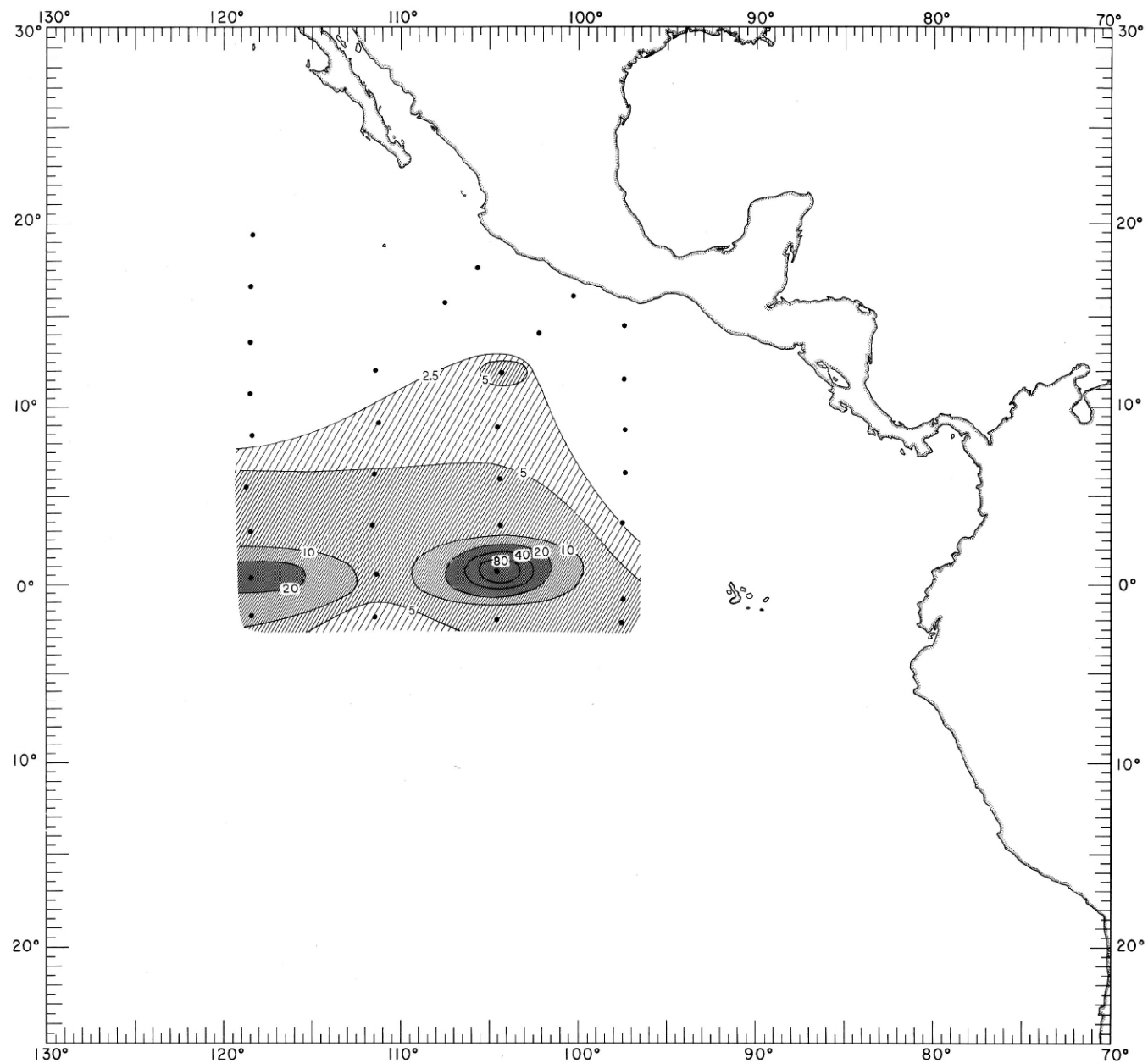
FIGURE 30-EL. — Thickness of the euphotic layer in meters, June-July 1967.





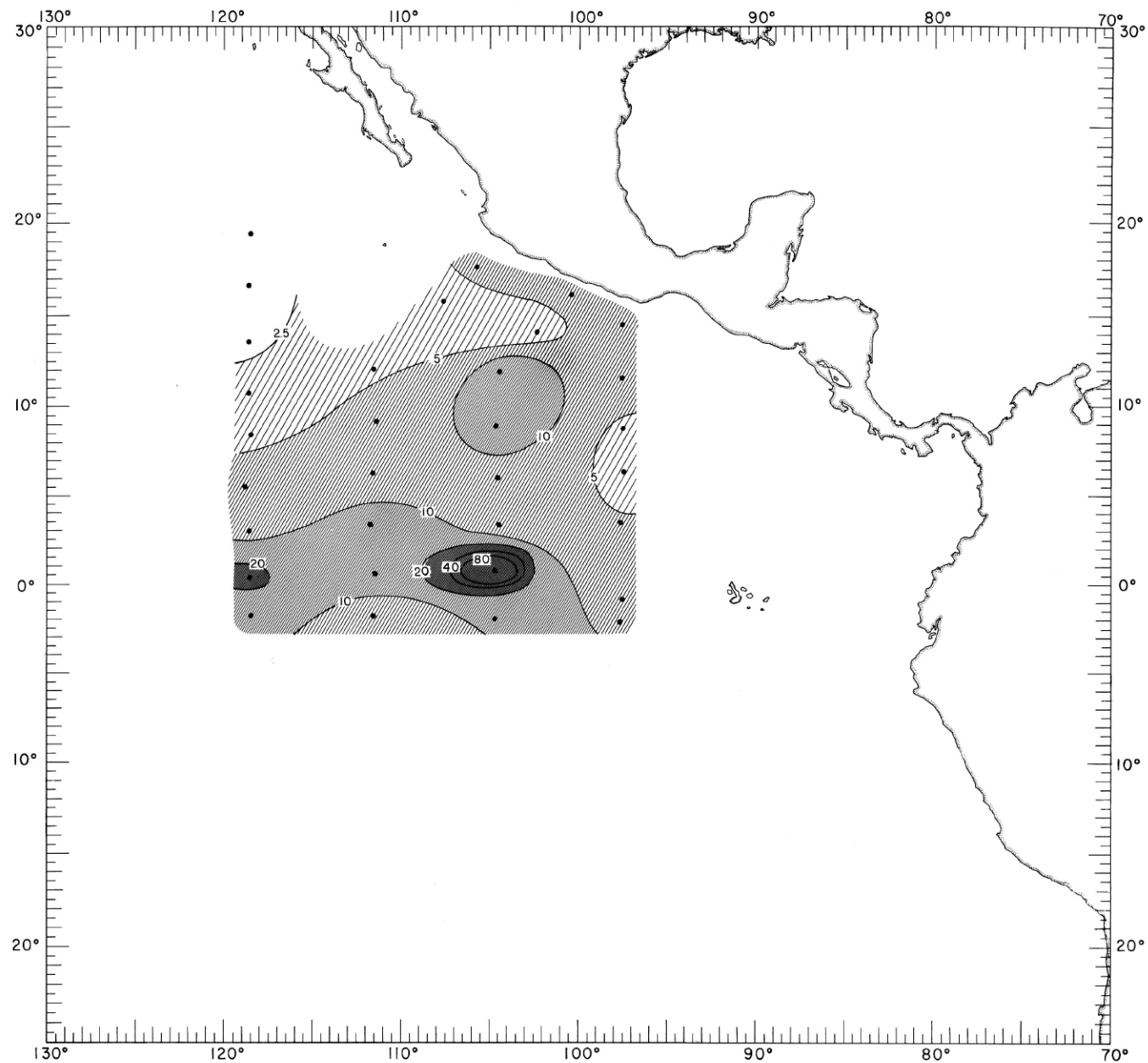
30-FCp.

FIGURE 30-FCp. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of total fish and cephalopods taken in night micronekton hauls during June-July 1967.



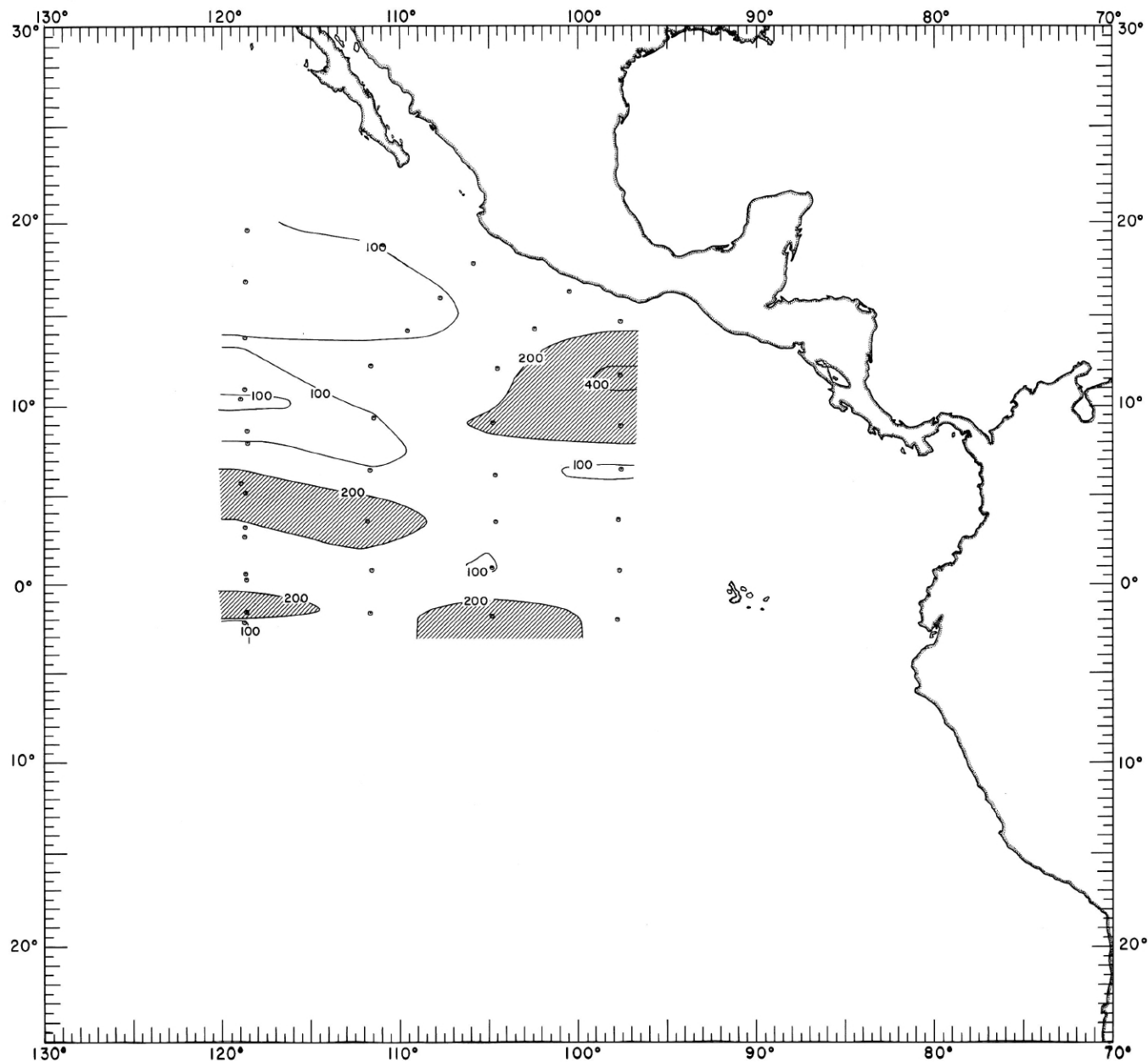
30-Cr.

FIGURE 30-Cr. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of total crustaceans taken in night micronekton hauls during June-July 1967.



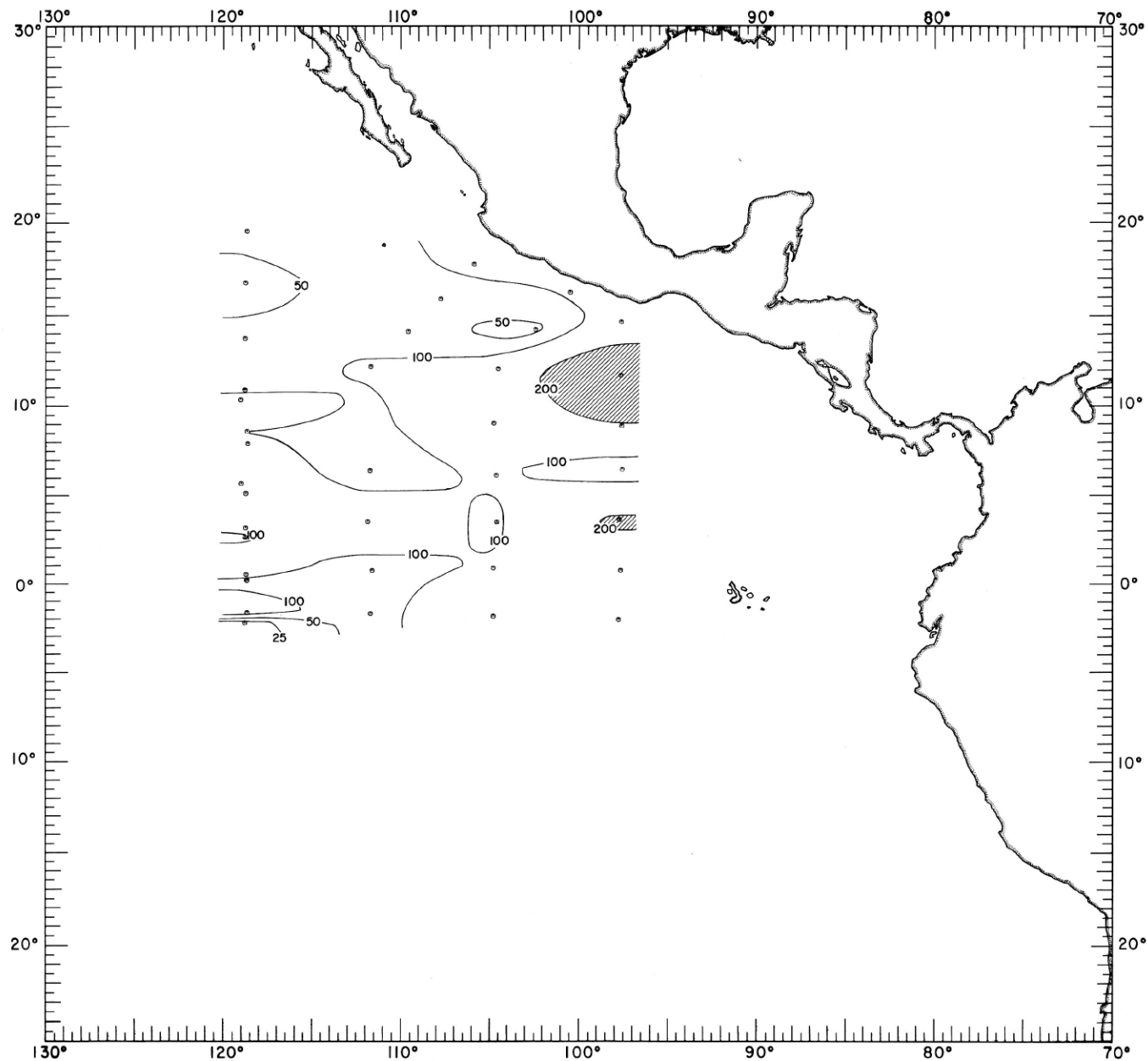
30-Nk.

FIGURE 30-Nk. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of total micronekton taken in night micronekton hauls during June-July 1967.



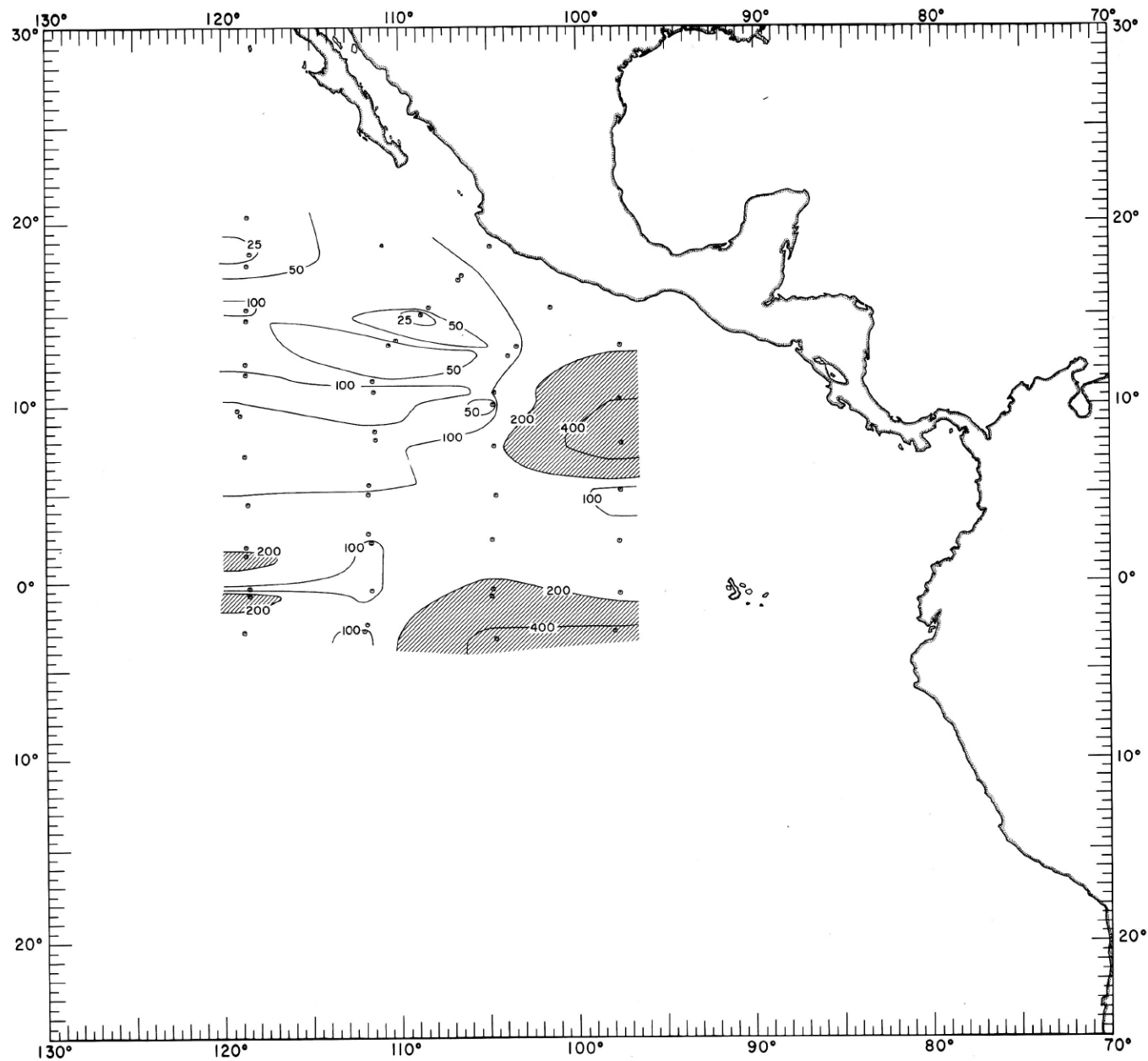
30-ZhN.

FIGURE 30-ZhN. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 50-cm. net hauls at night, June-July 1967.



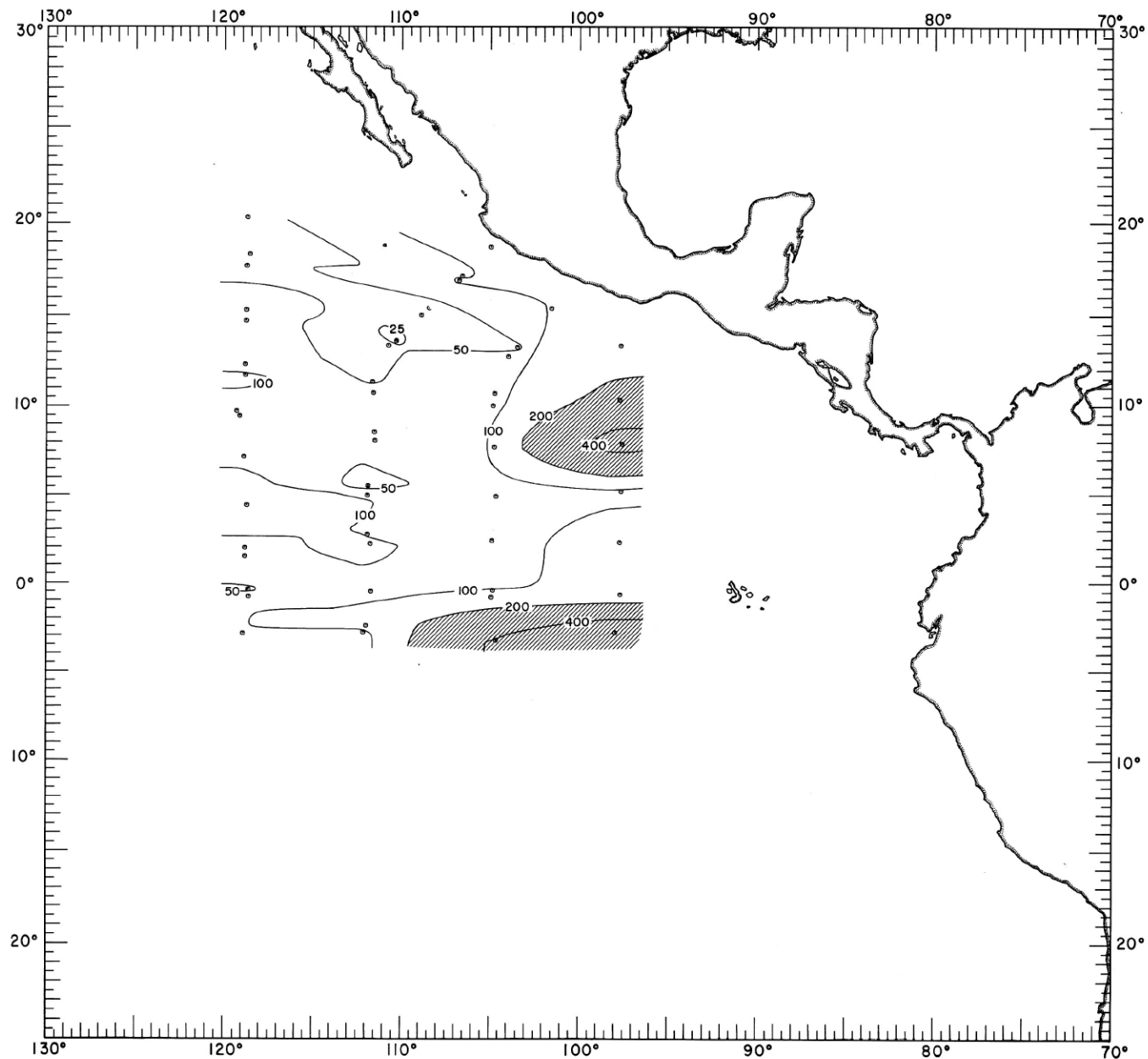
30-ZIN.

FIGURE 30-ZIN. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 1-m. net hauls at night, June-July 1967.



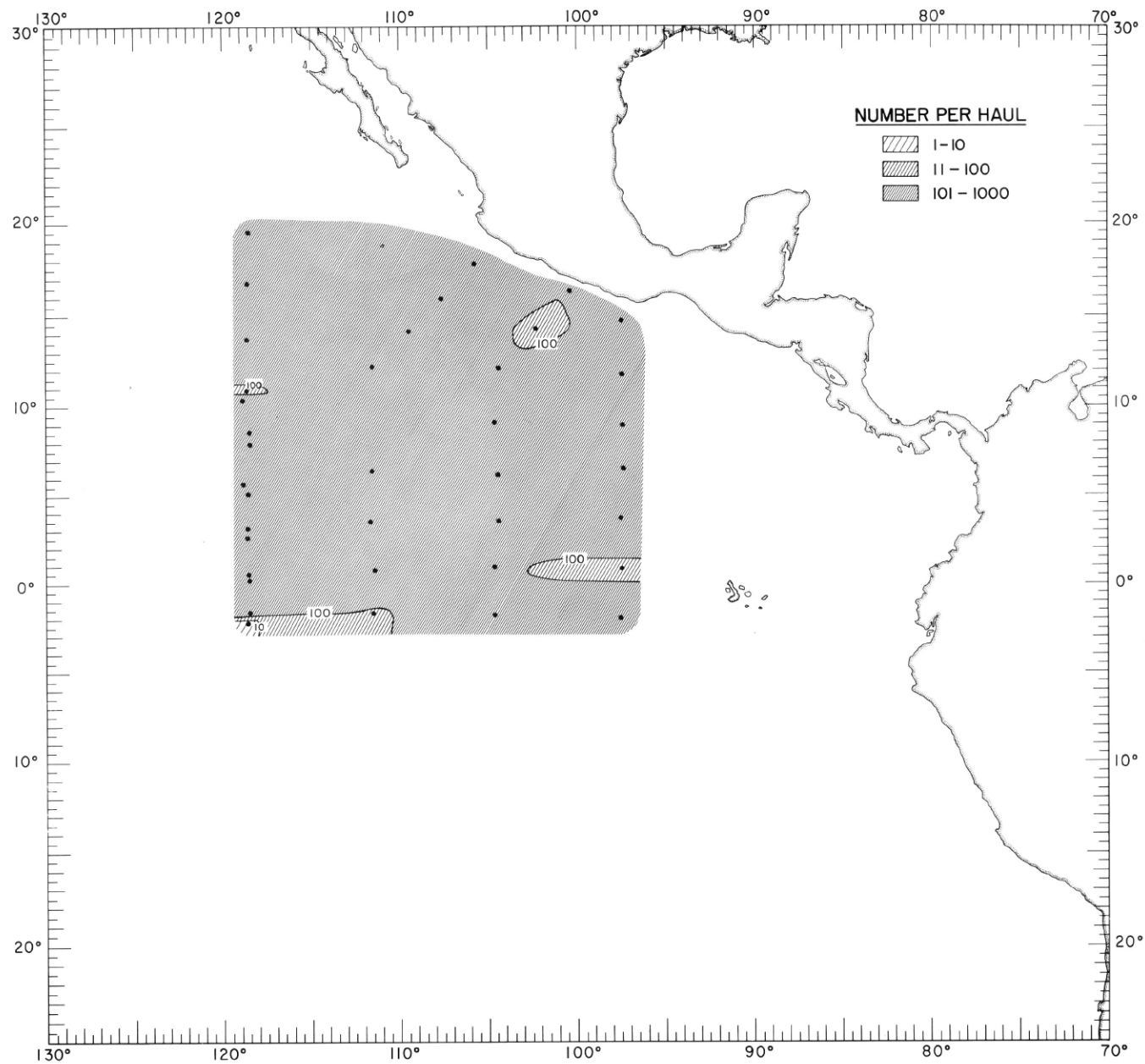
30-ZhD.

FIGURE 30-ZhD. —Distribution of standing stock (ml./1,000 m.) of zooplankton taken in 50-cm. net hauls during the day, June-July 1967.



30-Z1D.

FIGURE 30-Z1D. — Distribution of standing stock (ml./1,000 m.<sup>3</sup>) of zooplankton taken in 1-m. net hauls during the day, June-July 1967.



30-FLN.

FIGURE 30-FLN. — Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls at night during June-July 1967.



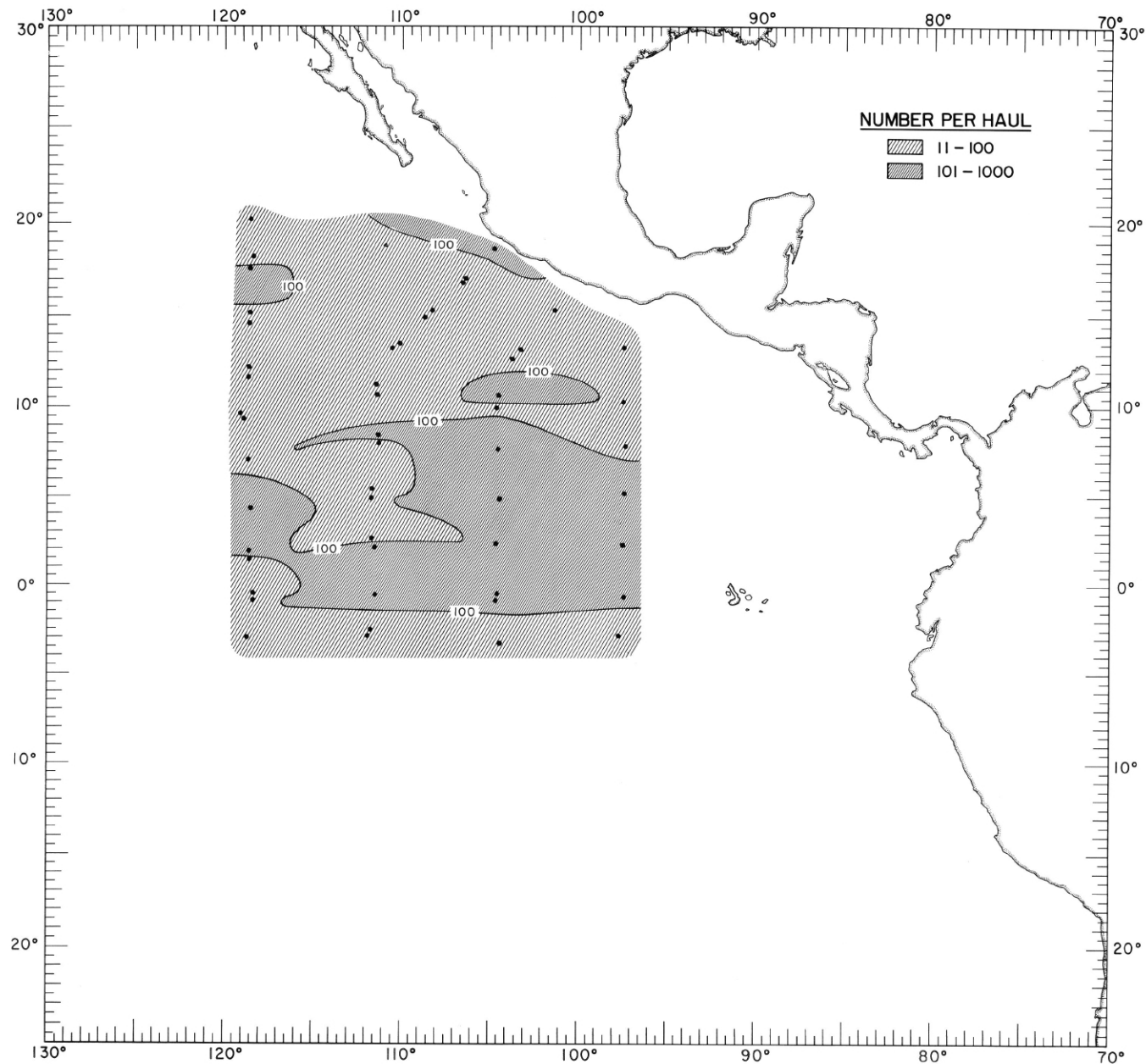
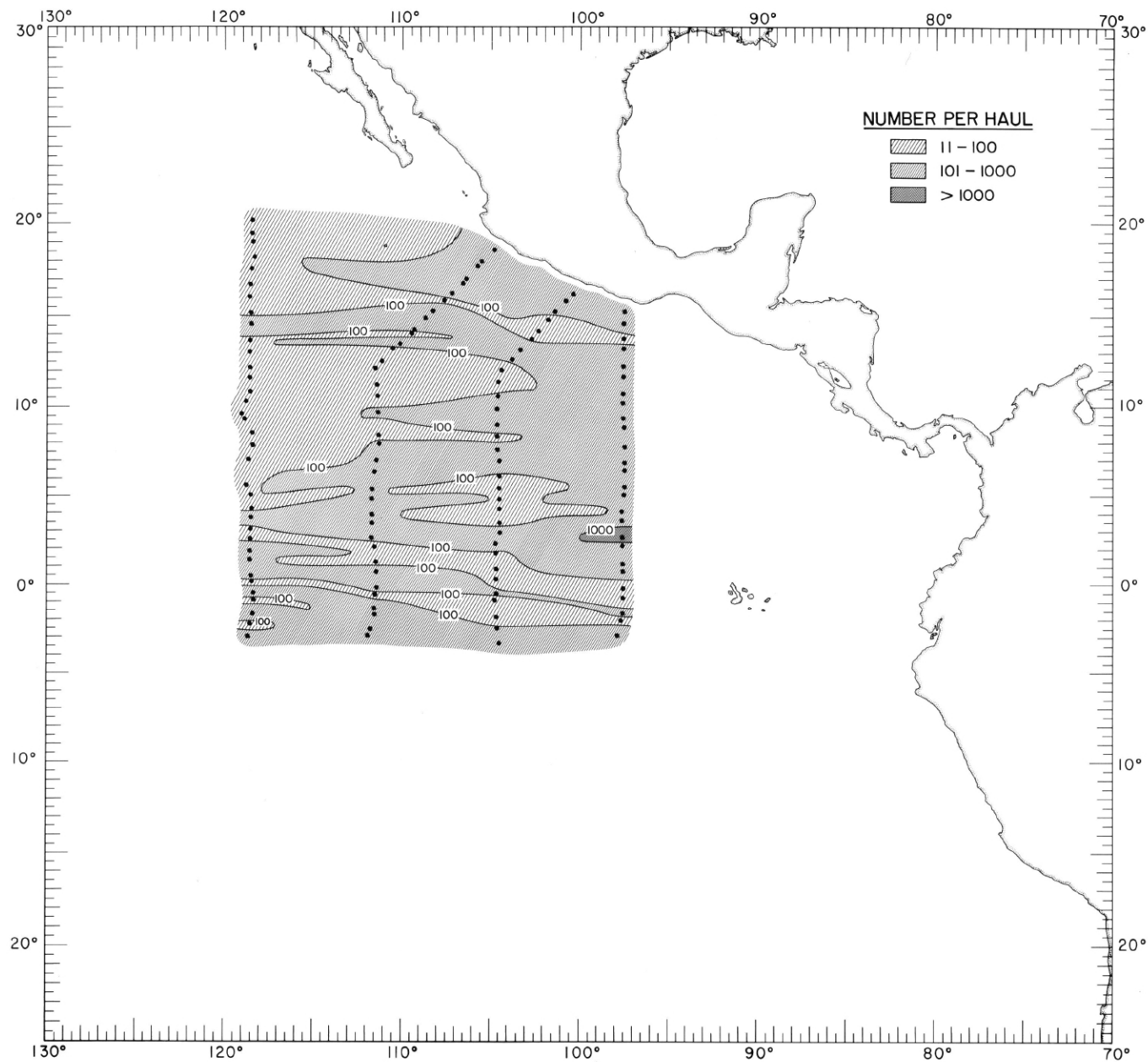
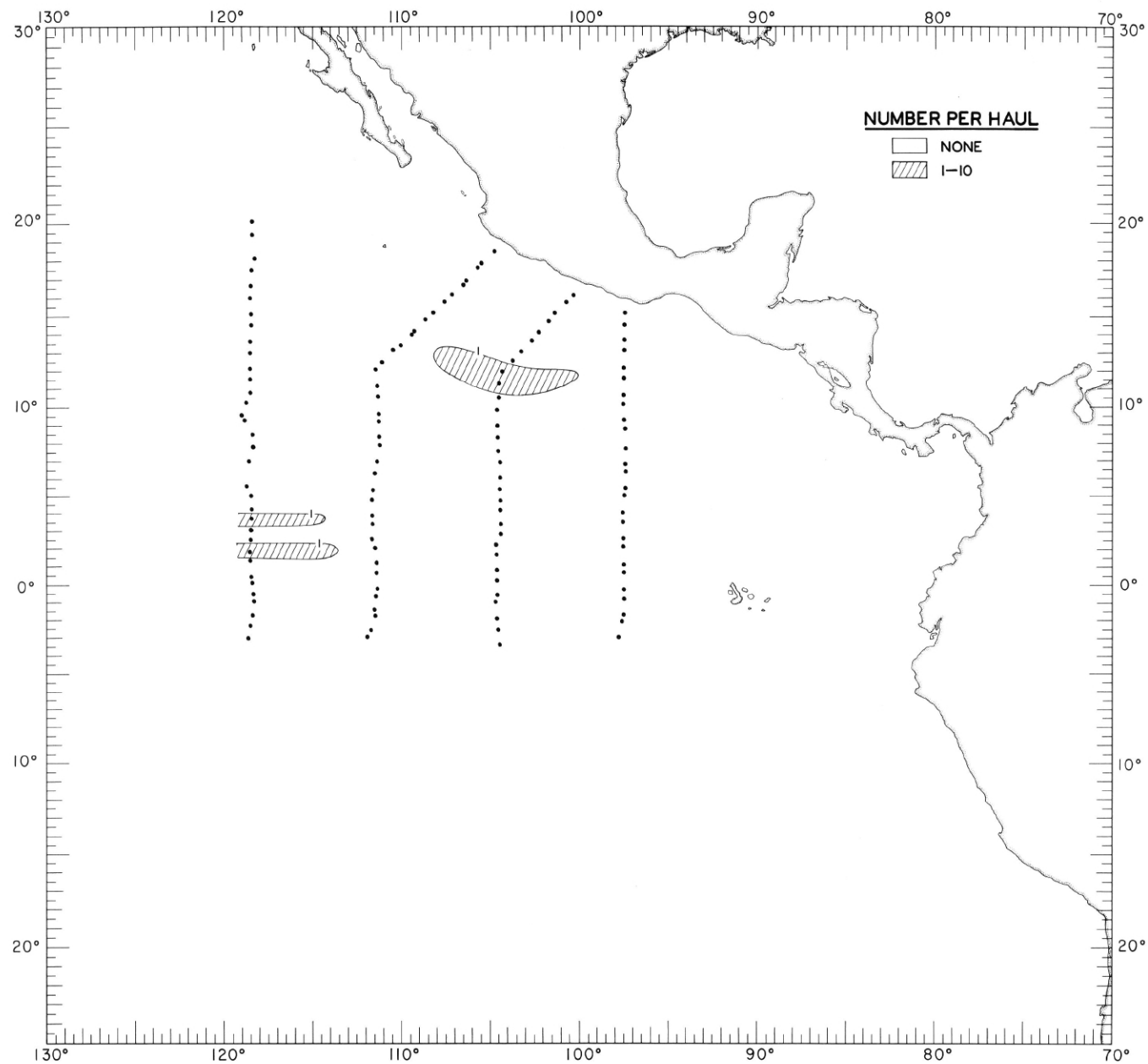


FIGURE 30-FLD. — Total fish larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, June-July 1967.



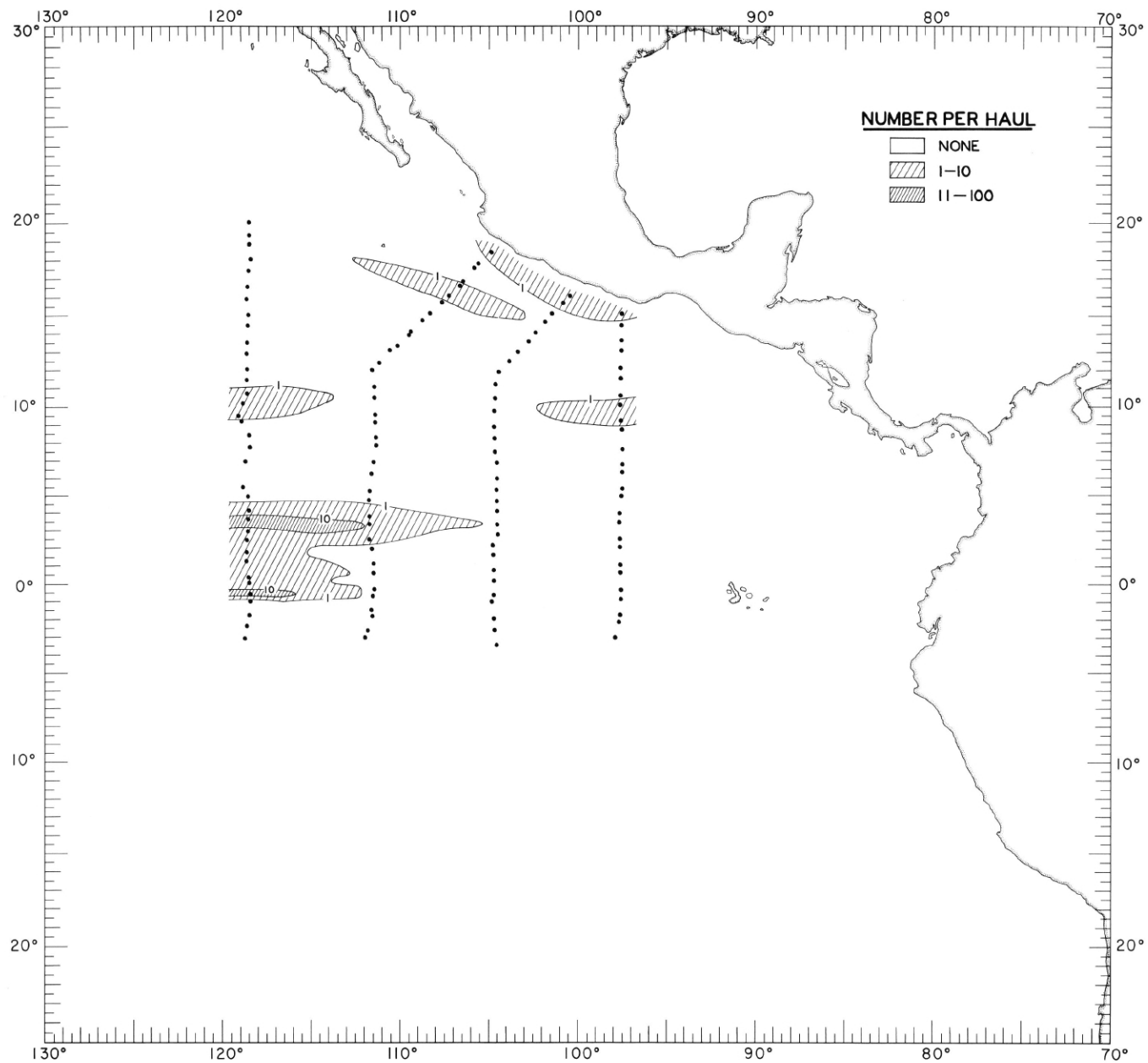
30-FE.

FIGURE 30-FE. — Total fish eggs (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.



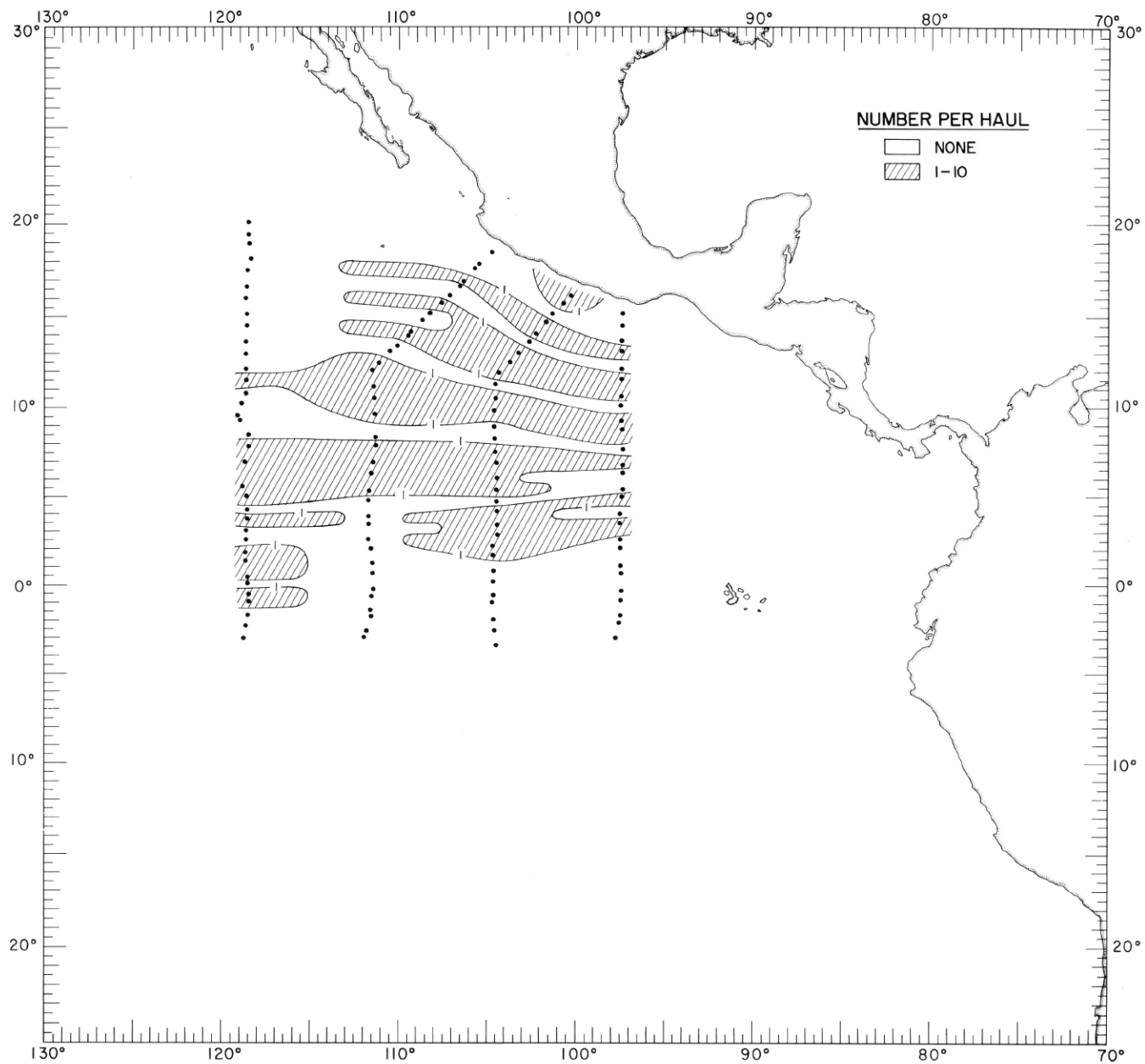
30-FS.

FIGURE 30-FS. — Total skipjack tuna, *Katsuwonus pelamis*, larvae (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967



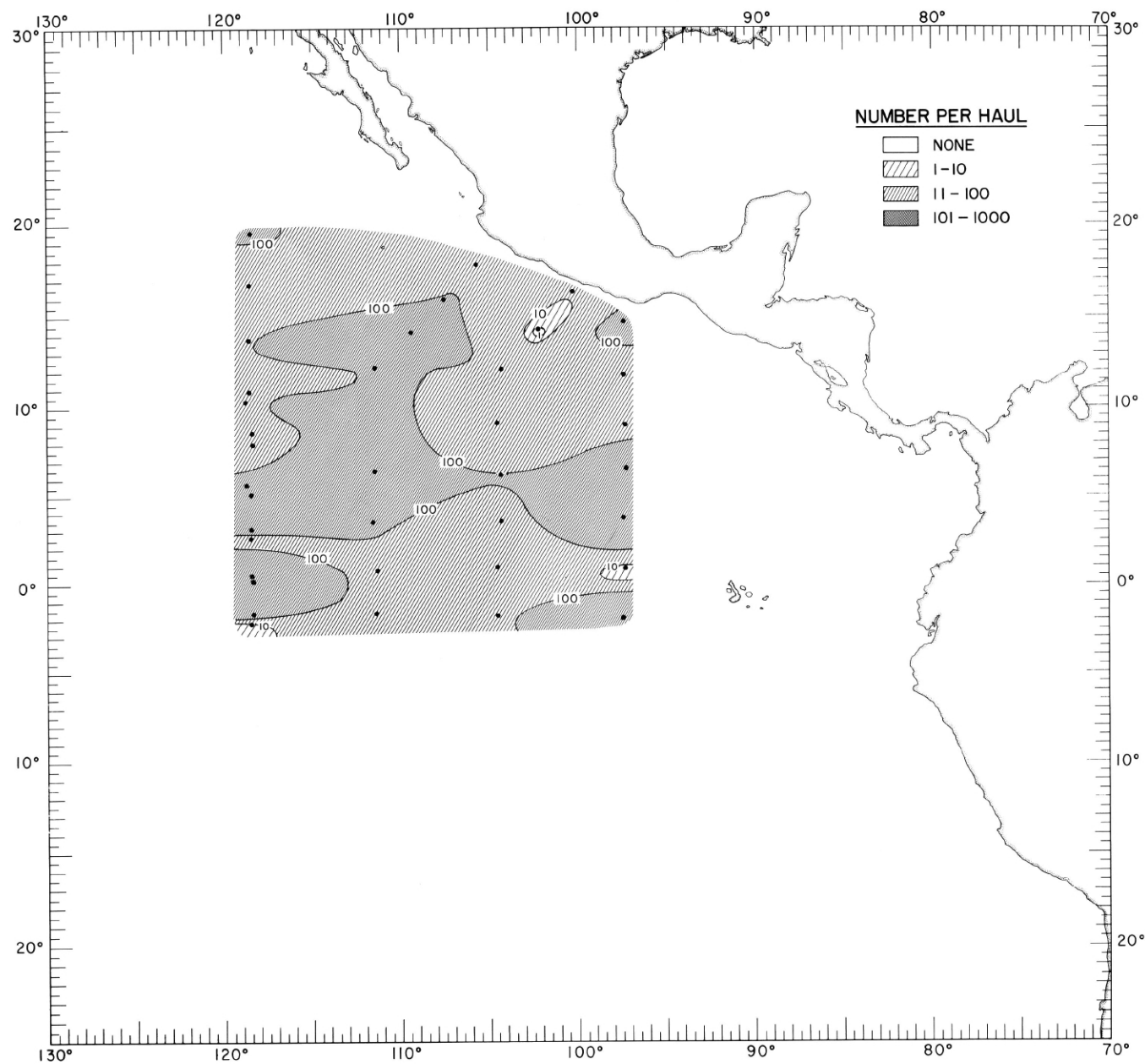
30-FA.

FIGURE 30-FA. — Total frigate mackerel, *Auxis*, larvae (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.



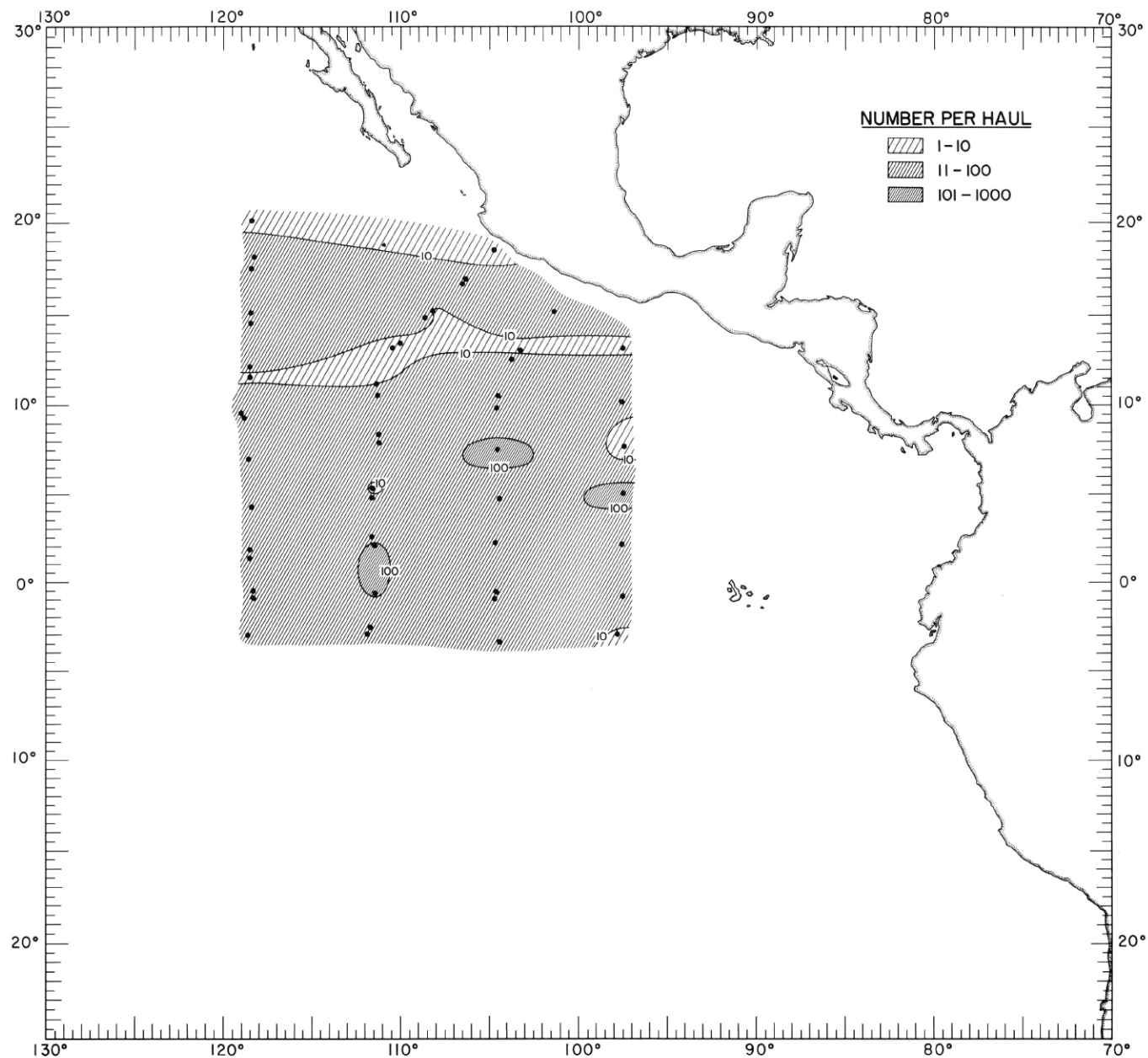
30-FC.

FIGURE 30-FC. — Total dolphin (fish), *Coryphaena*, larvae (number/haul) taken in 1-m. oblique plankton hauls during June-July 1967.



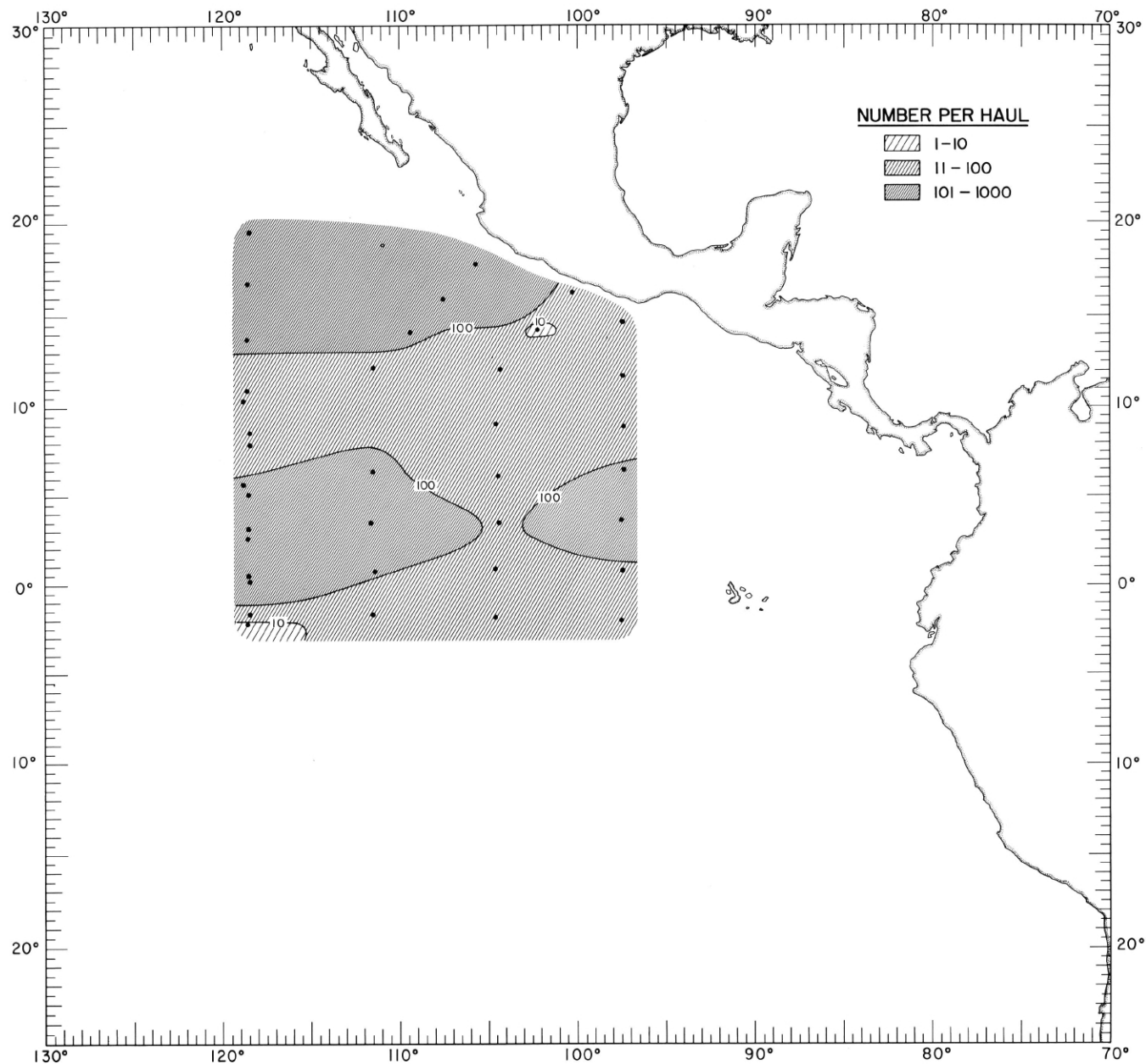
30-FMN.

FIGURE 30-FMN. — Total *Myctophid* larvae (number/haul) taken in 1-m. oblique plankton hauls at night during June-July 1967.



30-FMD.

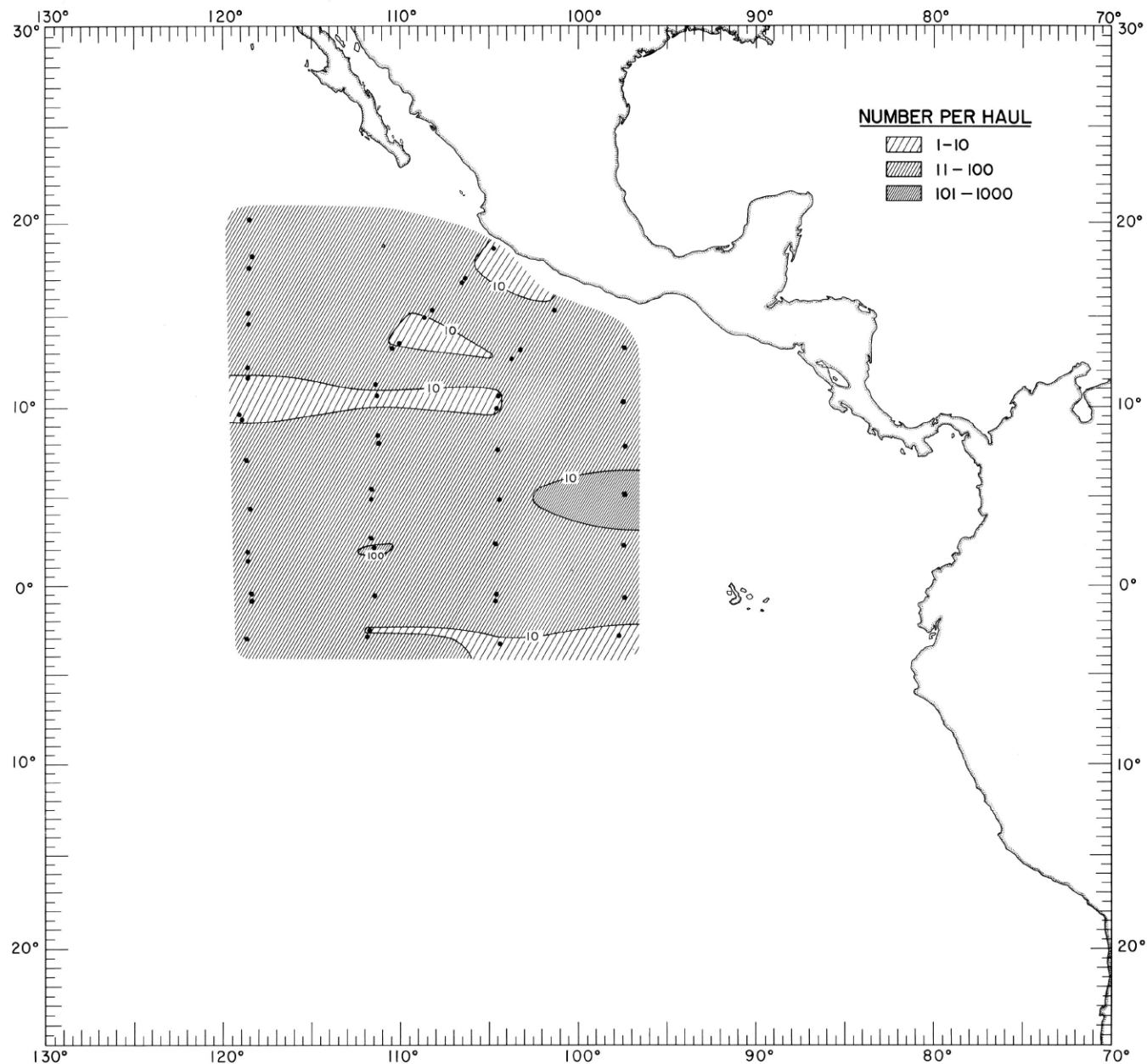
FIGURE 30-FMD. — Total *Myctophid* larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, June-July 1967.



30-FGN.

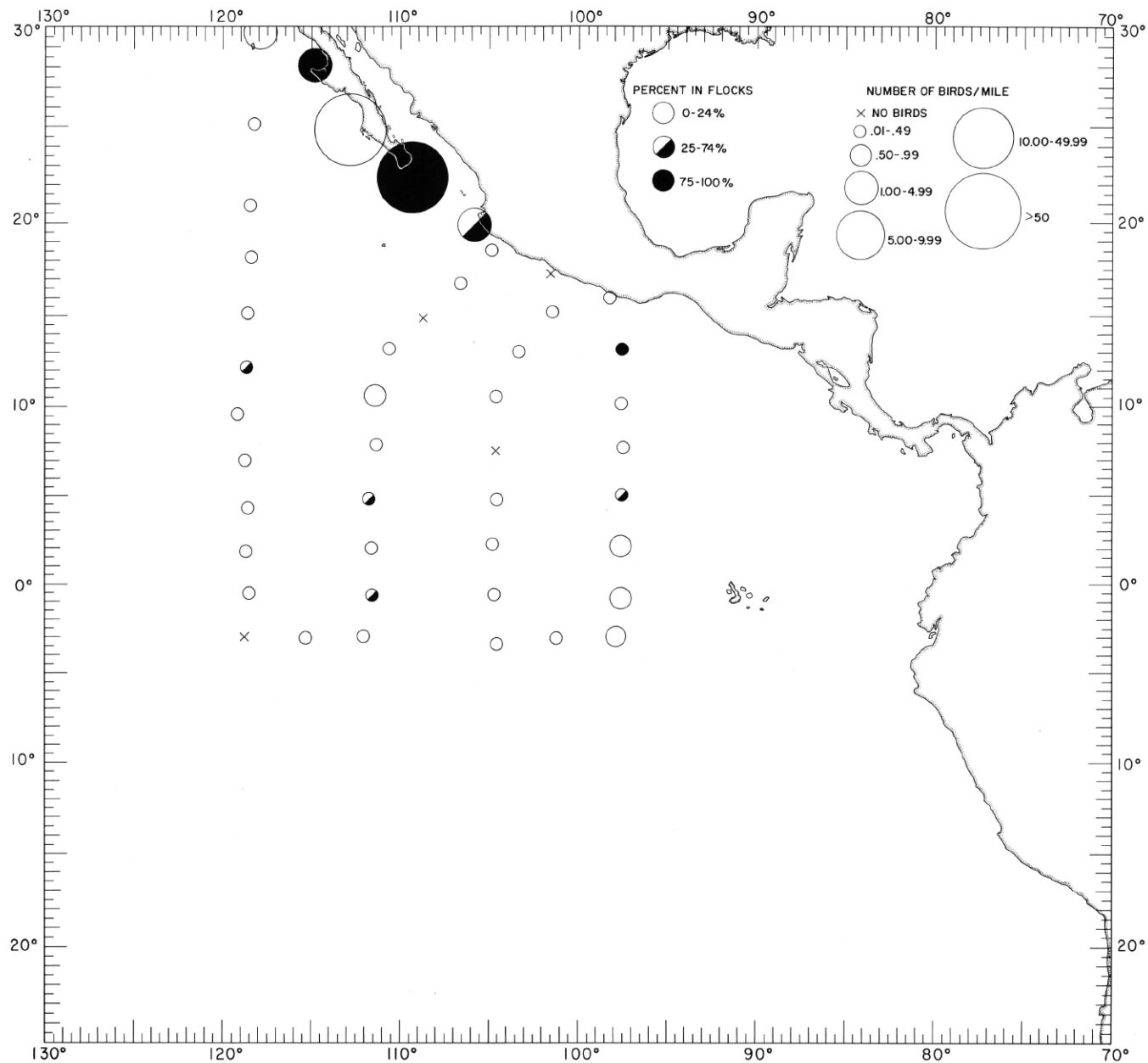
FIGURE 30-FGN. — Total *Gonostomatid* and *Sternoptychid* larvae (number/haul) taken in 1-m. oblique plankton hauls at night during June-July 1967.





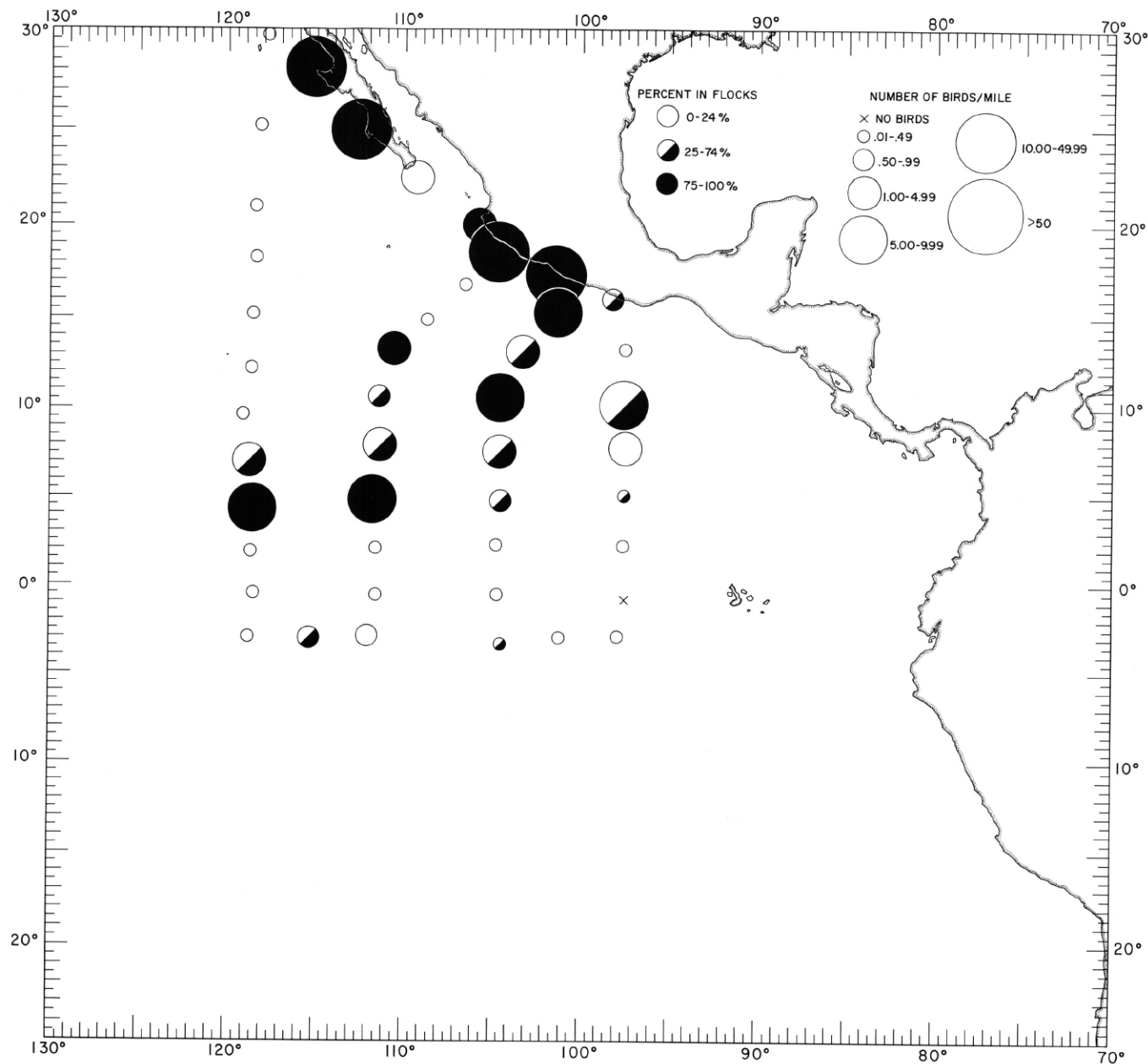
30-FGD.

FIGURE 30-FGD. — Total *Gonostomatid* and *Sternoptychid* larvae (number/haul) taken in 1-m. oblique plankton hauls during the day, June-July 1967.



30-BP.

FIGURE 30-BP. — Relative abundance of plankton-feeding birds (birds/mile), June-July 1967.



30-BF.

FIGURE 30-BF. — Relative abundance of fish and cephalopod-feeding birds (birds/mile), June-July 1967.

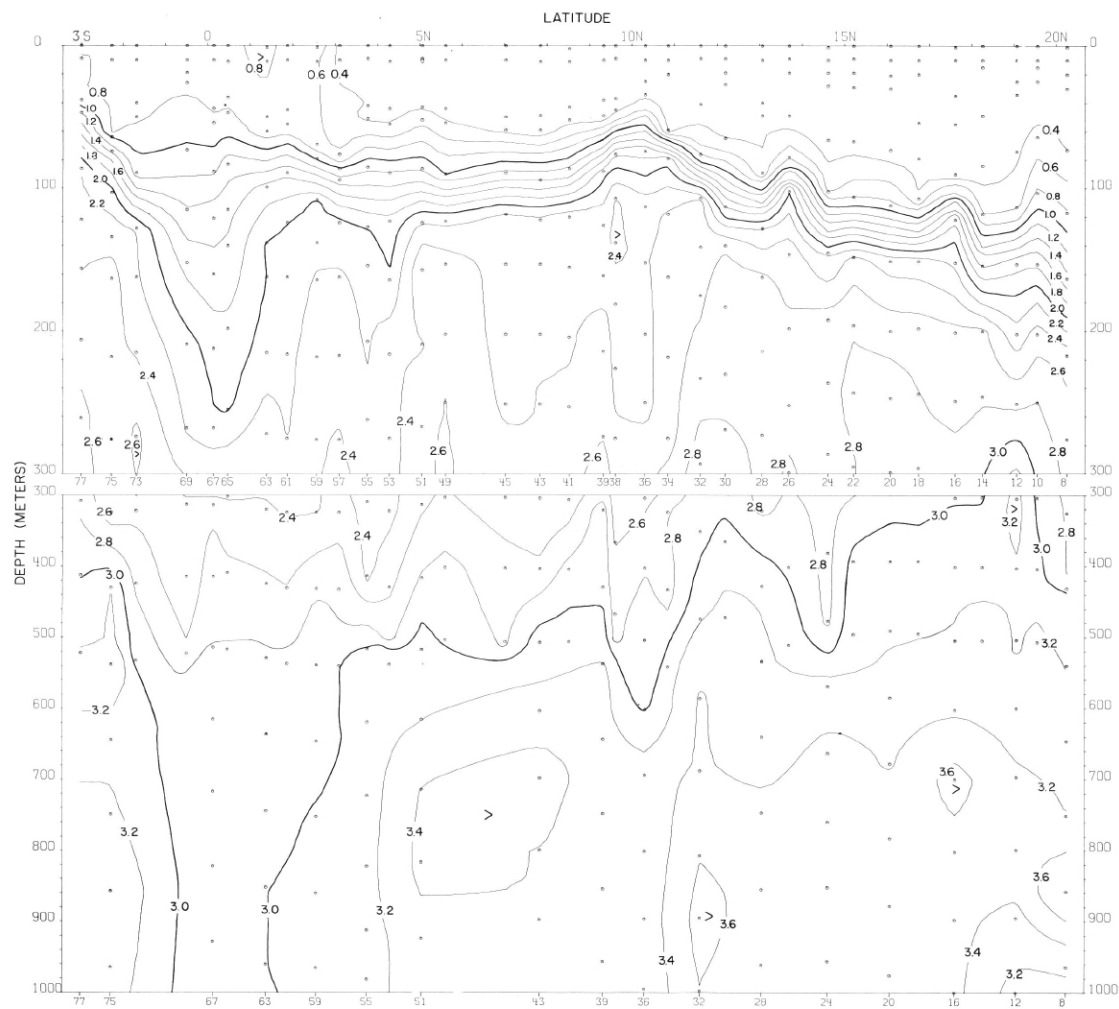
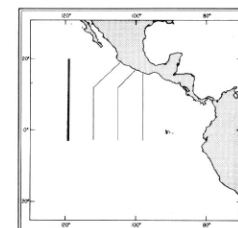


FIGURE 30-P-v1. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $118^{\circ}30' \text{ W.}$ , June 17-26, 1967.



30-P-v1.

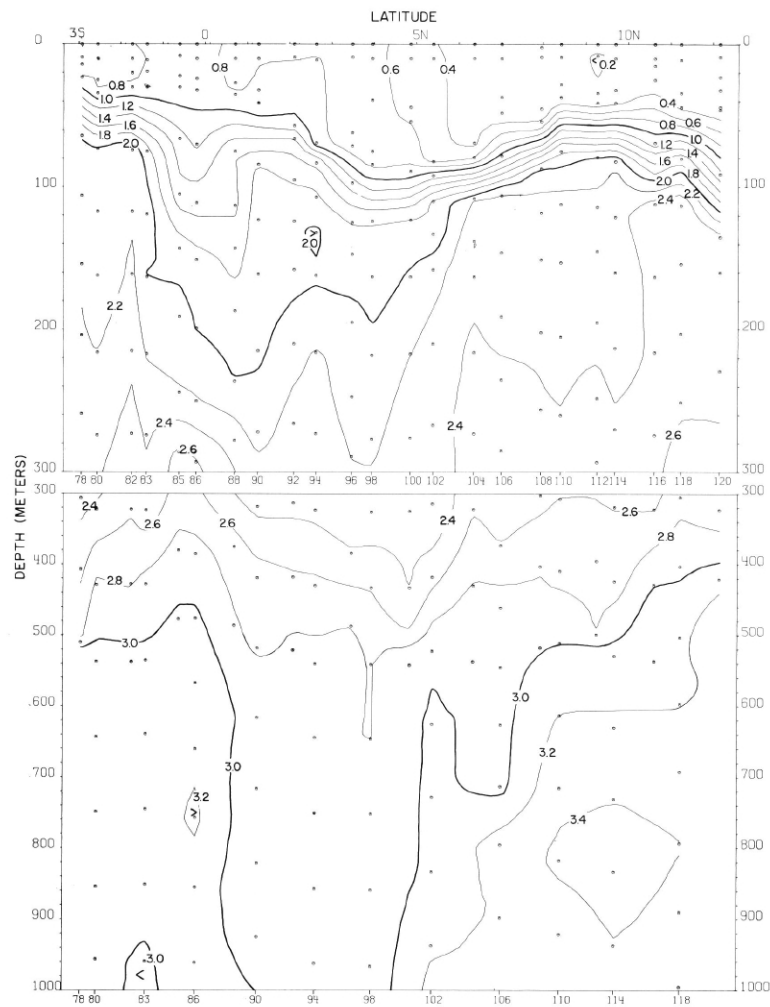


FIGURE 30-P-v2. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $111^{\circ}30' \text{ W.}$ , June 28-July 4, 1967.

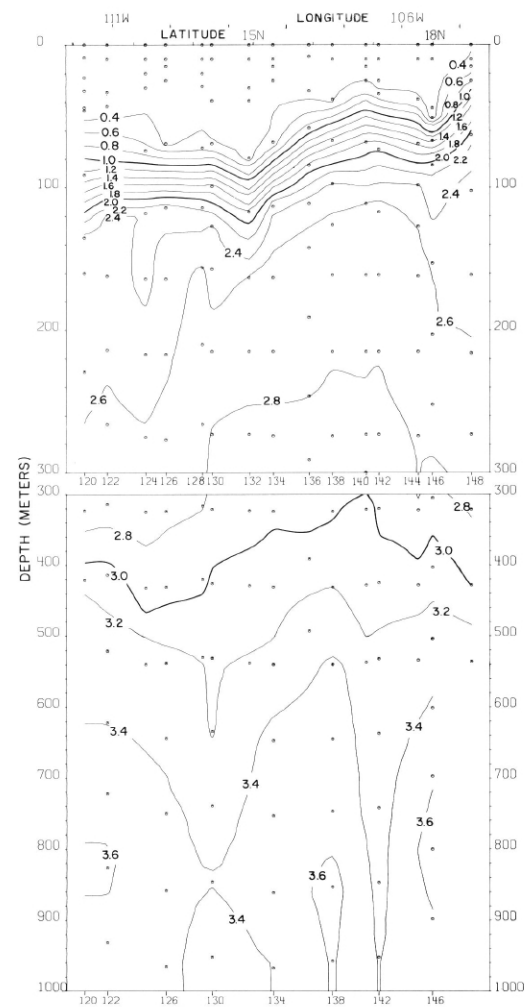
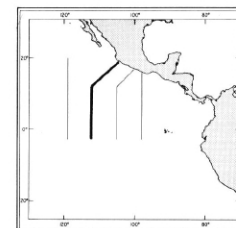


FIGURE 30-P-v3. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $111^{\circ}30' \text{ W.}$  to Manzanillo, July 4-7, 1967.



30-P-v2.

30-P-v3.

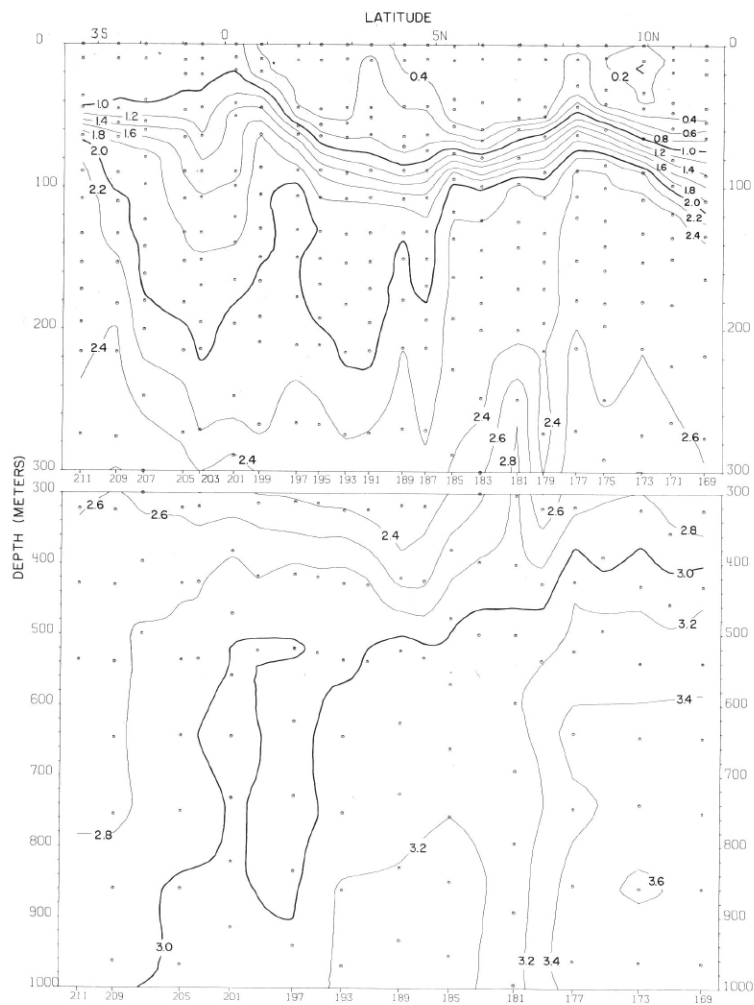


FIGURE 30-P-v5. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $104^{\circ}30' \text{ W.}$ , July 13-18, 1967.

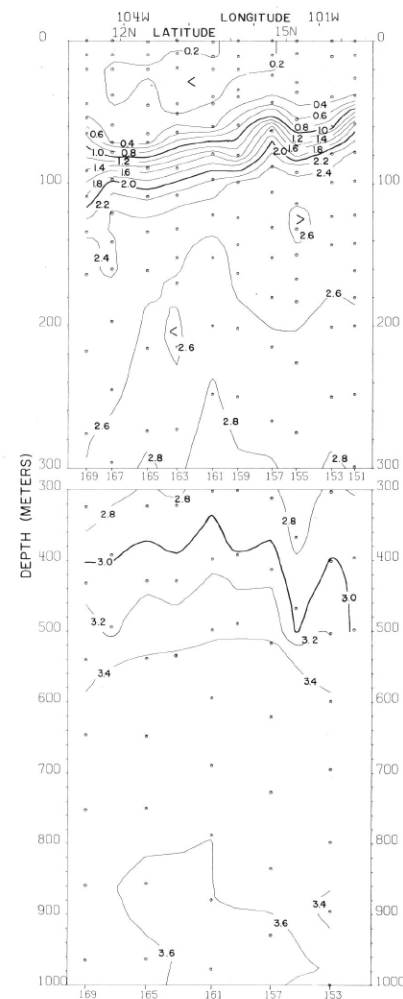
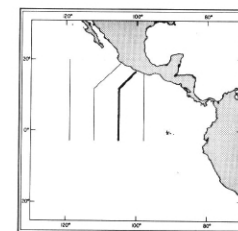


FIGURE 30-P-v4. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $104^{\circ}30' \text{ W.}$ , July 10-13, 1967.



30-P-v5.

30-P-v4.

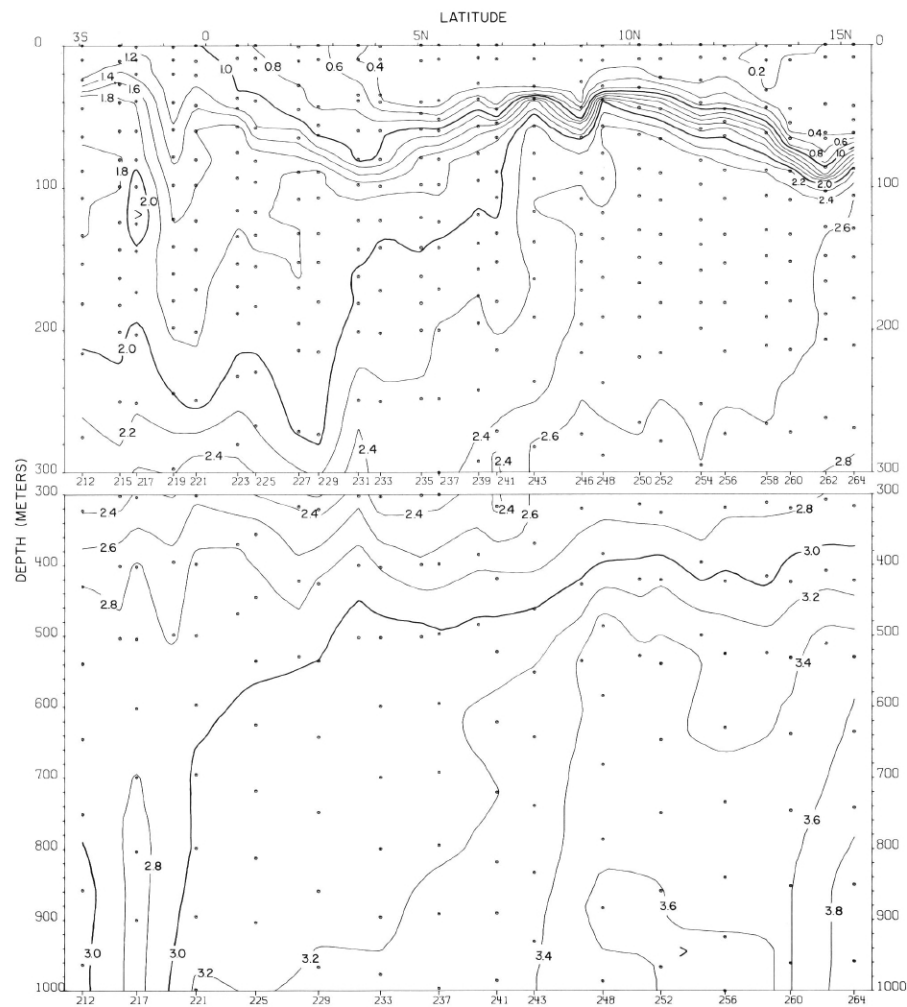
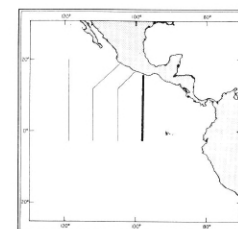


FIGURE 30-P-v6. — Vertical distribution of phosphate-phosphorus ( $\mu\text{g-at./l.}$ ) along  $97^{\circ}30' \text{ W.}$ , July 20-27, 1967.



30-P-v6.

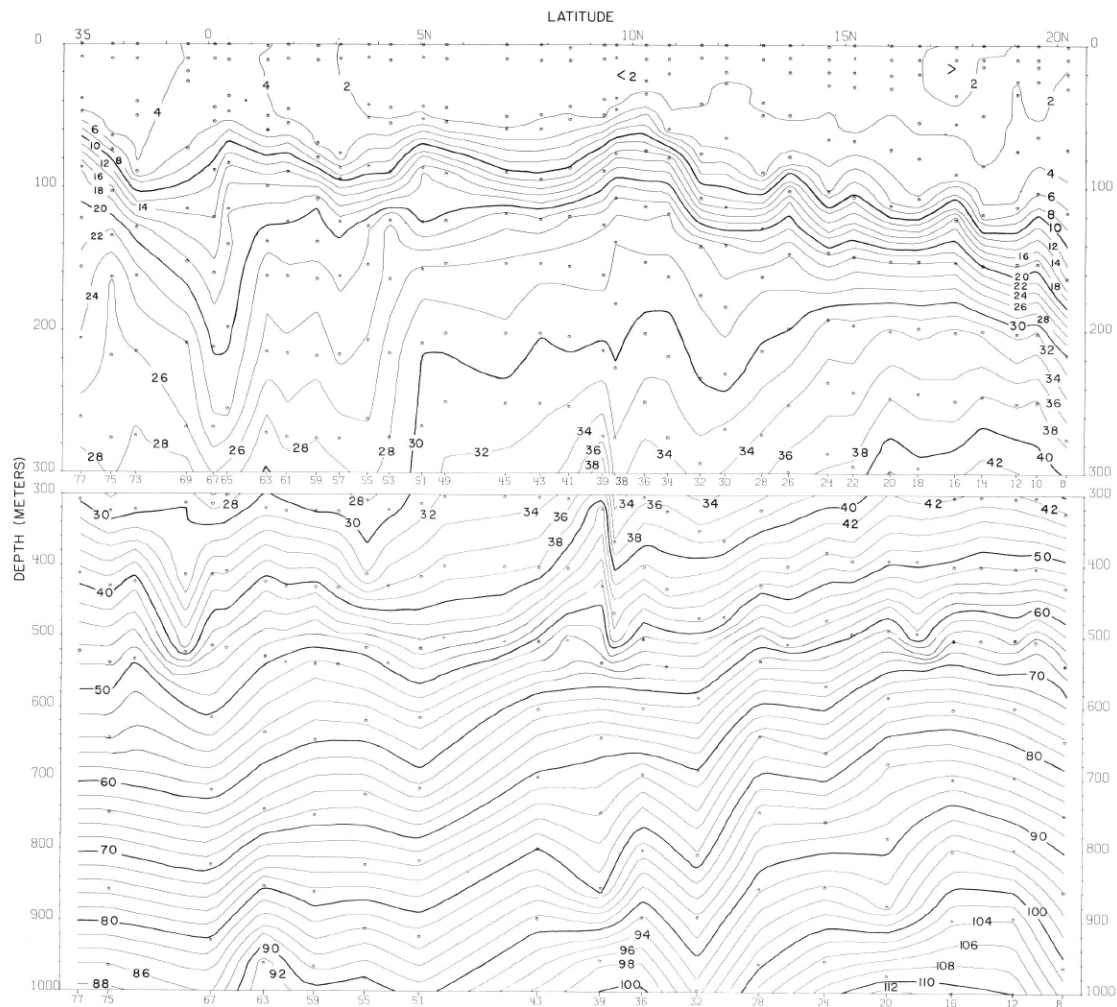
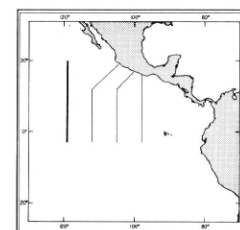


FIGURE 30-Si-v1. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./L}$ ) along  $118^{\circ}30' \text{ W.}$ , June 17-26, 1967.



30-Si-v1.



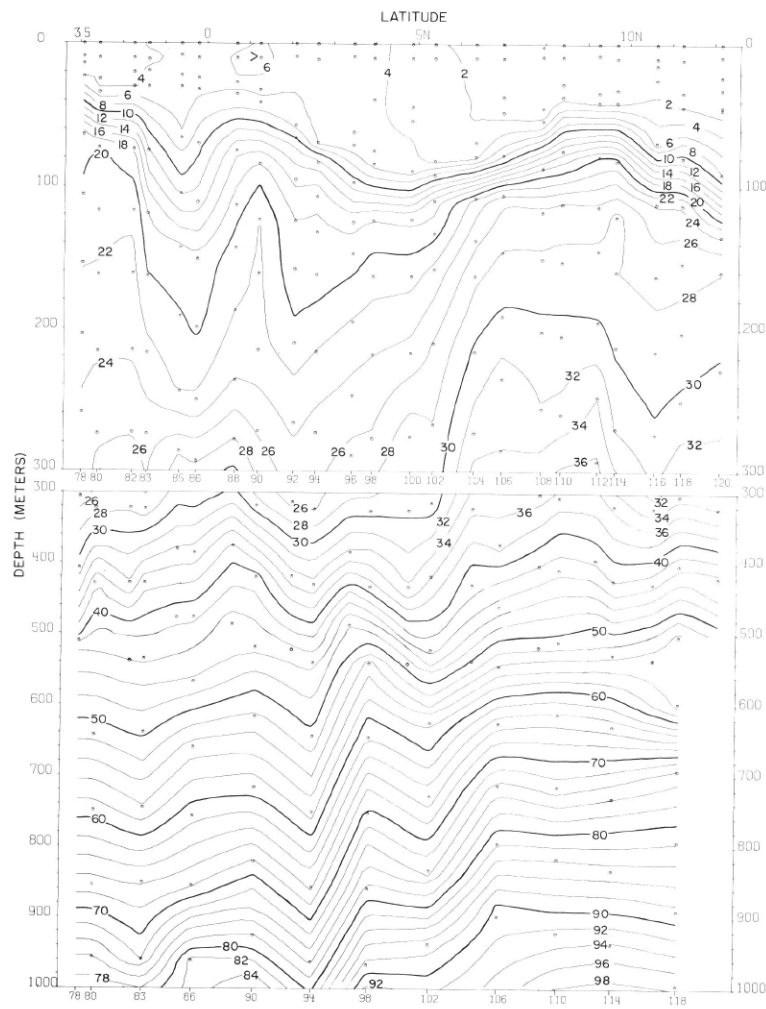


FIGURE 30-Si-v2. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $111^{\circ}30' \text{ W.}$ , June 28-July 4, 1967.

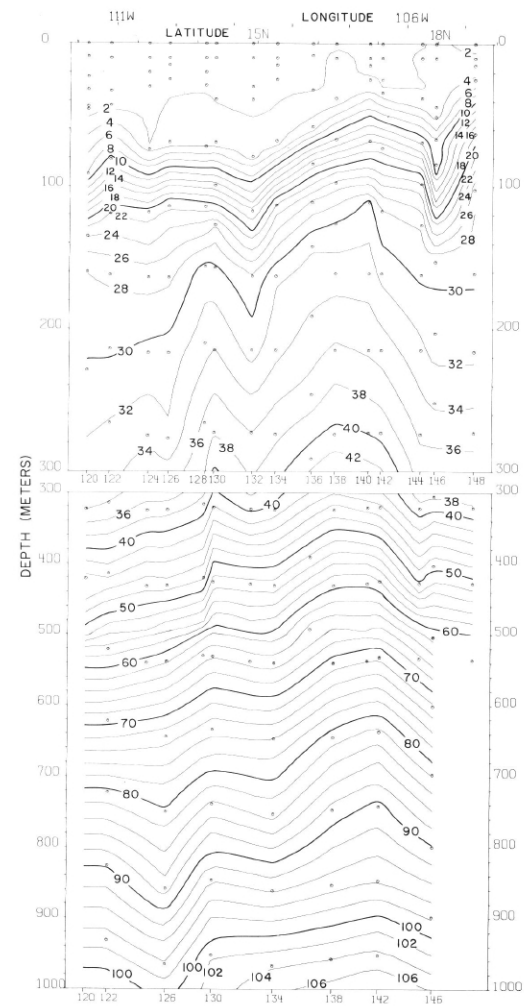
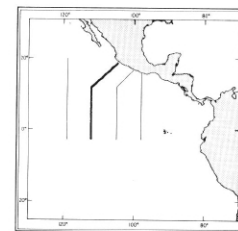


FIGURE 30-Si-v3. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $111^{\circ}30' \text{ W.}$  to Manzanillo, July 4-7, 1967.



30-Si-v2.

30-Si-v3.

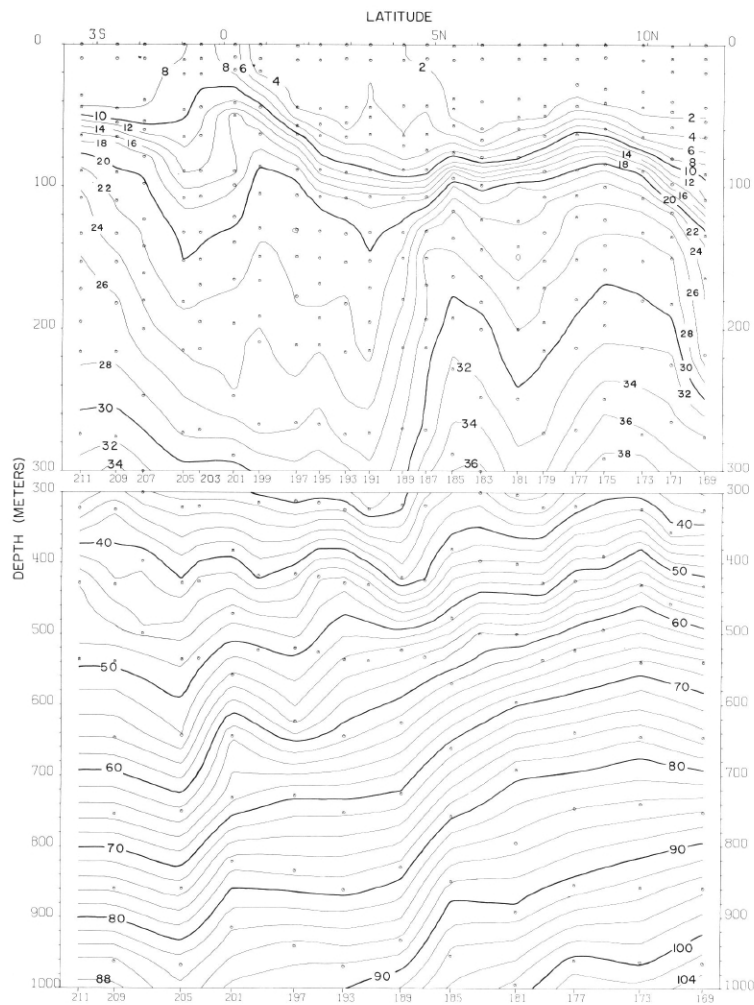


FIGURE 30-Si-v5. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $104^{\circ}30'$  W., July 13-18, 1967.

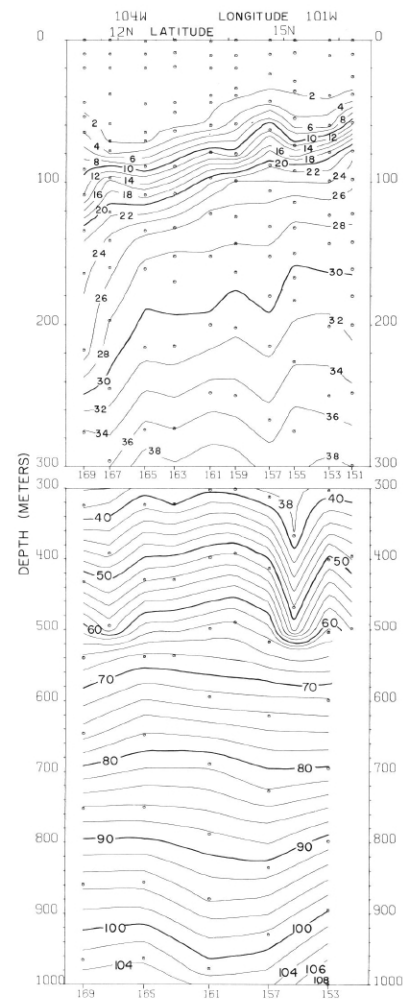
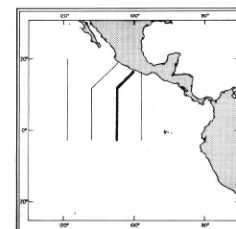


FIGURE 30-Si-v4. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ}$  N.,  $104^{\circ}30'$  W., July 10-13, 1967.



30-Si-v5.

30-Si-v4.

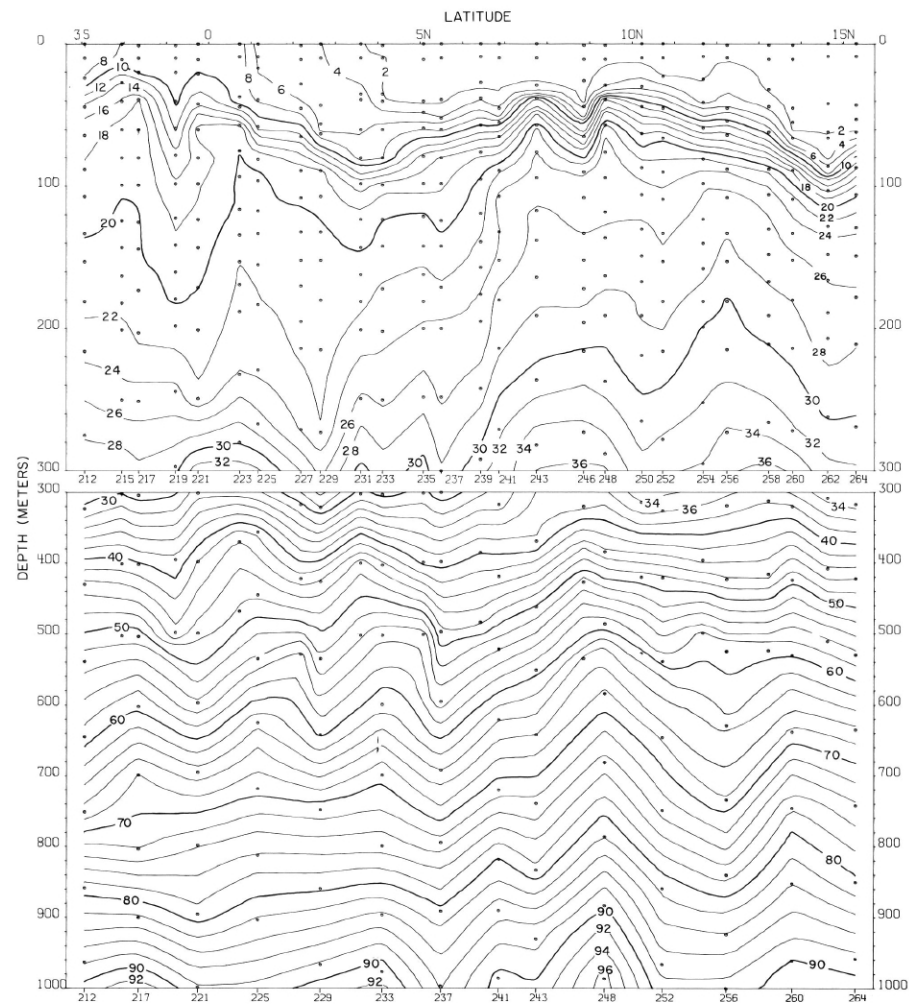
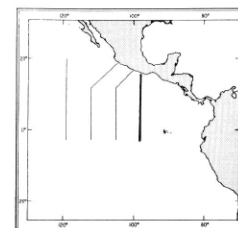


FIGURE 30-Si-v6. — Vertical distribution of silicate-silicon ( $\mu\text{g-at./l.}$ ) along  $97^{\circ}30'$  W., July 20-27, 1967.



30-Si-v6.

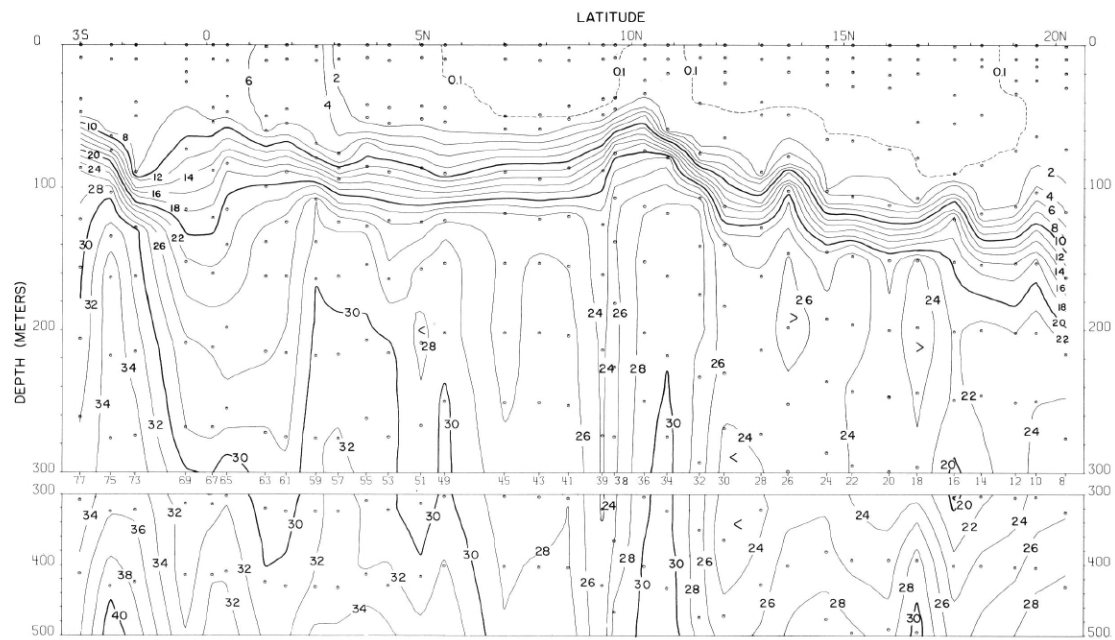
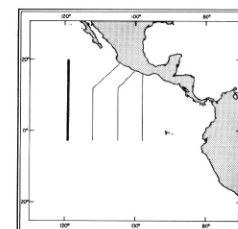


FIGURE 30-NO<sub>3</sub>-v1. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./L.}$ ) along  $118^{\circ}30' \text{ W.}$ , June 17-26, 1967.



30-NO<sub>3</sub>-v1.

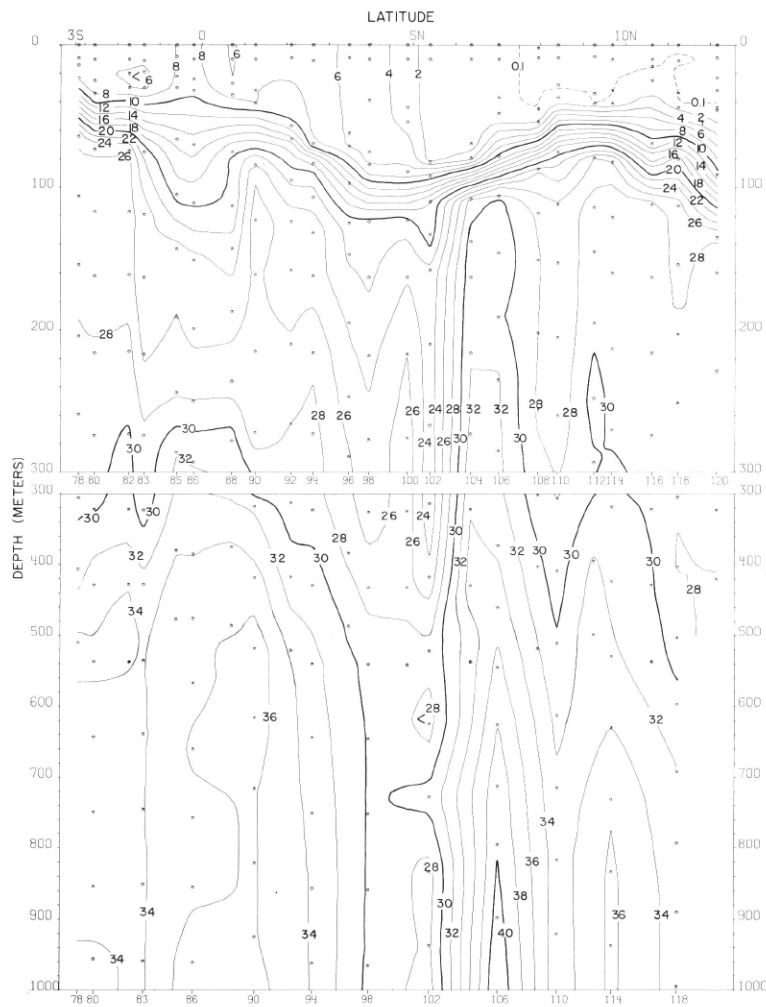


FIGURE 30-NO<sub>3</sub>-v2. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along  $111^{\circ}30' \text{ W.}$ , June 28-July 4, 1967.

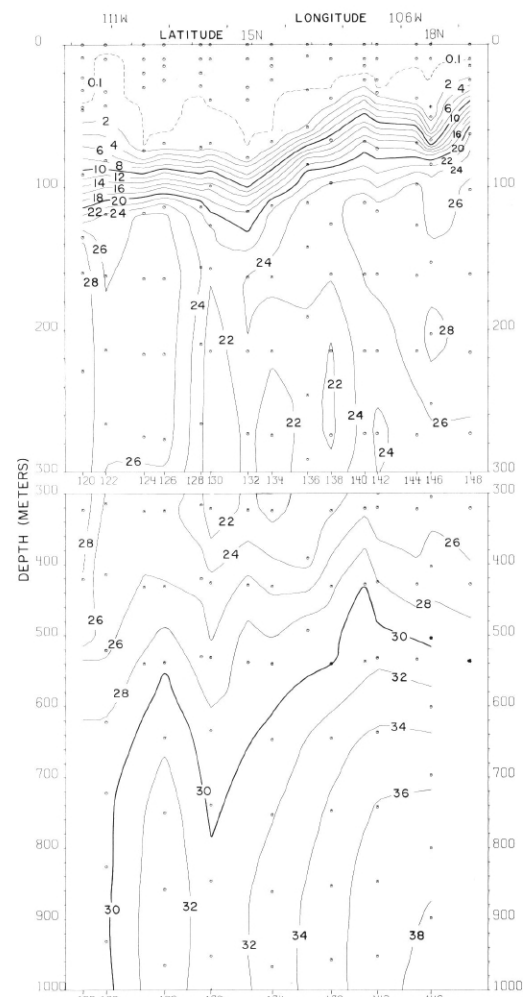
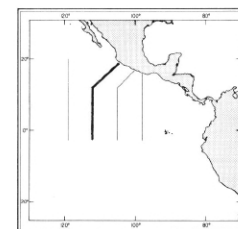


FIGURE 30-NO<sub>3</sub>-v3. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from  $12^{\circ} \text{ N.}$ ,  $111^{\circ}30' \text{ W.}$  to Manzanillo, July 4-7, 1967.



30-NO<sub>3</sub>-v2.

30-NO<sub>3</sub>-v3.

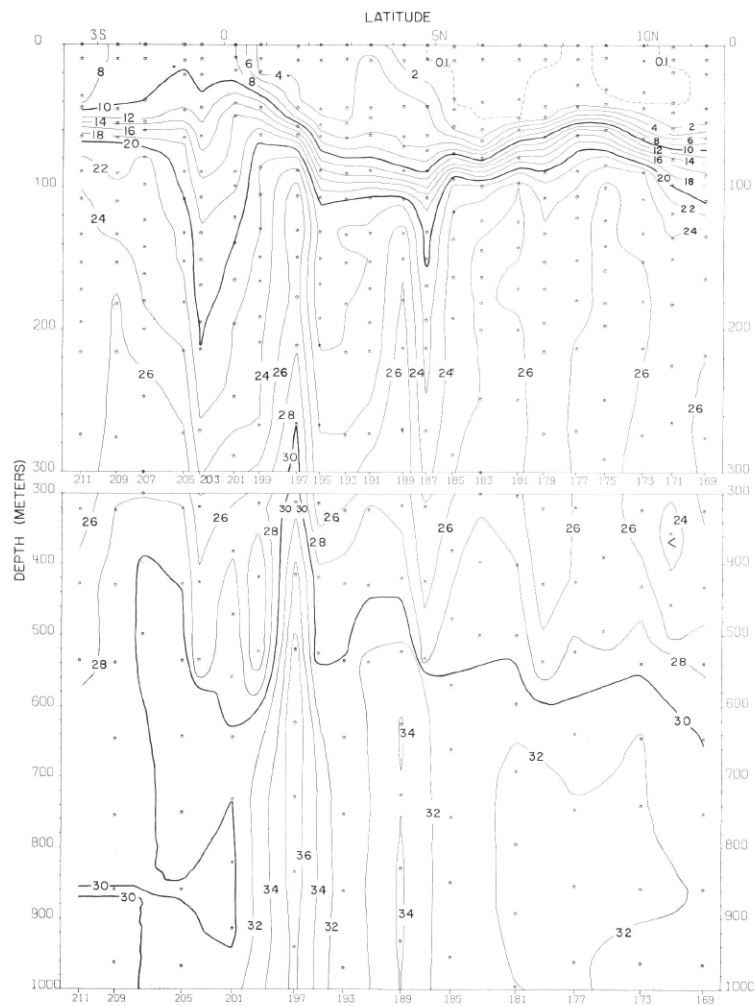


FIGURE 30-NO<sub>3</sub>-v5. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along  $104^{\circ}30' \text{ W.}$ , July 13-18, 1967.

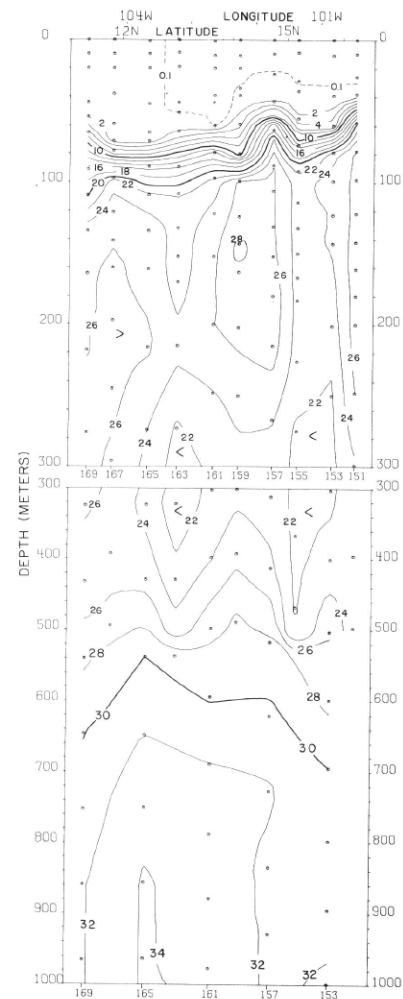
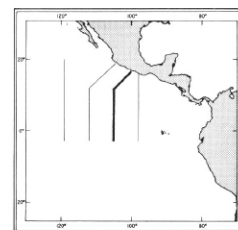


FIGURE 30-NO<sub>3</sub>-v4. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $104^{\circ}30' \text{ W.}$ , July 10-13, 1967.



30-NO<sub>3</sub>-v4.

30-NO<sub>3</sub>-v5.

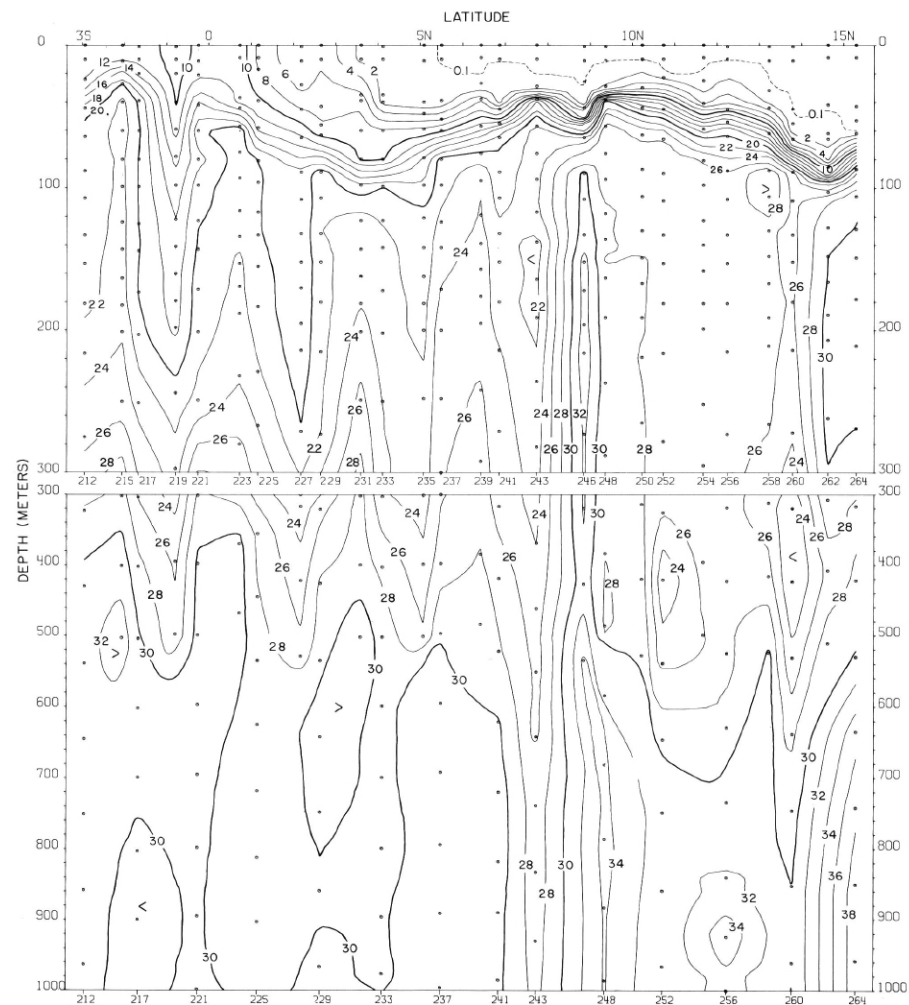
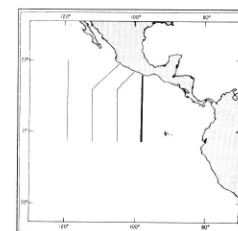


FIGURE 30-NO<sub>3</sub>-v6. — Vertical distribution of nitrate-nitrogen ( $\mu\text{g-at./l.}$ ) along  $97^{\circ}30'$  W., July 20-27, 1967.



30-NO<sub>3</sub>-v6.

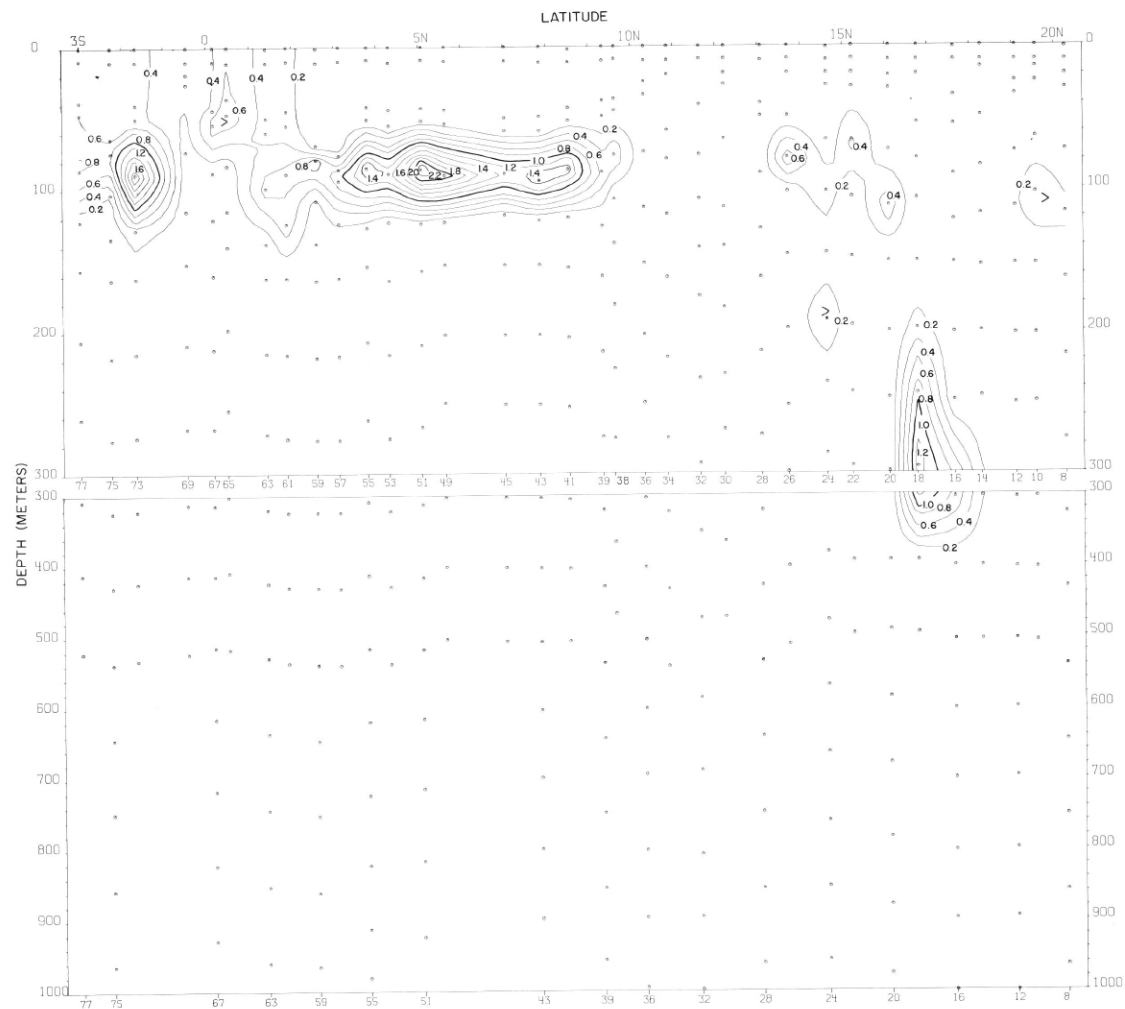
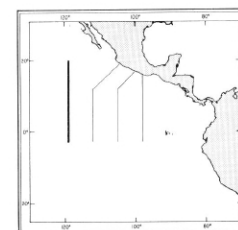


FIGURE 30-NO<sub>2</sub>-v1. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along  $118^{\circ}30'$  W., June 17-26, 1967.



30-NO<sub>2</sub>-v1.





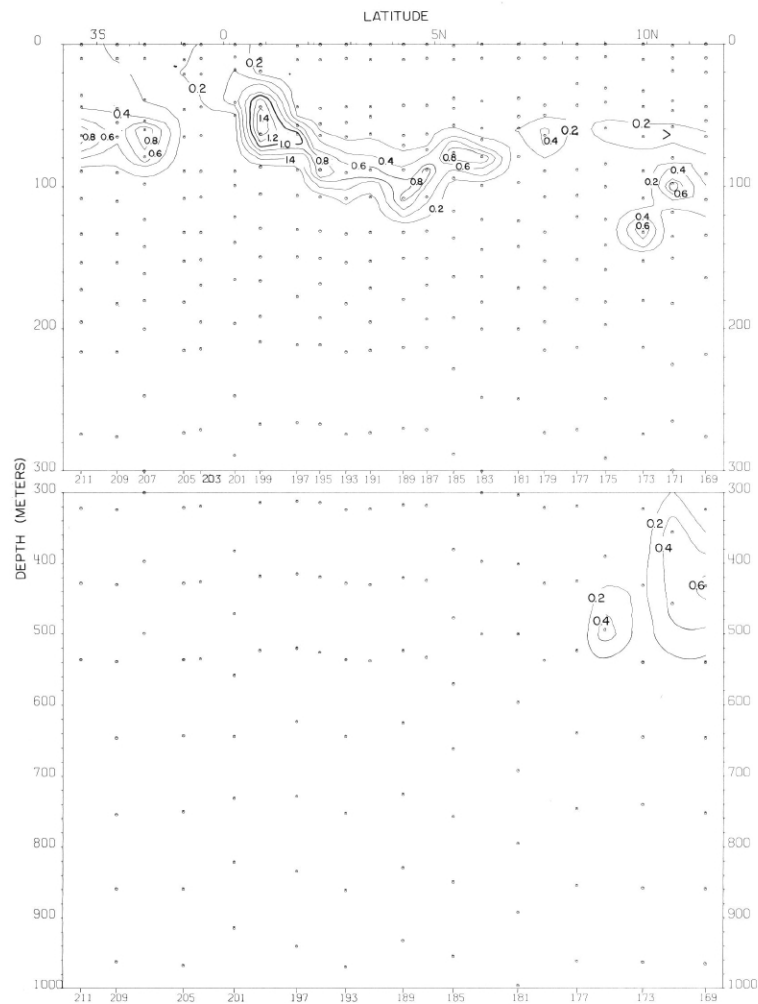


FIGURE 30-NO<sub>2</sub>-v5. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along  $104^{\circ}30' \text{ W.}$ , July 13-18, 1967.

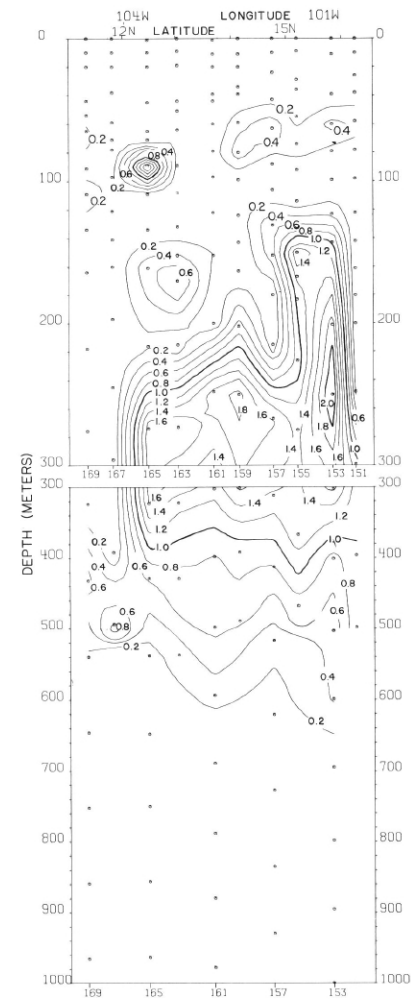
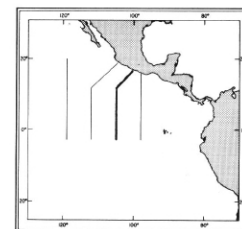


FIGURE 30-NO<sub>2</sub>-v4. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along a section from Acapulco to  $12^{\circ} \text{ N.}$ ,  $104^{\circ}30' \text{ W.}$ , July 10-13, 1967.



30-NO<sub>2</sub>-v4.

30-NO<sub>2</sub>-v5.

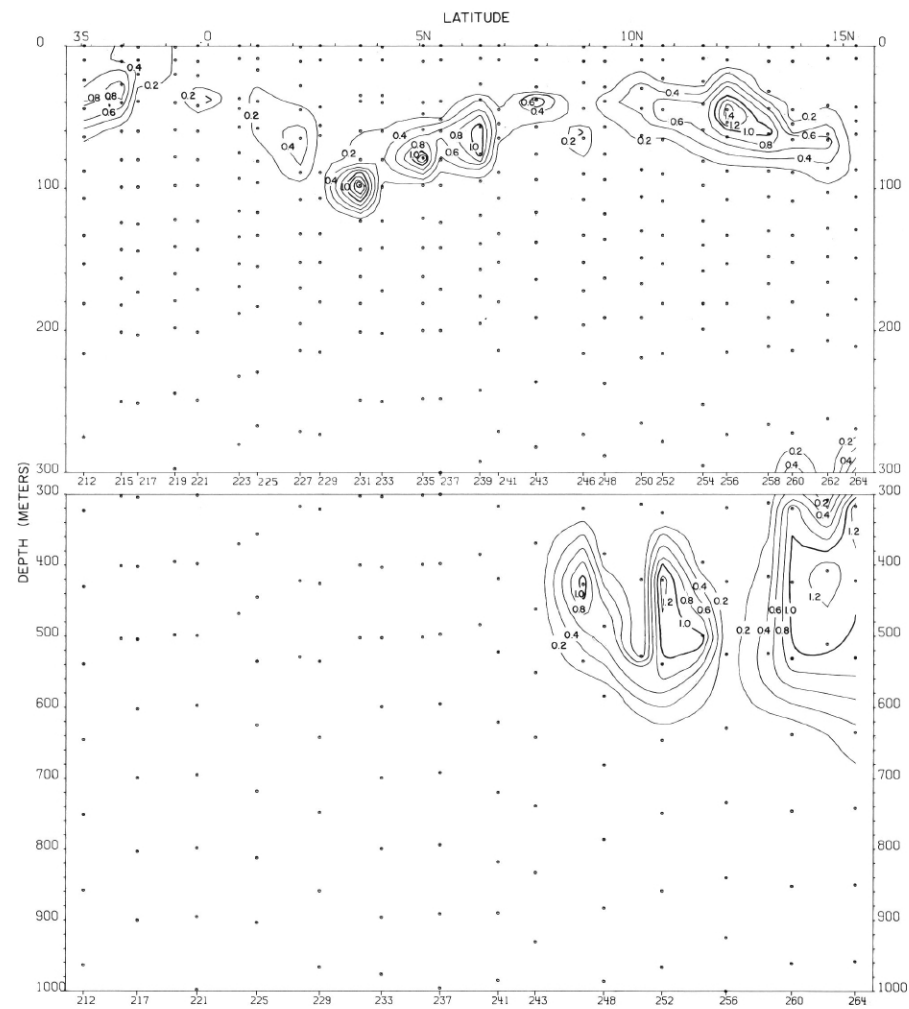
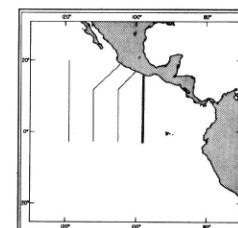


FIGURE 30-NO<sub>2</sub>-v6. — Vertical distribution of nitrite-nitrogen ( $\mu\text{g-at./l.}$ ) along 97°30' W., July 20-27, 1967.



30-NO<sub>2</sub>-v6.

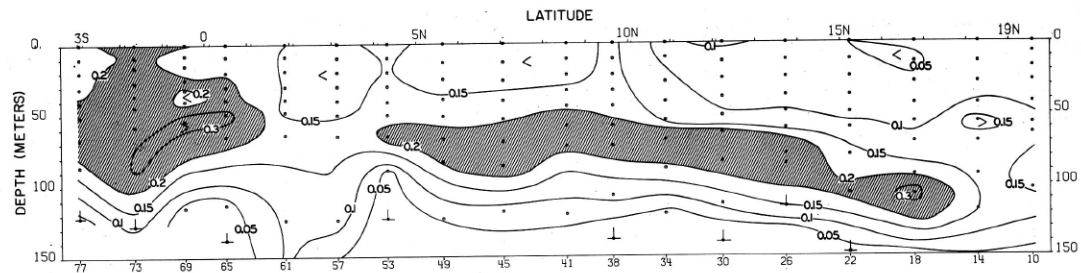


FIGURE 30-Ch-v1. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 118°30' W., June 17-26, 1967.

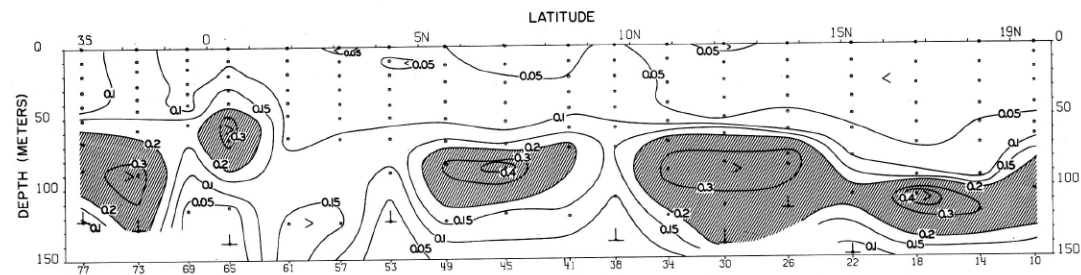


FIGURE 30-Ph-v1. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 118°30' W., June 17-26, 1967.

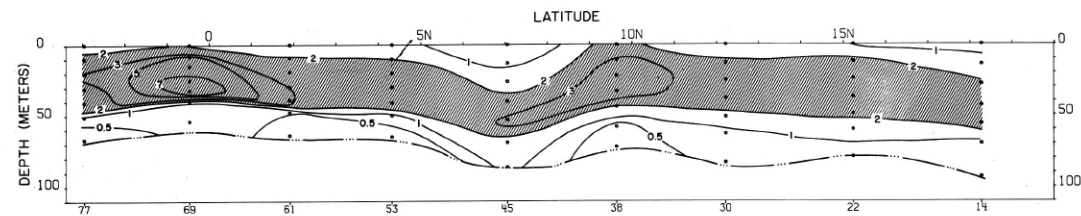
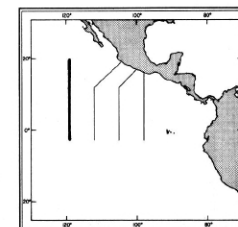


FIGURE 30-PP-v1. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along 118°30' W., June 17-26, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



30-Ch-v1.

30-Ph-v1.

30-PP-v1.

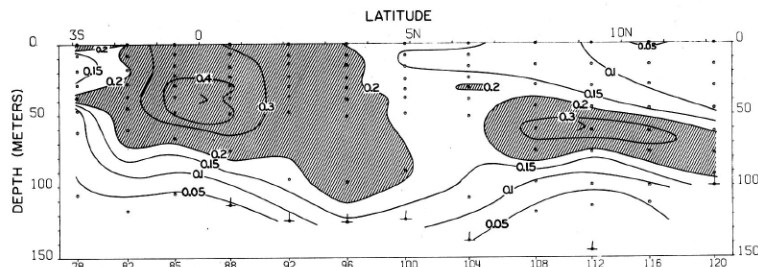


FIGURE 30-Ch-v2. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 111°30' W., June 28-July 4, 1967.

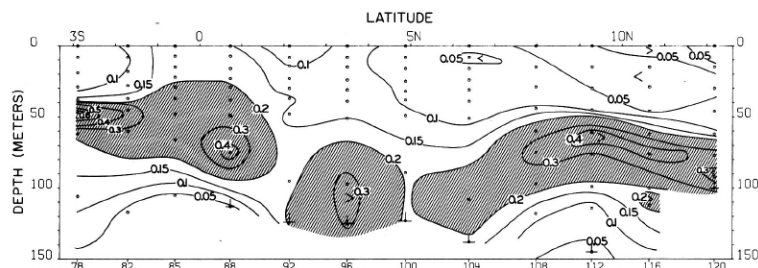


FIGURE 30-Ph-v2. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 111°30' W., June 28-July 4, 1967.

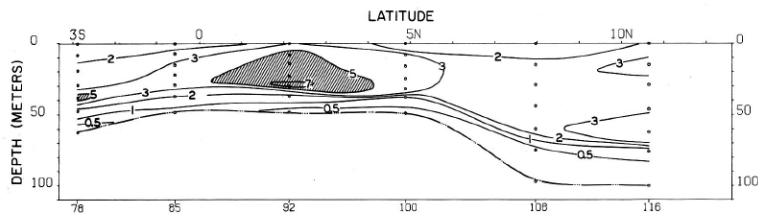


FIGURE 30-PP-v2. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along 111°30' W., June 28-July 4, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

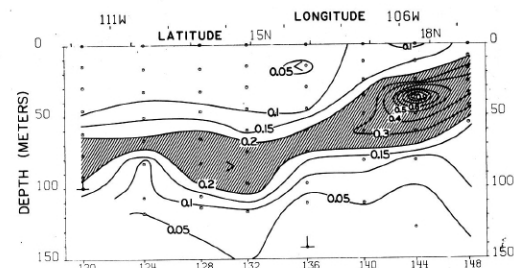


FIGURE 30-Ch-v3. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

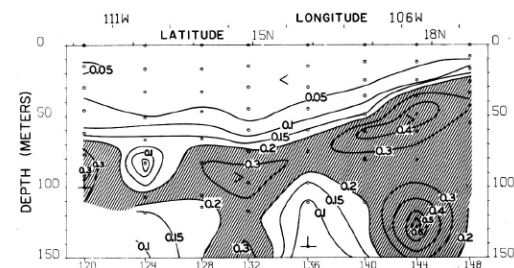


FIGURE 30-Ph-v3. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967.

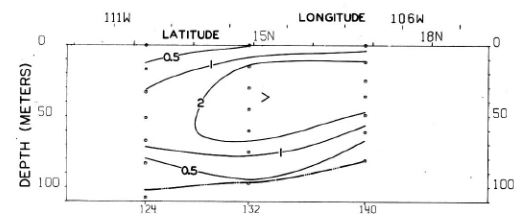
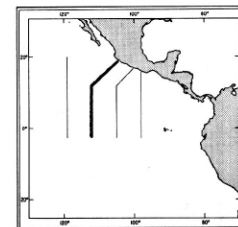


FIGURE 30-PP-v3. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along a section from 12° N., 111°30' W. to Manzanillo, July 4-7, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



30-Ch-v2.

30-Ph-v2.

30-PP-v2.

30-Ch-v3.

30-Ph-v3.

30-PP-v3.

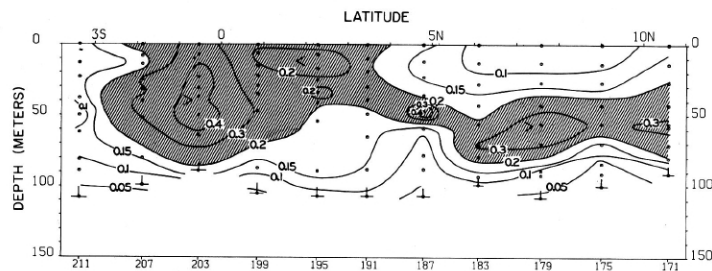


FIGURE 30-Ch-v5. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 104°30' W., July 13-18, 1967.

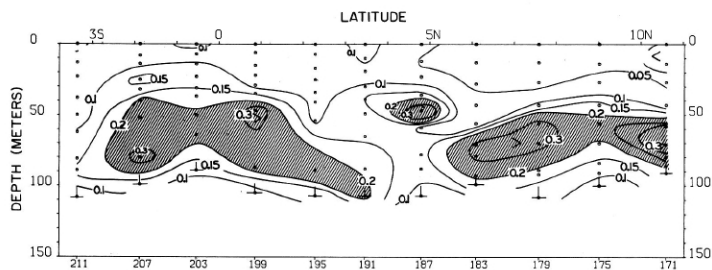


FIGURE 30-Ph-v5. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 104°30' W., July 13-18, 1967.

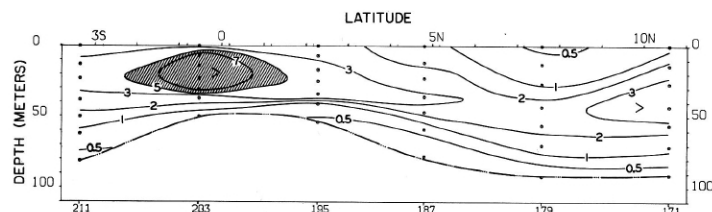


FIGURE 30-PP-v5. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along 104°30' W., July 13-18, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.

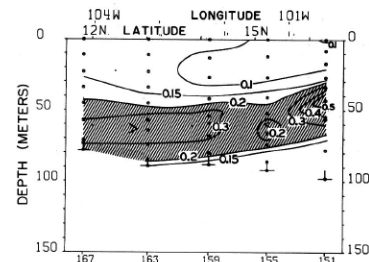


FIGURE 30-Ch-v4. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along a section from Acapulco to 12°N., 104°30' W., July 10-13, 1967.

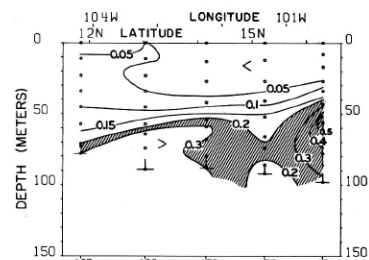


FIGURE 30-Ph-v4. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along a section from Acapulco to 12°N., 104°30' W., July 10-13, 1967.

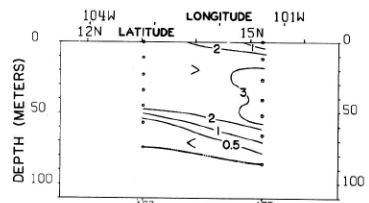
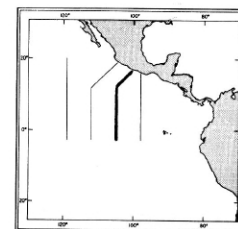


FIGURE 30-PP-v4. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along a section from Acapulco to 12°N., 104°30' W., July 10-13, 1967. The heavy dash-dot line indicates the bottom of the euphotic layer.



30-Ch-v5.

30-Ph-v5.

30-PP-v5.

30-Ch-v4.

30-Ph-v4.

30-PP-v4.

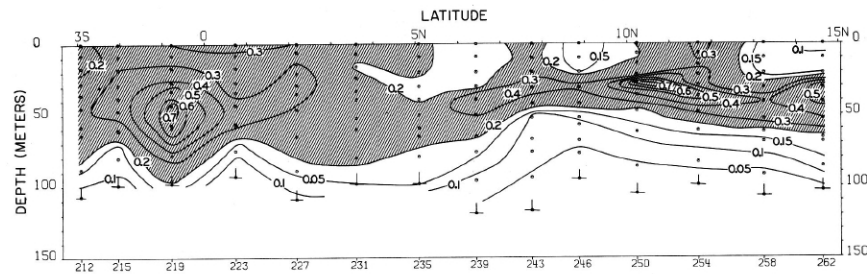


FIGURE 30-Ch-v6. — Vertical distribution of chlorophyll-a (mg./m.<sup>3</sup>) along 97°30' W., July 20-27, 1967.

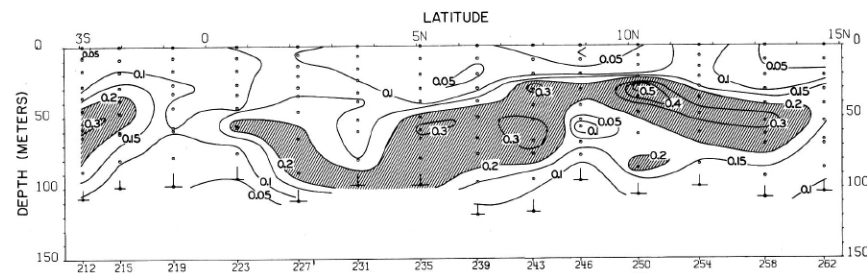


FIGURE 30-Ph-v6. — Vertical distribution of phaeophytin (mg./m.<sup>3</sup>) along 97°30' W., July 20-27, 1967.

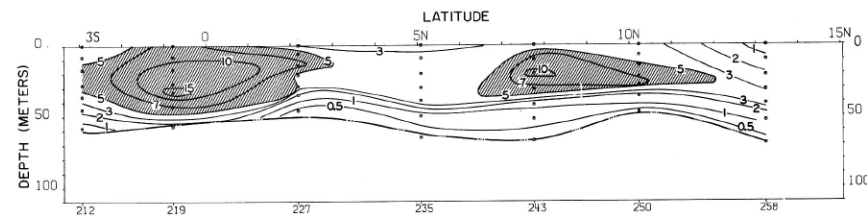
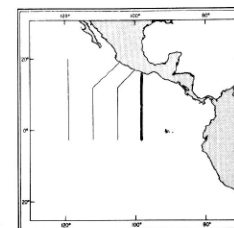


FIGURE 30-PP-v6. — Vertical distribution of primary production (mg.C/m.<sup>3</sup>/day) along 97°30' W., July 20-27, 1967.  
The heavy dash-dot line indicates the bottom of the euphotic layer.



30-Ch-v6.  
30-Ph-v6.  
30-PP-v6.