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Ocean Variability: Effects on U.S. Marine Fishery Resources - 1975

Julien R. Goulet, Jr. and
Elizabeth D. Haynes, Editors

December 1978

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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384. Marine flora and fauna of the northeastern United States. Higher plants of the marine fringe. By Edwin T. Moul. September 1973, iii + 60 p., 109 figs. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

385. Fishery publications, calendar year 1972: Lists and indexes. By Lee C. Thorson and Mary Ellen Engett. November 1973, iv + 23 p., 1 fig. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

386. Marine flora and fauna of the northeastern United States. Pycnogonida. By Lawrence R. McCloskey. September 1973, iii + 12 p., 1 fig. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

387. Marine flora and fauna of the northeastern United States. Crustacea: Stomatopoda. By Raymond B. Manning. February 1974, iii + 6 p., 10 figs. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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Ocean Variability: Effects on U.S. Marine Fishery Resources - 1975

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MARMAP
Contribution No. 130
(Marine Resourses Monitoring,
Assessment, and Prediction Program)

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary
National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator
Terry L. Leitzell, Assistant Administrator for Fisheries
National Marine Fisheries Service

CONTENTS

Ocean Variability: Effects on U.S. Marine Fishery Resources - 1975

JULIEN R. GOULET, JR. and ELIZABETH D. HAYNES, EDITORS[1]

ABSTRACT

Ocean variability, and its effects on U.S. marine fishery resources in 1975, is summarized. Also included is a collection of data products and contributed papers focusing on the impacts on fisheries resources of ocean variability. The emphasis is on large scale, both in time and space, environmental processes, the variations of index properties, and the consequent modulations of fisheries responses.

INTRODUCTION

cean Variability: Effects on U.S. Marine Fishery ources - 1975 is the second report in an evolving series ed at providing decision makers and resource nagers with a synopsis of the marine environment and potential influence on living marine resources. The report was titled *The Environment of the United tes Living Marine Resources - 1974,* and was released as a review copy. Oceanographers, meteorologists, resource biologists both inside and outside of the ional Marine Fisheries Service (NMFS) have conuted to this report. It was produced by the Marine ources Monitoring, Assessment, and Prediction ARMAP) program of the NMFS.

he MARMAP program is an NMFS national gram providing information needed for management allocation of the nation's marine fisheries resources. program encompasses the collection and analysis of a to provide information on the abundance, comtion, location, and condition of the commercial and eational marine fisheries resources of the United tes. It includes a consideration of the environment of se resources, not in the narrow sense of the habitat of ticular species, but in the broader sense of the innce of ocean processes and changes in ocean proper- on living marine resources.

hanges in physical and chemical properties of the an (currents, temperatures, nutrients, etc.), and the ociated modulation of biological processes, directly or rectly affect not only long-term yields and annual ndances of fish stocks, but also their distribution and ilability. Fishery oceanography activities under RMAP include the analysis of physical, chemical, biological oceanographic data collected during RMAP and other NMFS surveys and from oceanohic and meteorological operational and research acties of other agencies.

It is hoped that this report will contribute to the understanding necessary for optimal development, allocation, management, and control of our fisheries resources. As a communications medium it seeks to provide information in a usable manner to those involved in fisheries problems.

In Section 1, Goulet presented an overview of aspects of the environment of the living marine resources of the United States in 1975. It was based on the analyses presented in the several contributions to this volume. This section also includes an interpretation of some potential effects of the environment on marine fisheries resources. This interpretation is to be considered just that—not a statement of fact nor of policy, but merely a presentation of interesting possibilities.

Section 2 is a compendium of data products. The present selection was based on product availability. In future reports, we hope to select data products on a more logical basis—a consideration of their significance to the fisheries environment and their repeatability.

The remaining sections are contributions on various aspects of the environment of the United States living marine resources.

ACKNOWLEDGMENTS

We thank, in addition to the many contributors: R. Muirhead of the U.S. National Ocean Survey for providing tide station temperature data (Section 2.1), D. McLain of the Pacific Environmental Group, NMFS, for providing the Atlantic, Pacific, and Bering Sea surface temperature charts (Section 2.3); R. J. Lynn and R. M. Laurs, Southwest Fisheries Center, NMFS, for providing the Pacific salinity transects (Section 2.4); and D. Smith of the MARMAP Field Group, NMFS, for preparing the report on temperature-salinity-copepod relationships (Section 2.5). We also thank the U.S. Geological Survey for the Chesapeake Bay streamflow information (Section 2.2).

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Section 1

SUMMARY

Julien R. Goulet, Jr.[1]

A first approach to understanding the effects of ocean variability on U.S. marine fishery resources can be made by considering the broad-scale conditions of the atmosphere, for it is the atmosphere that provides the most important boundary of the oceans. The atmospheric circulation must be considered in connection with the climatology of the oceans, for the atmosphere has no "memory." It must depend on the oceans, in particular the broad expanse of the Pacific Ocean, to provide the "flywheel" or "memory" which controls the persistence of phenomena.

The salient feature of the atmospheric circulation in 1975 was the persistence of strong westerly winds over the Northern Hemisphere (Dickson and Namias, Section 3). This "high-index" circulation, or increased strength of the westerlies, has persisted since 1971, and is chiefly a feature of the oceanic areas. However, there was a basic difference in the conditions of this increased westerly circulation between 1975 and the previous four years. In 1974, the increased westerlies were caused by a tandem intensification of the subtropical high pressure cells and the subpolar low pressure cells over both oceans. In 1975 there was an intensification and a northward movement of the high pressure cells, but the low pressure anomaly became a single intense polar low. The anomalies of the height of the 700 mb pressure surface changed radically from 1974 to 1975. The 1974 position of the arctic front, the edge of the cold polar air mass, was typical of the previous four years. In contrast, the 1975 front appeared unstable, the zero anomaly contour wandering with no clear pattern instead of defining a cold polar air mass as with the high pressure anomaly of 1974 (Fig. 1.1).

The sea surface temperatures in the Pacific associated with these climatological regimes were similar in 1974 and 1975. A region of abnormally cold water underlay the area of strongest

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[1]Fisheries Assessment Division, National Marine Fisheries Service, Washington, DC 20235.

westerlies in the Pacific Ocean, while a region of abnormally warm water underlay the subtropical high pressure system. In 1975 the cold-water band shifted to the northeast and the anomaly of temperature along the Canadian coast reached -1.5C. The warm-water pool also shifted to the northeast and slightly increased in intensity, but decreased in areal extent. The gradients of temperature in the Transition Zone (approximately two-thirds of the distance from Hawaii to California; Saur, Section 7) are therefore much reduced on an annual average.

SEASONAL CYCLES

To understand the environmental conditions influencing the U.S. marine fishery resources, we must look at the seasonal cycle of oceanographic conditions existing in the Atlantic and Pacific, and at the climatological conditions existing over these oceans and the North American continent (Figs. 1.2 and 1.3).

During winter 1974 (December 1973-February 1974), the 700 mb pressure anomalies were typical of the increased westerly circulation that has persisted since 1971. The subpolar lows and the subtropical highs were anomalously intense and there was a slight low trough over the North American continent. The entire western Atlantic was anomalously warm and there was a large pool of anomalously warm water underlying the Pacific high pressure system, while the Pacific coast was anomalously cold.

In spring 1974, the high-index circulation continued, but the low pressure systems had intensified and broadened to form one continuous band across the northern reaches of the continent. The high pressure anomalies decreased in intensity, while the sea surface temperatures were still anomalously warm in the western Atlantic. The warm pool in the Pacific remained essentially unchanged.

The pressure anomaly patterns for summer 1974 presented some puzzling features. While the anomalies did not dominate the annual average, the anomalous features had all but disappeared. The subtropical highs and the subpolar lows were near the long-term mean. The polar air mass was anomalously high and had extended southward, and the sea surface temperature showed some warm anomalies in the Bering Sea and an eastward extension of the warm Pacific pool. The Atlantic remained essentially unchanged from the previous season.

In fall 1974, the pressure anomalies did not indicate high-index conditions. The high pressure anomalies were found far north, while the low pressure anomalies did not exist except for a cell over the northeast portion of the continent. There was a strong high pressure cell over the northwest coast of the United States. In response to these conditions, the warm anomalies of sea surface temperature penetrated northwest into the Gulf of Alaska and warmed the northwestern coast of the United States. Cold anomalies extended southeastward from the northwest Pacific toward California.

High-index circulation conditions returned in winter 1975, but with strong differences from the winter of 1974. The Atlantic high pressure cell was in approximately the same position as in the previous winter, but extended significantly northwestward over the continent. The Pacific high pressure cell intensified in comparison to 1974 and moved significantly northwestward. The subpolar lows intensified and formed a band across the northern limits of the continent. The western center of the subpolar low was over the Bering Sea, whereas in 1974 it was over the Gulf of Alaska. The trough centered on the continent had retrograded and lay over the Rockies in 1975, whereas in 1974 it lay over the Mississippi valley. The sea surface temperature anomalies were cold throughout most of the western Atlantic with a remnant pool of warm anomaly water lying close to the coast. In the Pacific, the warm pool had been much reduced and the cold anomaly water extended south from the Gulf of Alaska as well as lying in an unbroken band along the coast.

There were some interesting developments in spring 1975. The continental trough remained over the Rockies and had intensified. The subtropical high pressure cell in the Atlantic was no longer anomalous, and there was a strong high pressure anomaly over the north central portion of the continent. The subpolar lows were much reduced, or shifted beyond the limits of the maps in Figure 1.2 which cover only the American sector of the Northern Hemisphere. The subtropical high pressure cell in the Pacific remained in the southern Gulf of Alaska, but its center shifted eastward towards the American continent. The sea surface temperatures were cold throughout the western Atlantic except for the Gulf of Mexico and small patches off the U.S. coast. The warm anomaly pool in the Pacific shifted northward to lie closer to the center of the high pressure anomaly. It also was reduced in size, and cool anomalies were found in a broad band surrounding this warm pool.

The subpolar low pressure anomaly regrouped, in summer 1975, into a single intense anomaly north of the center of the American continent. The high pressure cell that overlay the north central portion of the continent in the previous season had shifted eastward, and there was a low pressure anomaly to the east of that. The Pacific had a very small high pressure anomaly lying quite close to the continent. The sea surface temperatures were cold throughout the western Atlantic except for a small patch in the New York Bight. The Pacific had a much reduced pool of warm anomaly water, and generally was much cooler than in summer 1974.

In fall 1975 there was a return to high-index circulation conditions with a single subpolar low. The subtropical high pressure systems lay in approximately the same positions as during the previous winter. The trough of low pressure remained over the Rockies. The Atlantic had some warm sea surface temperature anomalies extending east and northeast from the Middle Atlantic Bight. The Pacific's pool of warm anomaly water was even more reduced than in the previous season, and the winter of 1976 was approached with a far smaller supply of warm Pacific surface water than had existed in the previous year (Saur, Section 7).

Interpretation

Let us examine some possible consequences of these atmospheric and oceanic conditions. While 700 mb heights are not important for steering individual storms, it is probable that the total collection of storm tracks is influenced by mean atmospheric conditions. The Pacific summer storms of 1974 tracked south of their normal position and reached the American continent in the vicinity of Washington and Oregon.[2] Likewise, in fall 1974, storms did not penetrate into the Gulf of Alaska. Instead of tracking southward, they backed and tracked into the Bering Sea. These backing conditions continued into winter 1975. Possibly the winter storms' tracking into the polar regions instead of over the continent produced the instabilities of the arctic front that were mirrored in the annual average (Fig. 1.1). These instabilities are also reflected in the spring and summer conditions of 1975 (Fig. 1.2), and we can consider that the polar front went through a regrouping in 1975. Whether it will, in 1976, return to the conditions that existed since 1971 or to conditions that prevailed prior to that remains to be seen.

PACIFIC

The whole eastern North Pacific was colder in 1975 than in 1974. The cold anomalies of sea surface temperature extended farther offshore and farther south from the Gulf of Alaska. The central patch of warm anomaly water was much reduced in area compared to 1974. In spring and summer 1975 the warm anomaly water lay northeastward of its position during the previous year. Whereas 1974 ended with a large pool of anomalously warm water occupying

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[2]Mariners Weather Log, smooth log, North Pacific weather, vols. 19 and 20 (1975, 1976).

he central portions of the eastern North Pacific and extending o the Canadian coast and into the northern Gulf of Alaska, 1975 nded with a much diminished pool of anomalously warm water and road expanses of anomalously cold water (Fig. 1.3).

everal data products in Section 2 portray aspects of the Pacific cean environment. Section 2.1 comprises time vs. distance ontours of coastal temperatures along the U.S. west coast and outh coast of Alaska. Section 2.3 contains monthly sea surface emperature anomalies in the Gulf of Alaska and in the eastern orth Pacific. Section 2.4 depicts vertical transects of alinity along 137W30' in June of 1972, 1973, 1974, and 1975.

he bulletin, <u>Fishing Information</u>, published monthly by the outhwest Fisheries Center, NMFS, La Jolla, CA 92038, presents urface atmospheric pressure, surface wind, sea surface emperature, its anomaly, and its year to year change, as well as emperature transects across the Transition Zone between the alifornia Current water and the Eastern North Pacific water.

everal contributors discussed various aspects of the Pacific cean environment during 1975 in Sections 4 through 11.

ohnson, McLain, and Nelson (Section 4), in an update to their ontribution in the first volume of this series (Johnson, et al. 976), discussed the Pacific climatology as indicated by sea urface temperature at selected locations. The annual average nomalies of sea surface temperature were dominated by the summer nomalies. The data presented by Dickson and Namias (Section 3) how that the annual average 700 mb height anomalies are ominated by the winter anomalies.

cLain (Section 5) presented anomalies of coastal temperature long the Pacific coast and discussed the persistence of these nomalies. South of Washington, the negative anomalies of oastal temperature were not as persistent since 1970 or 1971 as hey were in the Gulf of Alaska. Part of the reason for this is he station locations. In the Gulf of Alaska, index stations (Johnson et al., Section 4) were used. Along the Canadian coast he data were collected at exposed light stations, while along he U.S. coast the data were collected at more protected tidal stations.

akun (Section 6) discussed the upwelling along the Pacific oast. In the early winter of 1975-76, the northern Gulf of laska had nearly normal vigorous downwelling in contrast to the ower intensity of downwelling the previous winter. Upwelling as unusually strong and sustained during 1975 in the California urrent region as a whole.

Section 1

Saur (Section 7) gave an interesting analysis of the heat content in the surface layers of the Pacific between the U.S. west coast and the Hawaiian Islands. In time vs. distance plots of anomalies, the salinity anomalies tended to align themselves along the time axis, while the temperature anomalies tended to align themselves along the distance axis. The salinity anomalies also migrate westward across the Transition Zone from California Current waters to Eastern North Pacific waters. The surface salinity anomalies were positive in the Transition Zone from May 1974 through May 1975 in contrast to 1972 and 1973 when the anomalies were negative from January through July. The surface temperature anomalies in 1974 and 1975 were quite different than in 1972 and 1973. Whereas the anomalies in 1972 and 1973 were confused, they were warm in the last half of 1974. The beginning of 1975 was warm, but the last half was cold. The results derived from an analysis of heat storage in the surface layer are quite different. The anomalies of heat storage were indeterminate in 1972 and 1973. In 1974 and 1975 the Transition Zone heat storage anomalies were near zero except for the 1975 winter which was warm. The Eastern North Pacific waters were warm throughout most of 1974, while the heat storage anomalies were near zerc throughout mcst of 1975.

Miller (Section 8) discussed the distributions of yellowfin and skipjack tunas and Peruvian anchoveta in relation to sea surface temperature in the eastern tropical Pacific.

Quinn (Section 9) presented an update to his excellent El Nino analysis in the earlier volume of this series (Quinn 1976).

Favorite (Section 10) presented an interesting review of sunspot activity vs. Pacific oceanic conditions and potential relations between oceanic conditions and survival of salmon and Dungeness crab.

Hastings (Section 11) discussed his eastern Bering Sea hydrodynamical-numerical model that simulates tidal currents for studies of larval transport and dispersion.

Although not a contributor to this report, Lasker (in press) has given an excellent review of ongoing research on biolcgical changes affected by variability in the ocean environment. His paper is necessary reading for anyone who would gain an understanding of the complex interactions between biolcgical changes and the ocean envircnment.

Interpretation

The climatic regime, both atmospheric pressure and sea surface temperature, as presented by Dickson and Namias (Section 3) is a starting point for examining the environmental conditions in the reas of our Pacific fishery resources. The spring 1975 pressure nomalies indicate that upwelling along the western coast of orth America should have been strong north of California. ndeed, Bakun (Section 6) showed an upwelling index with ercentile values greater than 70 in March and April north of 9N.

ormal vigorous downwelling in fall 1975 (Bakun, Section 6) in he Gulf of Alaska was associated with weaker cooling Section 2.1). The rapid relaxation of winter conditions in arch and April 1975 mentioned by Bakun was reflected in colder onditions at Yakutat and Sitka, and in a slight extension of the ooling season (Section 2.1). The unusually strong and sustained pwelling throughout the California Current region (Bakun, ection 6) was reflected in the colder temperatures at tidal tations (McLain, Section 5).

o the data in the several contributions support the thesis that 975 was a year for regrouping? Was 1975 a transition year etween the regime which existed from 1971 to 1974 and a ollowing regime?

he anomalies presented by Saur (Section 7) showed that changes egan in 1974. Quinn (Section 9) found a shortening of the outhern oscillation period beginning in 1974. The maximum ercentile of upwelling index shifted southward in 1975, from etween 48N and 39N to between 39N and 30N (Bakun, Section 6; akun 1976).

he Transition Zone was weak and diffuse in 1974. It became harp and definite again in 1975, but much broader than in 1972 r 1973 (Section 2.4). _Fishing Information_ portrayed sea surface emperatures colder throughout 1975 over major areas of the astern North Pacific.

hat does this disparate set of facts indicate for the climatic-ceanic regime of 1975? Was 1975 a transition year? It was a ear that repeated the previous four years in certain aspects, uch as the above average strength of the westerlies. It was a ear that showed profound changes in other aspects, such as the ize, location, and heat storage of the warm-water pool in the acific. _Fishing Information_ portrayed above average strength of he westerlies during the early months of 1976. Sea surface emperature in the Pacific continued a cooling trend in the inter of 1976. If 1975 was a year in transition, it was only art of a multi-year transition whose final disposition is still nknown.

Section 1

ATLANTIC

The western Atlantic had colder sea surface temperatures in 1975 than in 1974. Positive temperature anomalies were found in the entire western Atlantic in all four seasons of 1974. In 1975, there were major areas with negative temperature anomalies (Fig. 1.3). Positive temperature anomalies were limited to the coast in the winter 1975. In spring, the positive anomalies were limited to the Gulf of Mexico and to a narrow band extending seaward from the Cape Hatteras area. There were almost no positive anomalies in the summer of 1975, and the fall had only a band of anomalies extending seaward from the Middle Atlantic Bight.

There are several data products concerned with the Atlantic Ocean. Section 2.1 comprises time vs. distance contours of coastal temperatures in the Gulf of Maine, Long Island Sound, the U.S. east coast, and the Gulf of Mexico. Section 2.2 contains profiles of Chesapeake Bay runoff. Section 2.3 (McLain) contains monthly plots of sea surface temperature anomalies in the western North Atlantic. Section 2.5 (Smith and Jossi) is an analysis of copepod species as an indicator of water types.

Sections 12 through 20 are contributions by several authors regarding various aspects of the Atlantic Ocean environment during 1975.

Gunn (Section 12) discussed the variations in the position of the front between Shelf Waters and Slope Waters off the U.S. east coast. Two years of data were available and the details of the frontal positions differ between 1974 and 1975. However, the statistical profile of the frontal position was quite similar in the two years, as shown by the mean and the standard deviation of the frontal positions along transects. Noticeable differences in mean and standard deviation were found at the Casco Bay transects offshore of the coast of Maine, and in the mean position at the Cape Romain transect in the South Atlantic Bight. The frontal position transgressed over Georges Bank and the Bank was covered partially by Slope Water to varying amounts throughout the two years. The peaks in coverage by Slope Water were in August-September 1974, with a maximum of about 17% coverage, and July and September 1975, with maxima of about 40% coverage.

Gunn (Section 13) presented data on wind-driven transport along the U.S. east coast and in the Gulf of Mexico. Off Cape Hatteras the wind-driven transport was not favorable to the survival of menhaden larvae during the menhaden spawning season.

Davis (Section 14) made a rather thorough analysis of the bottom temperatures in the Gulf of Maine and on Georges Bank. There has been a warming trend since 1968 in both the Gulf of Maine and on

Georges Bank. The bottom temperatures reversed that trend from 1974 to 1975, but 1975 remained warmer than the mean temperature of the study period.

Chamberlin et al. (Section 15) presented an analysis of standard sections across the mouth of the Bay of Fundy from Bar Harbor, ME, to Yarmouth, N.S.

Chamberlin (Section 16) presented a review of shelf and slope bottom temperatures south of New England.

Bisagni (Section 17) analyzed the number of eddies, and their persistence, passing through the New York Bight. The number of eddy-days in the last half of 1975 was almost double the number in the last half of 1974.

Barans and Roumillat (Section 18) presented an analysis of surface drift in the South Atlantic Bight as determined by drift bottle studies.

Lough (Section 19) gave an interesting discussion on the distribution of herring larvae in the Georges Bank and Nantucket Shoals areas. While the number of herring larvae in December 1975 was much less than in December 1973 or 1974, mortality in the winter was so much less that the numbers were approximately equal in all three of the following Februaries. In addition, the growth rate had increased so that the average size of the larvae was greater in February 1976 than in either of the previous two years.

Rogers (Section 20) reported on a bloom of siphonophores which caused extensive fouling of fishing gear in the fall of 1975 in the coastal waters of New England.

<u>Interpretation</u>

As with the Pacific, the climatic regime, both atmospheric and oceanic, serves as a starting point for examining the environmental conditions in the areas of our fisheries resources.

Winter pressure anomalies were consistent with wind-driven transport unfavorable to menhaden larvae (Fig. 1.2; Gunn, Section 13). By far the most interesting sequence of events took place in summer and fall 1975 over the northeast sector of North America. In the summer an anomalous high pressure cell situated over northeastern Canada gave rise to an anomalous northeast atmospheric flow. This had two consequences: moist conditions were brought to the northeastern United States, and the Gulf Stream cast off an increased number of eddies (Section 2.2; Bisagni, Section 17). The northeast atmospheric flow possibly increased the inflow of cold water through Northeast Channel into the northern Gulf of Maine. This was not reflected in the Bar

Harbor-Yarmouth sections (Chamberlin et al., Section 15) except on the July 16th section. It was reflected in the bottom water cooling in the fall (Davis, Section 14).

In fall 1975, the anomalous high pressure cell had moved southeast and was situated over the Middle Atlantic Bight. This brought anomalous atmospheric flow from the south and a warming situation to the northeastern states (Section 2.1). It did not decrease the runoff nor decrease the Gulf Stream eddies (Section 2.2; Bisagni, Section 17).

The summer climatic regime highlights an interesting feedback mechanism. The increased runoff would produce lower salinity in the Shelf Water unless it were compensated by increased mixing with Slope Water. The increased number of eddy days provides the source of high salinity water to mix into Slope Water. This mechanism tends to stabilize the salinities of Shelf Water and Slope Water, and makes the relative volumes of the two water categories the free variable.

A consequence of the increased eddy days in summer and fall 1975 would be an increase in Slope Water volume. This would be reflected in the position of the Shelf Water/Slope Water front. Along all bearing lines from Casco Bay 140 to Cape Romain 140 (Gunn, Section 12), the Shelf Water/Slope Water front was shoreward of its 1974 position, with an average difference of 12 km. In July and again in September, Slope Water covered 40% of Georges Bank. The maximum coverage in 1974 was 17%. The spawning success of herring was apparently much reduced, and by December the numbers of larval herring were one seventh of what they had been in December 1974 (Lough, Section 19).

While fall pressure distributions brought warm conditions to the New England states and warm sea surface temperatures to the Middle Atlantic Bight, sea surface temperatures off New England were colder than they had been in fall 1974 (Figs. 1.2, 1.3). The warm atmospheric conditions did bring warmer temperatures to the sea surface very near to shore (Section 2.1). The western reaches of the Gulf of Maine had fall bottom temperatures about 1.5C colder than in 1974 (Davis, Section 14). The tide stations nearby had fall temperatures about 2C warmer than in 1974 (Section 2.1). While the distance between these two measurements is about 50 km, there is an indication of increased layering (the temperature difference changed from 5.5C in 1974 to 9.0C in 1975). This is associated with the anomalous high pressure cell over the Middle Atlantic Bight which helped suppress the fall mixing that normally takes place.

Associated with these conditions were two biological phenomena. There was an extensive bloom of siphonophores in the Gulf of Maine-Georges Bank region (Rogers, Section 20). The survival of arval herring over the winter was far greater than in the revious two years (Lough, Section 19). The distributions of iphonophores and of herring larvae were approximately the same. he greatest concentrations were in the Nantucket Shoals and the orthern portions of Georges Bank. It is possible that the elatinous masses of siphonophore decreased the larval herring ortality by either providing an alternate food to predators or y providing increased hiding places for the larvae.

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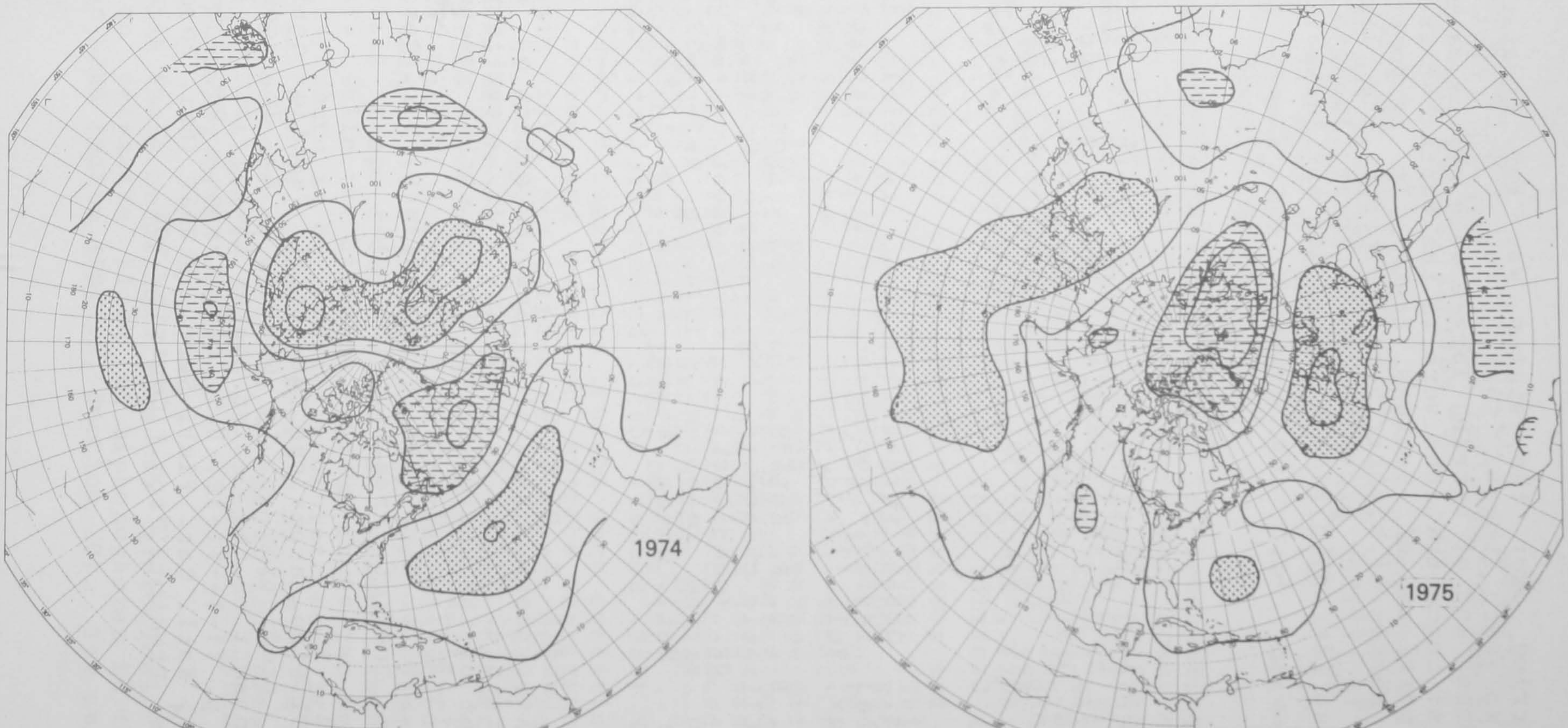

Figure 1.1--Annual mean height anomaly of 700 mb pressure surface for 1974 (left) and 1975 (right). Contour interval is 50 ft (15 m). Hatched shading is less than −50 ft (−15 m); stippled shading is greater than +50 ft (+15 m). Taken from Namias and Dickson (1976:fig. 3.1) and Dickson and Namias (Section 3, Fig. 3.1).

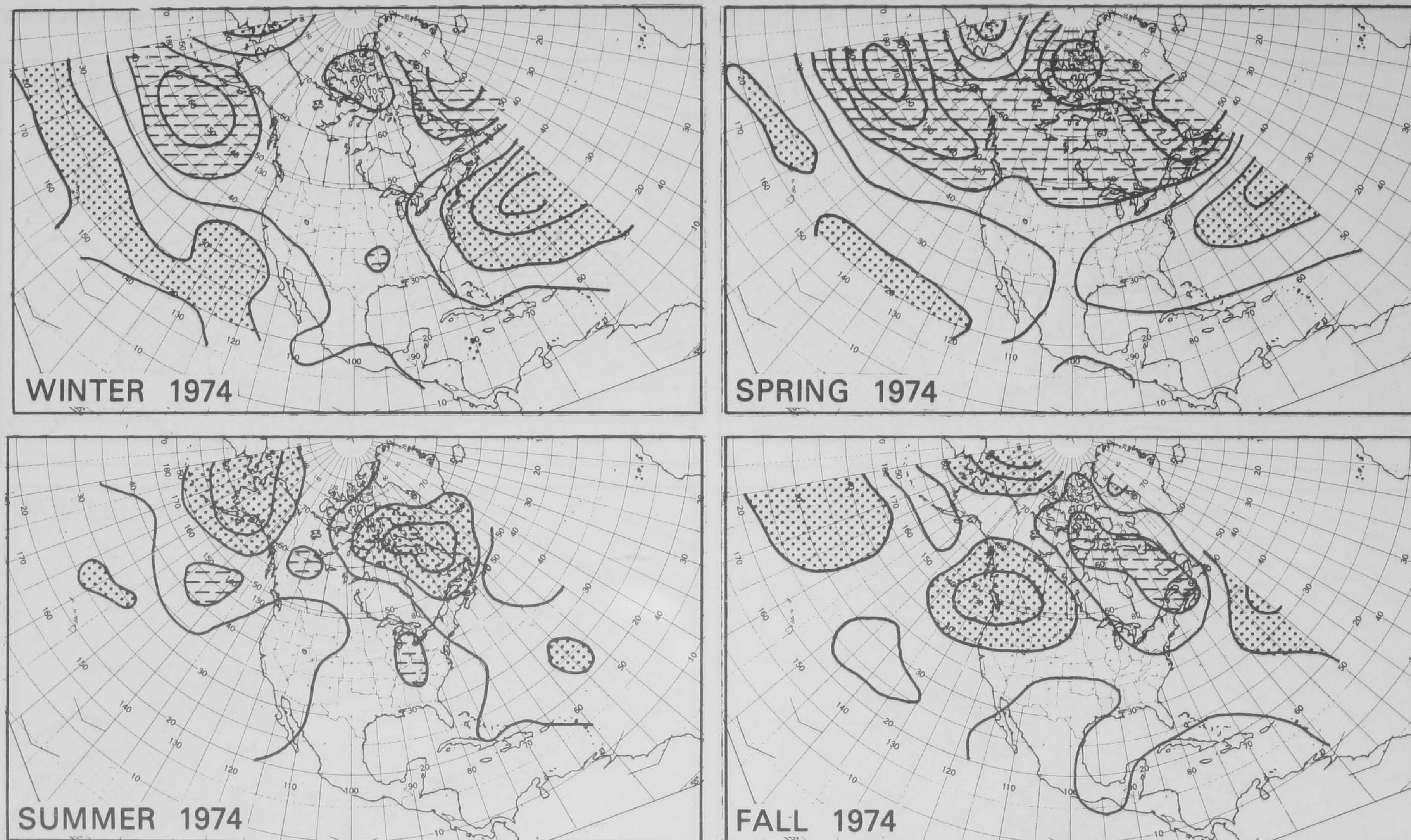

Figure 1.2a.—Quarterly mean height anomaly of 700 mb surface for 1974. Contour interval is 50 ft (15 m). Hatched shading is less than −50 ft (−15 m); stippled shading is greater than +50 ft (+15 m). Taken from Namias and Dickson (1976:fig. 3.3).

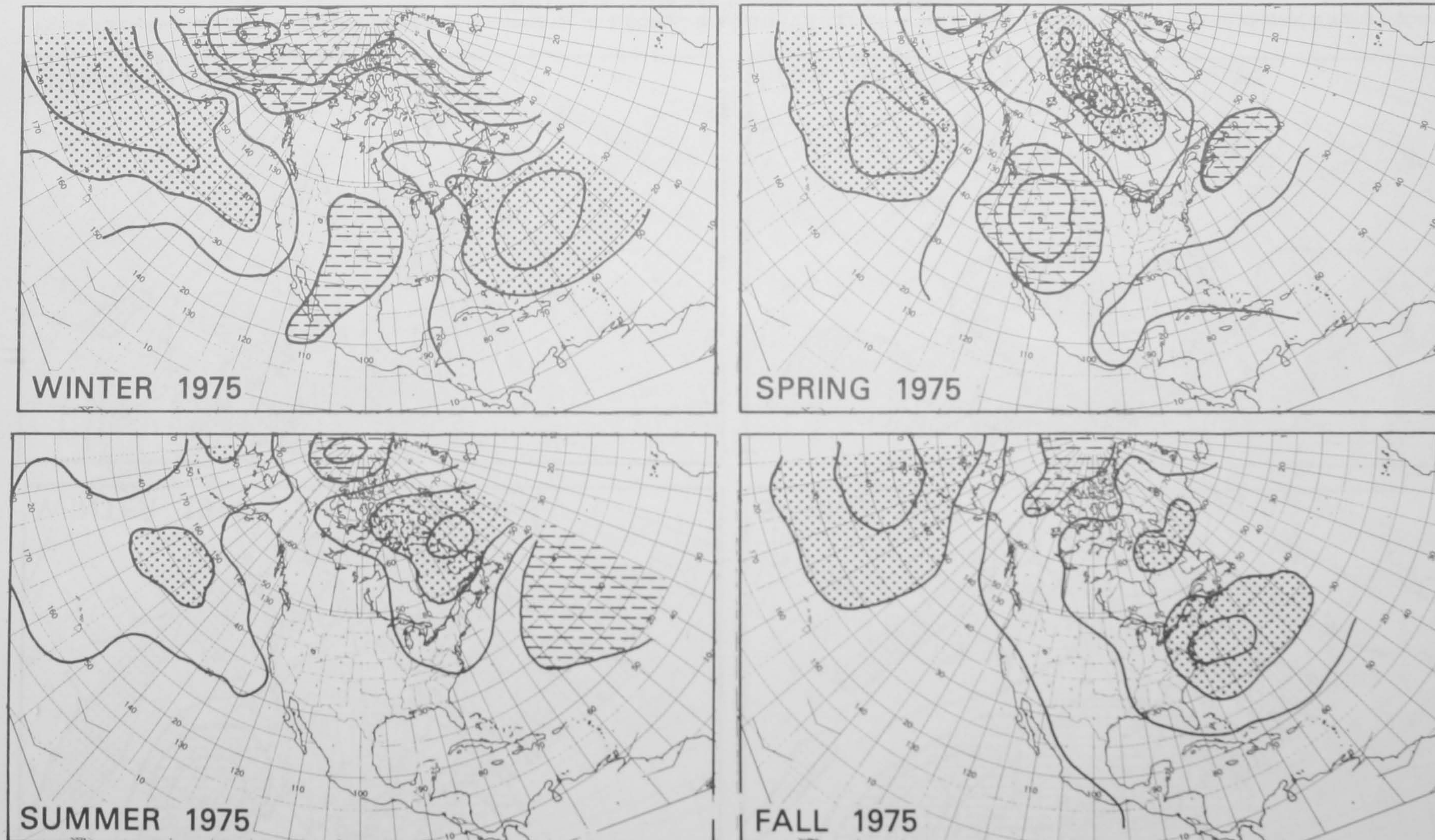

Figure 1.2b.—Quarterly mean height anomaly of 700 mb surface for 1975. Contour interval is 50 ft (15 m). Hatched shading is less than −50 ft (−15 m); stippled shading is greater than +50 ft (+15 m). Taken from Dickson and Namias (Section 3, Fig. 3.4).

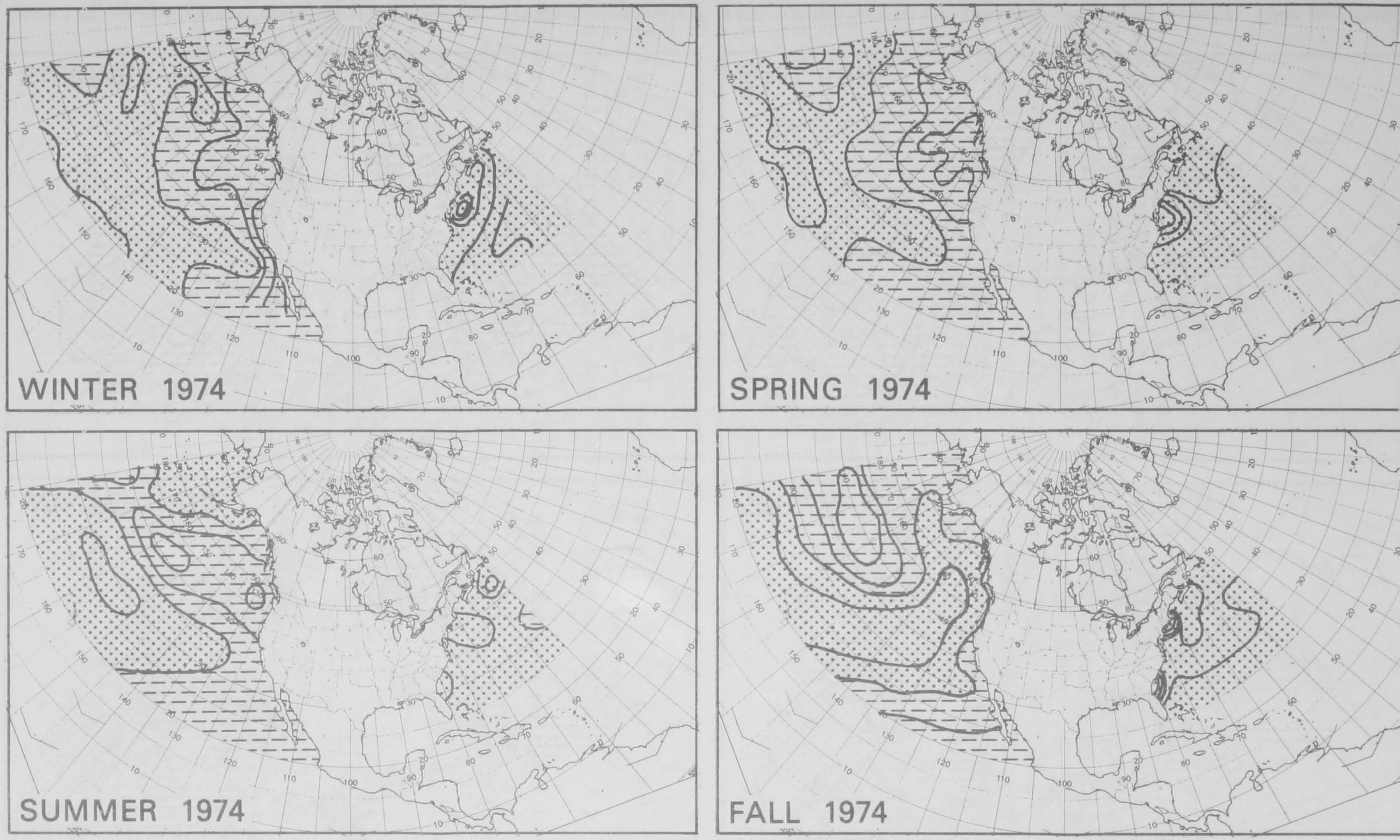

Figure 1.3a.—Quarterly sea surface temperature anomaly for 1974. Contour interval is 1F (0.6C). Hatched shading is negative; stippled shading is positive. Taken from Namias and Dickson (1976:fig. 3.3).

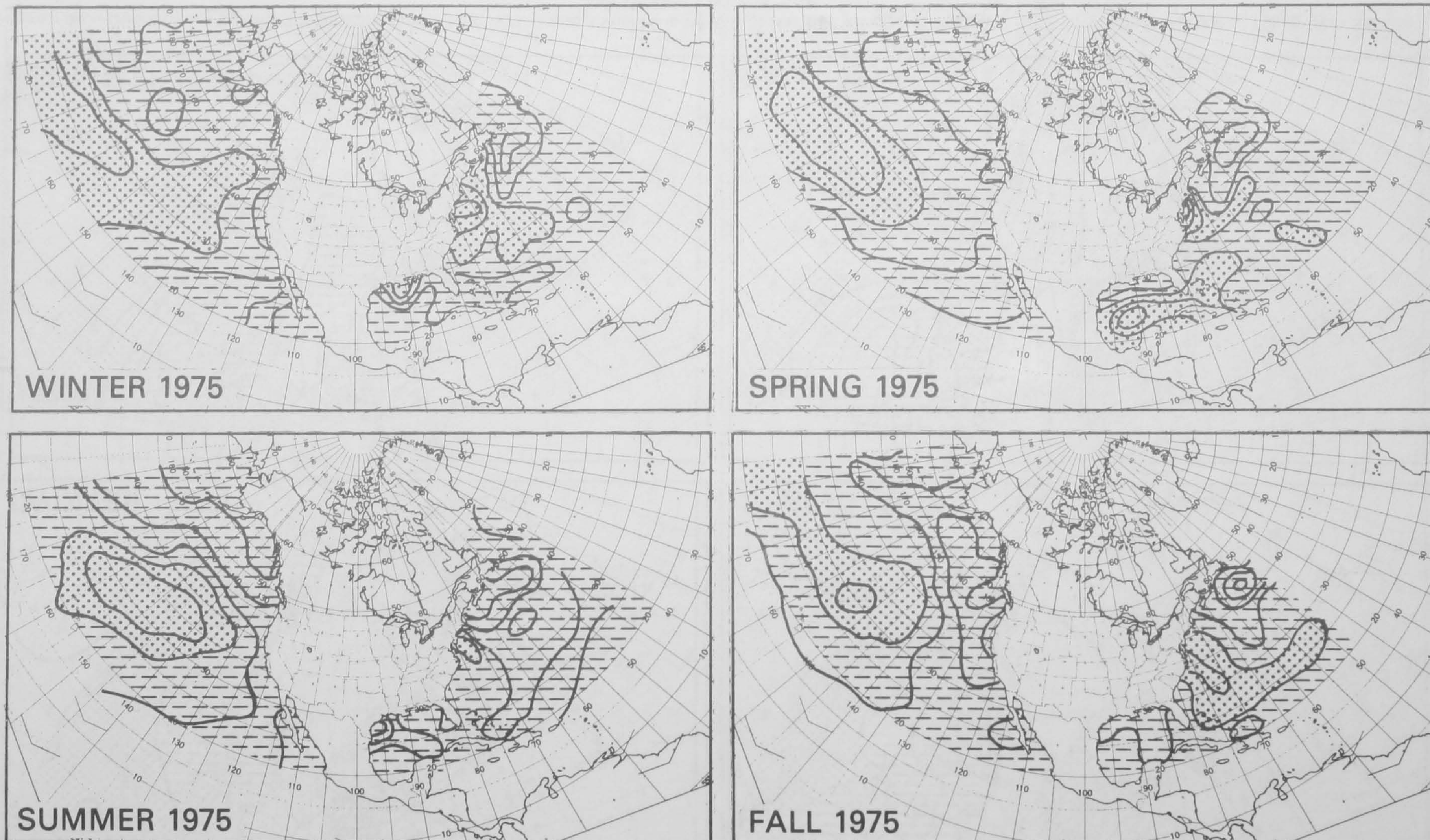

Figure 1.3b.—Quarterly sea surface temperature anomaly for 1975. Contour interval is 1F (0.6C). Hatched shading is negative; stippled shading is positive. Taken from Dickson and Namias (Section 3, Fig. 3.4).

Section 2

DATA PRODUCTS

e function of an annual summary of environmental conditions fecting living marine resources is to provide displays of vironmental data that are known to have fisheries significance d that are available repeatedly year after year. Due to the mplexity of interactions between living marine resources and eir environment an annual compendium of data products cannot ovide all the desirable information. This section contains veral environmental data products, with the aim of providing searchers a generally useful collection for studying the lationships of living marine resources to their environment.

rhaps the most basic environmental variables of significance to sheries are those describing the large-scale atmospheric and eanic circulations. Atmospheric variables include the stributions of surface barometric pressure and the height of mospheric pressure surfaces. Oceanic variables include the stributions of horizontal and vertical currents and of nd-driven transport. Observations of these variables, and of sociated variables such as sea surface temperature, are ailable to fisheries investigators because they are made utinely by merchant ships in support of weather forecasting. ps of the height of the 700 mb surface are published in the _nthly Weather Review_ (American Meteorological Society, ofessional journal), and are not duplicated here.

a surface temperature (SST) is often used as an indicator of vironmental fluctuations. It is affected by many atmospheric d oceanic processes, including insolation, currents, and xing. It correlates with the distribution of marine organisms many cases, and its anomaly patterns have coherence over great stances and time periods.

eleconnections" are found among a variety of parameters ncluding height of the 700 mb surface, SST, precipitation, and rrents). Such teleconnections, or coherence between vironmental processes over great distance and time intervals, fer the interesting possibility of relating biological uctuations in different areas, or different species, that may w appear as unrelated events.

bsurface temperature offers a means of portraying features such fronts or currents, but unfortunately is not as widely served as temperature at the sea surface.

Freshwater runoff into bays and estuaries is an importa variable. Excess runoff in springtime can affect the spawni and larval survival of many commercially important species fishes and shellfishes by decreasing the normal salinity of t water, increasing turbidity, and affecting the fishes' fo supply. Such runoff carries fertilizers, herbicides, and orga matter which act to reduce the available oxygen. The silt carries can cover the hard bottoms necessary for oysters other attached shellfish, and suspended particulate matt interferes with gill functioning in fish.

In this section are portrayals of coastal temperatures f U.S. National Ocean Survey tidal stations (Section 2.1) U.S. Geological Survey data on Chesapeake Bay streamf (Section 2.2). Also included are sea surface temperature anoma data from ship observations (McLain, Section 2.3), salinity d from transects of the Eastern North Pacific Transition Zone (L and Laurs, Section 2.4), and distributions of phytoplankton zooplankton between Cape Hatteras and Station Hotel (Smith Jossi, Section 2.5). These are continuing data observati which will be repeated in each annual SOE; other data sets w be added in the future as they become available. The goal is build a cohesive collection of data products that can be repea annually and that have fisheries significance.

DEFINITIONS

Several data products and contributions present anomali percentiles, or Z-statistics of selected data sets. The d sets are usually time series at a point or over a given ar Following are definitions:

__Anomaly__ - Departure from a defined norm. Usually, in applications, the norm is a monthly mean of the varia over some base period. It is not a deviation, in statistical sense, which is defined as a departure from mean of the whole data set.

__Percentile__ - In this technique, the data set or subset is ran by value, and the ranking of a data point, divided by 1 determines its percentile. This is a nonparamet statistic. It indicates, not the magnitude of the d point or its anomaly, but how significantly different it from the median value.

Z-statistic - Also called a standardized anomaly, this is calculated by dividing the anomaly by the standard deviation of the data set or subset. This is a parametric statistic, and for normally distributed data, is convertible to percentile using a table of cumulative standard normal distribution.

For any measured or estimated environmental element we can present the data in any of three fashions:

a) the actual data,
b) the anomaly, or
c) the percentile or Z-statistic.

The data set or derived data set can then be plotted or contoured in any of several standard ways. The technique of presentation is chosen by the individual contributor to best portray the phenomenon under study. Thus presentation of an upwelling index can give us a picture of actual upwelling or downwelling conditions. Presentation of the anomaly can give us a picture of the magnitude of the departures from normal conditions, while presentation of the percentile can give us a picture of the significance of the anomalies. For example, a small anomaly in a region with almost no variation is far more significant (very large or very small percentile) than a large anomaly in a region with large variations (percentile near 50).

2.1 COASTAL TEMPERATURES

Mean monthly SST's, from daily temperatures observed at NOS tidal stations, as well as the difference between monthly means, were contoured on time versus distance (latitude or longitude) plots. The available data were divided into six regions:

Gulf of Maine
Long Island Sound
East Coast, Montauk to Key West
Gulf of Mexico
West Coast
Gulf of Alaska

Because the 1974 SOE presented these data in degrees Fahrenheit, they are repeated here in degrees Celsius for comparison with the 1975 data.

Gulf of Maine - The SST's in the Gulf of Maine (Fig. 2.1) were essentially the same in 1975 as in 1974. The coldest temperatures, about 0.5C, occurred at Portland and Bar Harbor in February of both years. The warmest temperatures both years were about 20.5C at Boston in August.

The changes in mean monthly temperatures also appear qui similar. The change from cooling to warming occurred in mi February and from warming to cooling in early August of bo years. However, the time of maximum warming was nearly a mon earlier in 1975 than in 1974.

The short-lived rapid cooling at Bar Harbor and Eastport October 1974 was not repeated in 1975, but a more widespread ar of intense cooling began in November 1975, presaging a co January 1976.

Long Island Sound - In Long Island Sound (Fig. 2.2) summers 1 and 1975 appear almost identical in terms of SST's, with maximum of about 25C occurring at Bridgeport in August. December 1975, the sea was some 2C warmer than December 1974, the cooling trend towards the end of 1975 was stronge especially in the west, forerunning the cold January of 19 Though cooling began slightly earlier in 1975, the maximum ra was not reached until much later (November-Decemb vs. September-October). The same temperatures were reached abo half a month earlier in 1974 than in 1975. Both years reache low of 6C in December at the two ends of the Sound, wi Bridgeport again the warmest area, as it was throughout the ye

East Coast - Along the U.S. east coast (Fig. 2.3) SST's in first part of 1975 were about 2C cooler than in 1974, last into June in the northern areas. The month-to-month warming fairly similar in both years until late spring, when 1975 war 6C/mo compared to 4C/mo in 1974, to bring the summer maxima nearly the same value for both years, 1974 being just sligh warmer. The fall cooling was noticeably less rapid in 1975 th in 1974, with the result that by November the sea was (slightly less in the south) warmer than in 1974. This was warmest November along the east coast on record.

Rapid cooling was evident in December 1975, leading to a c January in 1976.

Gulf of Mexico - Around the U.S. Gulf Coast (Fig. 2.4) the fi quarter of 1974 was warmer than 1975 by up to 2C. But 1 showed a more intense warming trend in the spring, so that two summers were almost alike, reaching 30C at Key West Naples from June through September and at Cedar Key in August.

Cooling extended into February 1974, while heating had star already in January 1975. Maximum warming was reached April-May in both years, reaching 4C/mo between Cedar Key, and Port Mansfield, TX. In 1975 there was a small cell of 8C near Mobile (Dauphin Island). The cooling from September thro ecember was similar both years except in December in the Florida anhandle, where cooling approached 0C/mo in 1974 and 4C/mo in 975.

est Coast - The pattern of SST's during the past two years along he U.S. Pacific coast (Fig. 2.5) was virtually identical, but 975 was a degree or two cooler throughout. The cycle of warming nd cooling was essentially the same both years except for ctober at Astoria, OR, where cooling reached a maximum of 4C/mo n 1974. Cooling in southern California reached 2C/mo in ecember 1975, about twice the rate of cooling reached in ecember 1974.

ulf of Alaska - Along the south coast of Alaska (Fig. 2.6) the ST's showed similar patterns in 1974 and 1975, with cold cells f 2C at Juneau, Kodiak, and Unalaska. It is impossible to educe from the observations whether the last two are local ffects or a cold area spread all along the coast between these wo stations, as there is no observation point in the 950 km etween them. Juneau was at all times colder than other outheastern Alaska stations. It lies 130 km from open ocean and s therefore not as representative of oceanic conditions. The armest spots both years were Sitka to Yakutat and Seward, which ere warmer than 12C in July and August both years. The maximum ate of summer warming reached 3C/mo from Juneau to Yakutat and t Seward in 1974, while in 1975 the summer warming was not as trong. Also, the summer of 1974 was warm somewhat longer than 975, although the maximum rate of fall cooling occurred a month arlier in 1974 than in 1975.

.2 CHESAPEAKE BAY STREAMFLOW

stimates of monthly streamflow into Chesapeake Bay are provided y the USGS in cooperation with the several States of the hesapeake Bay's drainage basin (Appendix 2.1).

he streamflow in 1975 followed the average pattern fairly losely through August. The extremely high flow in September was ue to a combination of the extensive rainfall system brought orthward by the dying hurricane Eloise and a stagnant frontal one. Rainfall amounted to 5 in (13 cm) or more over eastern irginia, extreme eastern West Virginia, Maryland, New Jersey, astern Pennsylvania, and southern New York. Storm totals xceeded 10 in (26 cm) along some of the eastern mountain slopes, riggering major flooding on the Chemung, Susquehannah, Potomac, nd Shenandoah Rivers (Hebert 1976). This excess flow continued nto October, but volume returned to normal by the end of the ear.

2.3 SEA SURFACE TEMPERATURE ANOMALIES[1]

Ships of many nations, including U.S. Navy and merchant vessels, routinely make surface water temperature observations at sea as part of normal weather observations. The NMFS Pacific Environmental Group has access to these real-time weather reports received by teletype by the U.S. Navy Fleet Numerical Weather Central. These weather reports are available globally o magnetic tape. This section presents monthly maps of numeri values of SST and its anomaly from a long-term mean (1948-1967) for three areas along the United States coasts (Appendix 2.2). These areas include the waters near the East Coast in th northwest Atlantic (20N-46N, from the coast east to 60W), nea Alaska (45N-63N, from the coast west to 180W), and near the Wes Coast (20N-50N, from the coast west to 150W). Similar SS monthly mean anomaly maps for the Atlantic area were presented b McLain (1976) for 1974.

The maps presented in Appendix 2.2 partially duplicate SS anomaly maps available elsewhere: Atlantic maps published i *gulfstream* by the National Weather Service, and Pacific map published in *Fishing Information*, Southwest Fisheries Center NMFS, La Jolla, CA 92038. These maps differ from those presente here in various respects. The *gulfstream* maps give numeri values of temperature and anomaly as do the maps presented here, but do not include the Gulf of Mexico. They are reference against a long-term mean of all available historical data. Th *Fishing Information* maps cover most of the North Pacific Ocean but do not include data for the Bering Sea. These maps ar contoured and do not give numeric values. They are reference against the same 1948-67 period as used herein.

The maps presented here (Appendix 2.2) are an attempt to provi data in a uniform format for areas of fishery importance on bo Atlantic and Pacific coasts. The maps are based on data that a available at low cost within hours after collection, and so off a possible system for near real-time monitoring of coast environmental conditions.

Data Processing

The maps were constructed from observations of SST received i "real-time" from merchant, naval, and other vessels by Flee Numerical Weather Central. These reports were edited by

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[1]Prepared by D. R. McLain, Pacific Environmental Group, Nationa Marine Fisheries Service, NOAA, Monterey, CA 93940.

two-stage filter. In the first stage all observations less than -2.0C or greater than 40.0C were rejected to eliminate obviously erroneous values. In the second stage, reports greater than 8.0C from a mean of two or more observations were rejected. This mean was that of the previous month for the first two reports of the month, and of the month itself for later reports. Monthly means of SST by one degree square of longitude and latitude were then computed, as were anomalies from a long-term monthly mean which had been computed earlier as 20-yr means (1948-67) of monthly means by one degree squares. These long term means were calculated from SST reports archived at the National Climatic Center (Tape Data Family-11).

The SST, the anomaly from the 1948-67 mean, and the number of observations for each one degree square were finally plotted on an electrostatic plotter for each month for each of the three areas of interest. The convention followed by the gulfstream and by McLain (1976) was not to plot means or anomalies if there were fewer than four observations per one degree square/mo. This procedure works well in the northwest Atlantic where observations are abundant, but in the Pacific, and particularly in the Gulf of Alaska and Bering Sea where observations are much scarcer, plotting only squares with four or more observations results in large areas void of any data. I, therefore, plotted means for all areas if only two or more observations were available. This may result in a slightly noisier data product than found in gulfstream or McLain (1976), but it does provide usable information in important fishery areas of the North Pacific.

The SST anomaly maps presented in gulfstream and by McLain (1976) show anomalies if historical data are available for any year or combination of years in their respective reference periods. In the present maps, monthly mean SST's but not anomalies are plotted if there are fewer than 5 years represented in the 1948-67 mean. The 1-degree squares are shaded for anomalies of .0C or greater and for -1.0C or lower to emphasize regions of large SST anomaly.

Sources of Error

There are a number of potential sources of bias and error associated with these data. Some of these errors are as follows:

1. The observing ships tend to avoid areas of bad weather and thus the observations are biased towards areas of fair weather.

2. The observations are not randomly distributed over the oceans, but instead are concentrated along shipping lanes. Thus observations are much more dense off New York and Los Angeles than in the infrequently traveled portions of the

Gulf of Mexico or Gulf of Alaska. Also the data may be biased due to varying distribution of observations in time and space within each one degree square.

3. Most of the observations of SST are "injection temperatures," that is, they are made with a thermometer in the ship's main cooling water intake. Thus they are subject to instrument calibration error and to warming of the intake water in the engine room. Using data from 12 selected ships, Saur (1963) studied these errors and found that the injection temperatures averaged about 1.2F (0.7C) higher than surface water temperatures taken by a bucket thermometer.

2.4 EASTERN NORTH PACIFIC TRANSITION ZONE[2]

The early season distribution and relative abundance of North Pacific albacore and the interannual variations in these factors have been shown to be associated with the Transition Zone (Laurs and Lynn, 1977). The Transition Zone waters are found between modified subarctic waters to the north and subtropic waters to the south. The subarctic and subtropic fronts form the boundaries of the Zone.

The subarctic and subtropic fronts were strongly developed and formed distinctive boundaries of the Transition Zone in June 1972 and 1973. In 1974, the frontal structure was poorly developed and the boundaries of the Transition Zone waters were indistinct (Laurs and Lynn 1976; Saur 1976). In June 1975, the frontal system was again strongly developed and appeared in much the same form as it had in 1972 and 1973.

For the fourth year in succession, the La Jolla Laboratory of the National Marine Fisheries Service, Southwest Fisheries Center has conducted a preseason albacore/oceanography survey across the Transition Zone in an offshore region centered about 800 nm (1500 km) west of central California. In each of these years, the survey was conducted in cooperation with commercial albacore vessels on charter to the American Fishermen's Research Foundation. In 1975, the survey operations were abbreviated in scope. The NOS RV Townsend Cromwell sailed from Seattle to Honolulu, conducting oceanographic stations enroute. A single north to south transect was made across the Transition Zone along 137W30'. Three chartered fishing vessels scouted along the same

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[2]Prepared by R. J. Lynn and R. M. Laurs, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, La Jolla, CA 92038.

track; however, participation by independent commercial fishing vessels, which had been so helpful in past years, did not materialize because of a late albacore price settlement. As a result, the fishing effort was very limited and the catch distribution was inconclusive as to association with oceanographic conditions.

Four oceanographic sections of the vertical distribution of salinity along 137W30' taken in June 1972-75 are given in Figure 2.7. The low salinity subarctic waters are depicted by hatched shading of salinities less than 33.8 o/oo. The high salinity subtropic waters are depicted with dotted shading. For the first three years, the dotted shading is shown for salinities greater than 34.2 o/oo. In June 1975, the salinities in the Transition Zone were generally 0.2 o/oo higher than in the earlier years, hence the lower limit for the dotted shading was given as 34.4 o/oo. The 58F (14.4C) and 62F (16.7C) isotherms are shown by heavy dashed lines.

In each of these sections, the fronts are identified by sharp horizontal gradients of salinity that extend from the surface to 150 m or more and by abrupt changes in depth of specific isotherms. The subarctic front involves a change in depth of the 58F (14.4C) isotherm and the vertical excursion of the 33.8 o/oo isohaline. To the north, the surface waters are low in salinity and the 33.8 o/oo isohaline is found in the halocline below 150 m. The subtropic front involves a change in depth of the 62F (16.7C) isotherm and a vertical excursion of the 34.4 o/oo and/or 34.6 o/oo isohalines. To the south, the surface waters are high in salinity and decrease abruptly below 180 m.

In June 1975, the subtropic front, at 32N, and the subarctic front, at 36N30', are seen to be clearly reestablished from the poorly developed conditions found in June 1974. This reestablishment lends support to the speculation that the 1974 conditions were atypical. However, there are some differences between the 1975 section and the 1972 and 1973 sections. The low salinity subarctic water is shallow in 1975, suggesting that slightly higher salinities prevailed in the deeper layers as well as in the Transition Zone. Also, the Transition Zone is half again as broad in 1975 as in 1972 and 1973. The broad separation between the subtropic and subarctic fronts was also found to the west in closely spaced expendable bathythermograph (XBT) observations on a transect taken between Seattle and Honolulu (Saur, Section 7).

2.5 COPEPODA, NET PHYTOPLANKTON, AND T-S-COPEPOD RELATIONSHIPS IN THE MIDDLE ATLANTIC BIGHT[3]

During 1974 and 1975 Hardy Continuous Plankton Recorders (CPR; Hardy 1939) collected samples monthly while being towed by U.S. Coast Guard cutters between the mouth of Chesapeake Bay and Ocean Weather Station HOTEL (38N, 71W). In addition, XBT and surface bucket temperature and surface salinity measurements were made at 1-hour intervals along these routes. This is part of a cooperative agreement between the MARMAP Program of the National Marine Fisheries Service and 1) the U.S. Coast Guard for the at-sea collection of data, and 2) the Institute for Marine Environmental Research (IMER) of the United Kingdom for a southern extension of the long-term survey of plankton dynamics in the North Atlantic by which IMER has been monitoring seasonal and long-term changes since 1930.

This section reports the seasonal abundance and variation of copepods; seasonal variation of net phytoplankton in the Shelf, Slope, and Gulf Stream Waters, at a 10 m depth along the CPR route; and copepod abundance in relation to surface temperature and salinity.

Figures 2.8 and 2.9 show the various positions of the thermal fronts and water masses according to the U.S. Navy Experimental Ocean Frontal Analysis (EOFA) for time periods as close as possible to the times of CPR tows. The CPR transects are superimposed to show their relationship to these oceanic features. The oceanographic features have been described in detail by Cook et al.[4]

The EOFA needed to be modified slightly in March, June, September, and November 1975 for either 1) conflict with the XBT data, or 2) conflict with species composition data. Water masses moved extensively from month to month, and plankton distribution reflected these changes. Slope Water was not sampled in June because it had moved north of the survey area.

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[3]Prepared by D. E. Smith and J. W. Jossi, MARMAP Field Group, NMFS, Narragansett, RI 02882. We thank the U.S. Coast Guard Marine Services Branch, Atlantic Area, and the officers and crews of the USCG cutters Taney, Tamaroa, Ingham, Unimak, and Chase for their assistance in conducting this survey.

[4]Cook, S. K., B. P. Collins, and C. Carty, 1977. Expendable bathythermograph observations from the NMFS/MARAD ships of opportunity program for 1975. MS. Atlantic Environmental Group, NMFS, Narragansett, RI 02882.

Relative abundance of phytoplankton versus month in three water masses is shown in Figure 2.10. Abundance of copepods versus month in each water mass is shown in Figure 2.11. Please note that on the latter figure the abundance scale differs for the Gulf Stream Water mass.

Shelf Water

The mixed diatom and dincflagellate flora of October 1974 was replaced by an all dinoflagellate flora by November. These dinoflagellates were replaced by diatoms by January 1975. Phytoplankton did not occur in February samples. A dinoflagellate bloom appears to have begun in March, and it peaked in June. Dinoflagellates were observed in lower numbers in August. Phytoplankton was not observed in September 1975. An autumn bloom of both diatoms and dinoflagellates occurred in November 1975. This was one month later than in autumn 1974 and was followed by a decline of both groups rather than by an increase of dinoflagellates as in 1974.

The Shelf Water copepods were a mixture of cold- and warm-water species. *Centropages typicus*, *Calanus finmarchicus*, *Temora longicornis*, and *Pseudocalanus* spp. were the abundant cold-water species. *Oncaea* spp., *Corycaeus* spp., *Centropages velificatus*, *Temora turbinata*, *Calanus minor*, *Farranula gracilis*, and *Mecynocera clausi* were the abundant warm-water species.

The maximum numbers of warm-water copepods occurred when sampling began in October 1974 (Fig. 2.11). They had declined greatly by November and most were absent by January. A few reappeared in May and June. They increased through August and reached an autumn maximum in September and were depleted by November and absent in December.

Centropages typicus (a cold-water copepod) was absent in October but had a fall increase, after the fall maximum of the warm-water copepods, in both 1974 and 1975. *Centropages typicus* was absent again by January 1975.

The cold-water--warm-water species made up the entire collections in January, had increased by February, and were gradually replaced through March and May by the cold-water species. These cold- and warm-water species were probably cold-water members of these three groups (shown in Fig. 2.11) rather than a mixture of cold- and warm-water species.

The spring increase of the cold-water species began in February and peaked in May. A declining remnant of *Centropages typicus* was present in June, but, otherwise, the cold-water copepods did not appear again until *C. typicus* reappeared in November.

The fall 1974 decline in diatoms was coincident with a decline of warm-water copepods and an increase of dinoflagellates and the copepod C. typicus.

Diatoms increased again in January when dinoflagellates were absent and copepods were at a minimum. The spring copepod increase followed the January diatom increase. The diatoms disappeared by February. Copepods continued to increase. Dinoflagellates began to increase about two months later than diatoms and copepods. They peaked while the copepods were in a June minimum. Dinoflagellates in August preceded the August to September copepod increase. Diatoms and dinoflagellates bloomed in November 1975 while the copepods were at a relatively low abundance. Copepods increased again after this fall phytoplankton bloom.

Slope Water

Dinoflagellates in the Slope Water were less abundant than in Shelf Water, while diatoms were more abundant and much more diverse than in Shelf Water. Silicoflagellates were found in Slope Water but were absent in Shelf and Gulf Stream Water.

There was a fall bloom of phytoplankton from August to November 1974 and a spring bloom from January to May. There was no fall bloom observed in 1975. Diatoms were always present when phytoplankton were found as opposed to their occurrence during only three months in Shelf Water. They were numerically dominant except in May 1975. Silicoflagellates increased and decreased along with the diatoms. They were absent when diatom numbers were low in August of both years and in January 1975.

Centropages typicus was the first cold-water copepod to appear in February. It steadily increased until May when it dominated the plankton. It was absent from the CPR samples by August. The cold-water Calanus copepodites and Pseudocalanus spp. were abundant in May but appeared neither before nor after.

The August-October 1974 decline in copepods occurred while there was an increase in diatoms. A November copepod increase coincided with a phytoplankton bloom made up mostly of diatoms. The spring increase of copepods and phytoplankton began about the same time but the phytoplankton reached peak abundance two months before the copepods. Diatoms were reduced significantly from their March peak by the time the copepods peaked in May. The dinoflagellates maintained their numbers during the copepod increase but did not occur after the May peak. The spring copepod increase coincided in time with that in Shelf Water and was dominated in both water masses by C. typicus. The presence of diatoms in August 1975 coincided with a copepod increase.

Gulf Stream Water

Data show a diatom bloom during January-March, which may have persisted--no April or May samples were obtained. They increased in February. The appearance of diatoms in August 1975 was followed by a copepod increase and a phytoplankton absence. Dinoflagellates which are large enough to be retained in the CPR silk were of low abundance. Gulf Stream diatoms were less abundant than Slope Water diatoms, but more abundant than Shelf Water diatoms.

Centropages typicus was the only cold-water copepod to appear in the Gulf Stream. It only appeared in samples taken close to the Shelf or Slope Water front, and mostly in winter. The Gulf Stream copepod population abundance was approximately one order of magnitude less than the Shelf or Slope Water population. Minima appeared in January and August 1975. There were maxima in February, June, and September 1975.

Temperature-Salinity-Copepod Distribution

T-S-copepod distributions of several species are shown in Figures 2.12 through 2.17. Centropages velificatus occurred in Shelf and Slope Water only at temperatures above 19C and salinites of <35 o/oo. Centropages typicus was limited to <36 o/oo and <24.5C. It was most numerous in nearshore Shelf Water. Centropages bradyi was found in Slope Water with salinities of 33-35 o/oo, and it appears to be a good Slope Water indicator species. Metridia lucens occurred only between 33 and 36 o/oo salinity and <17C in mostly Slope Water with one relatively abundant occurrence in Shelf Water. Pleuromamma abdominalis occurred only in Slope, Gulf Stream, and Sargasso Sea Water at salinities >34.5 o/oo and temperatures >22.5C. Pleuromamma gracilis was abundant in night samples in salinities between 34 and 36 o/oo and temperatures <26C. It was absent in daytime samples, indicating diel vertical migration greater than 10 m in the daytime. It had a high occurrence in Slope Water but occurred in only one Shelf Water sample. Pleuromamma robusta was found only in Slope Water, salinity 34-35.5 o/oo and temperature 15-23C. This appears to be a good Slope Water indicator species. Farranula gracilis was most numerous in Slope and Gulf Stream Waters at salinities >34.5 o/oo and temperatures >24.5C. The data show F. gracilis as a good indicator of warm water. Calanus minor occurred in all water masses from warmest Gulf Stream Water to most saline Sargasso Sea Water, least saline Shelf Water, and nearly the coolest Shelf Water, but was most abundant in <35 o/oo salinity and temperatures of 14-23C. Undinula vulgaris was most numerous in Slope and Gulf Stream Waters warmer than 23.5C, but occurred in Shelf Water at a lower temperature (19.5-21.8C). Temora stylifera had a high percentage occurrence in Slope Water where the temperature was >24C, but was present throughout the

Gulf Stream and Slope Waters at a lower percentage occurrence.

Summary

In every case in which diatoms were numerous enough to be recorded, either the copepods were more numerous than usual or they increased within a month.

In every case following a copepod increase, the diatoms were absent from the samples or had been reduced significantly. In most cases, dinoflagellates either increased along with diatoms or increased after the diatoms. Dinoflagellates were not depleted by copepod increases as much as diatoms were. It appears as if an increase in dinoflagellates is followed by a decline of the diatom population, but this may result from the diatoms' being consumed by the increased numbers of copepods and the dinoflagellates' not being grazed upon.

These data indicate that several copepods are indicators of water characteristics: *Centropages vilificatus* was indicative of warm Shelf Water; *Centropages bradyi*, *Pleuromamma gracilis*, and *P. robusta* were indicators of Slope Water.

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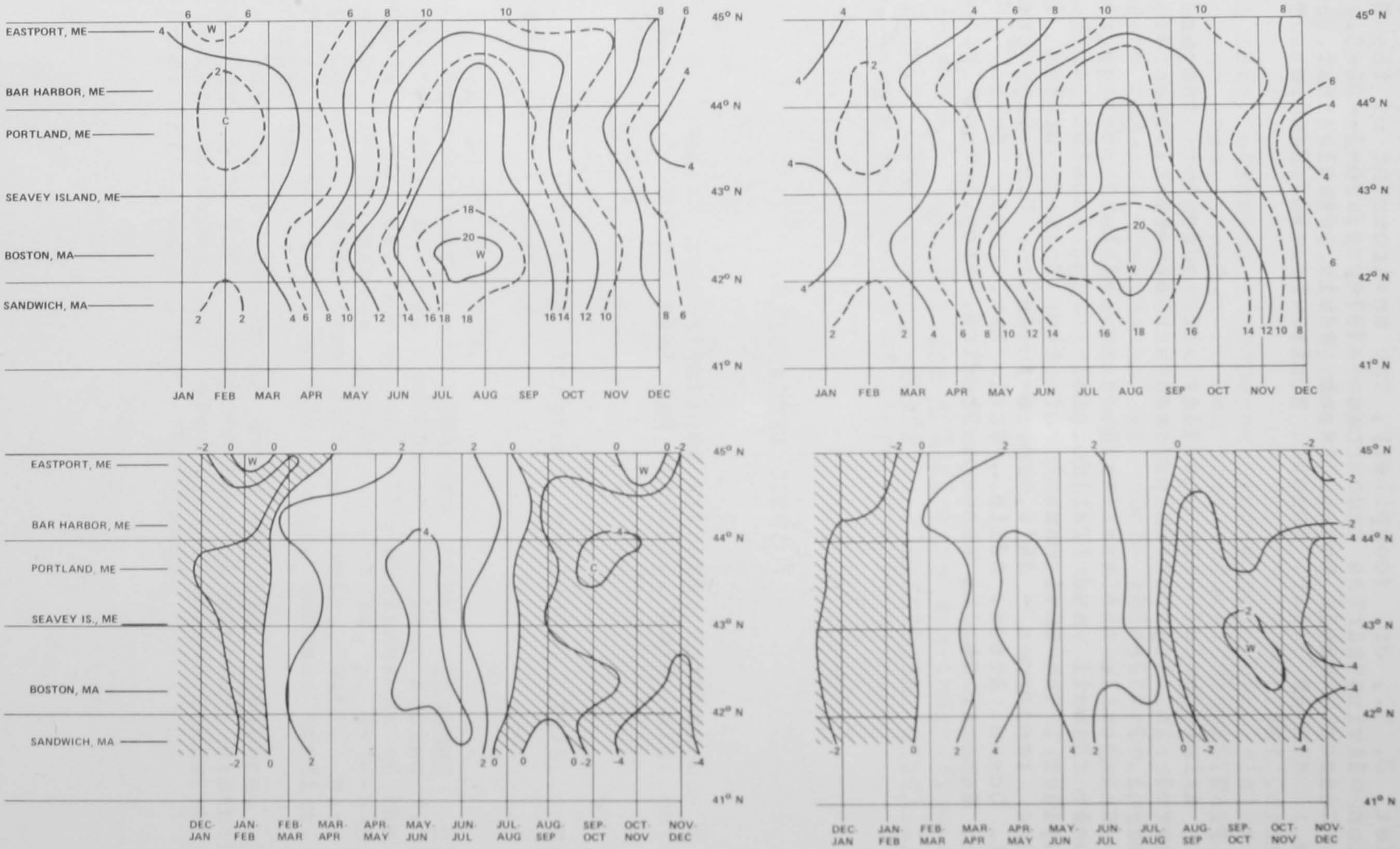


Figure 2.1.—Gulf of Maine: monthly mean sea surface temperatures (upper) and changes in monthly mean temperatures (lower) in degrees C for 1974 (left) and 1975 (right).

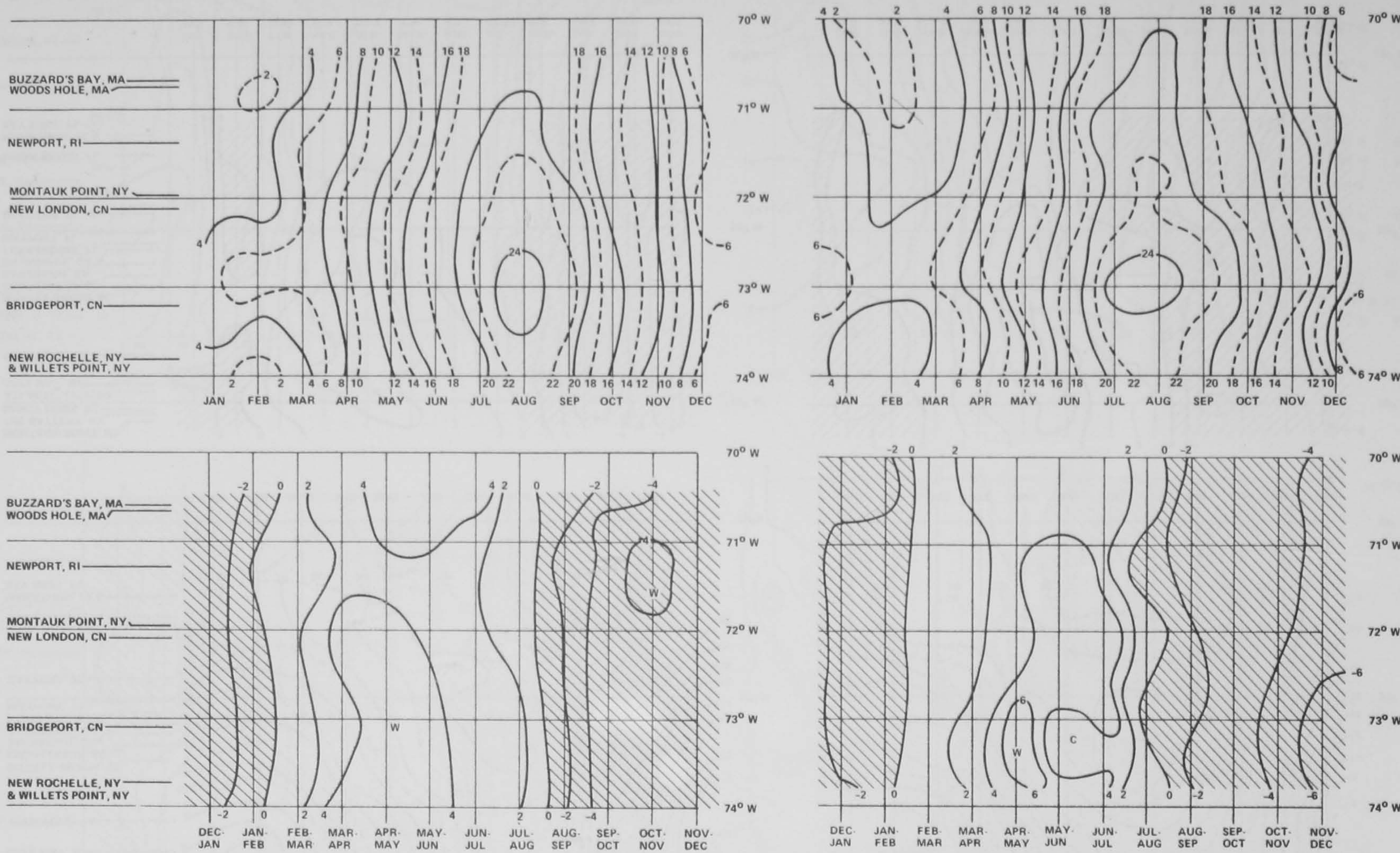


Figure 2.2.—Long Island Sound: monthly mean sea surface temperatures (upper) and changes in monthly mean temperatures (lower) in degrees C for 1974 (left) and 1975 (right).

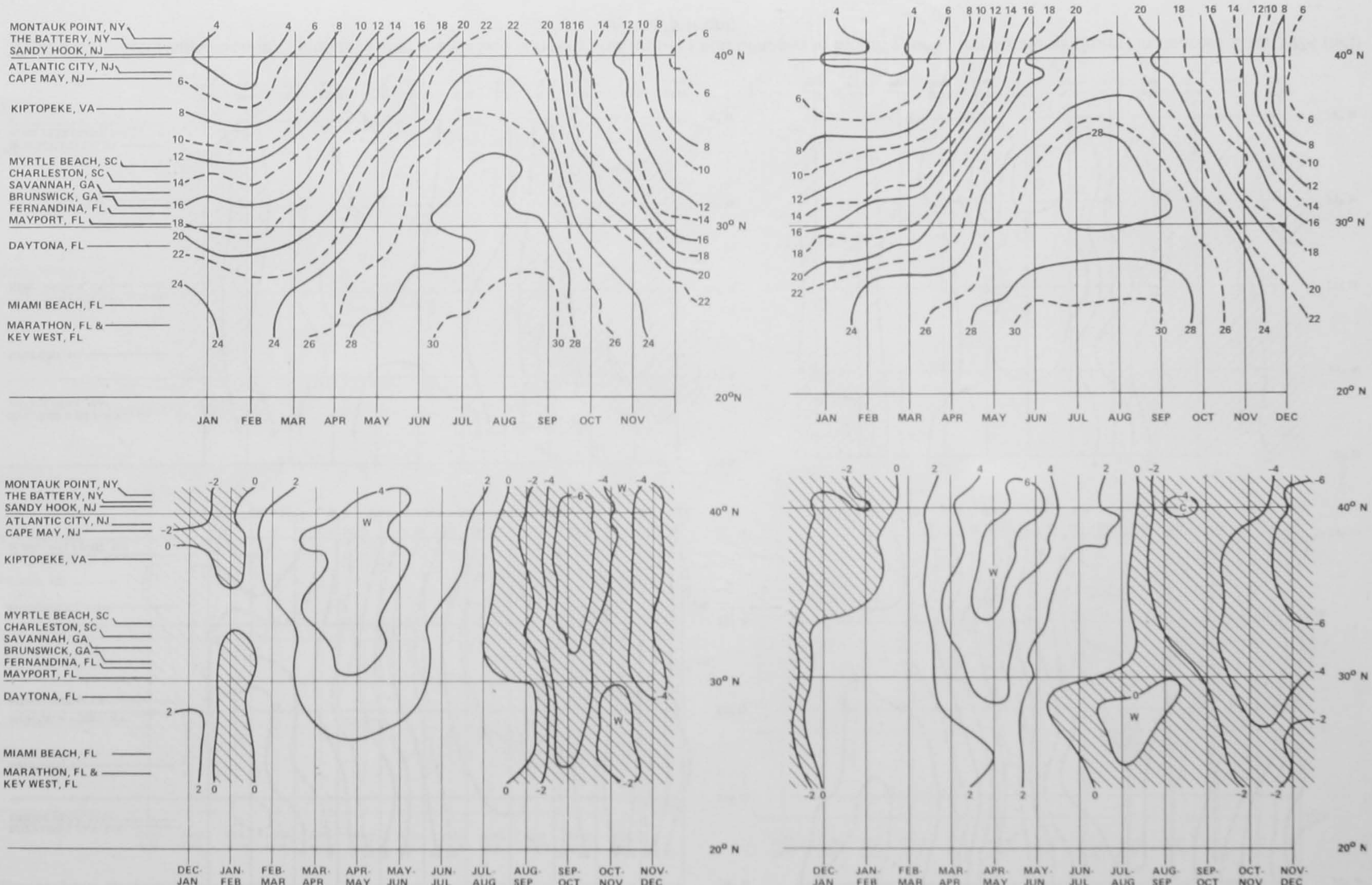


Figure 2.3.—U.S. East Coast: monthly mean sea surface temperatures (upper) and changes in monthly mean temperatures (lower) in degrees C for 1974 (left) and 1975 right).

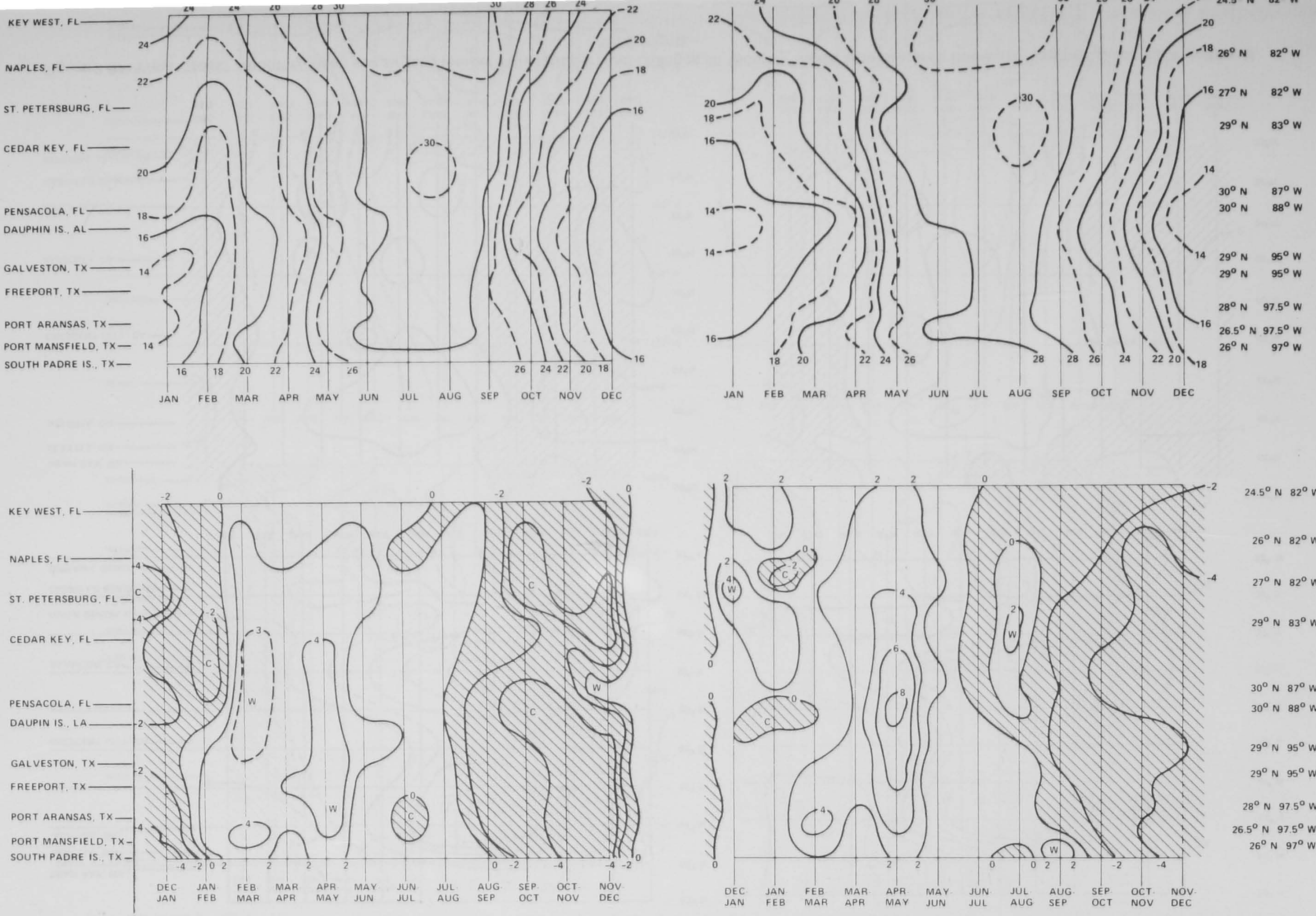


Figure 2.4.—Gulf of Mexico: monthly mean sea surface temperatures (upper) and changes in monthly mean temperatures (lower) in degrees C for 1974 (left, and 1975 (right).

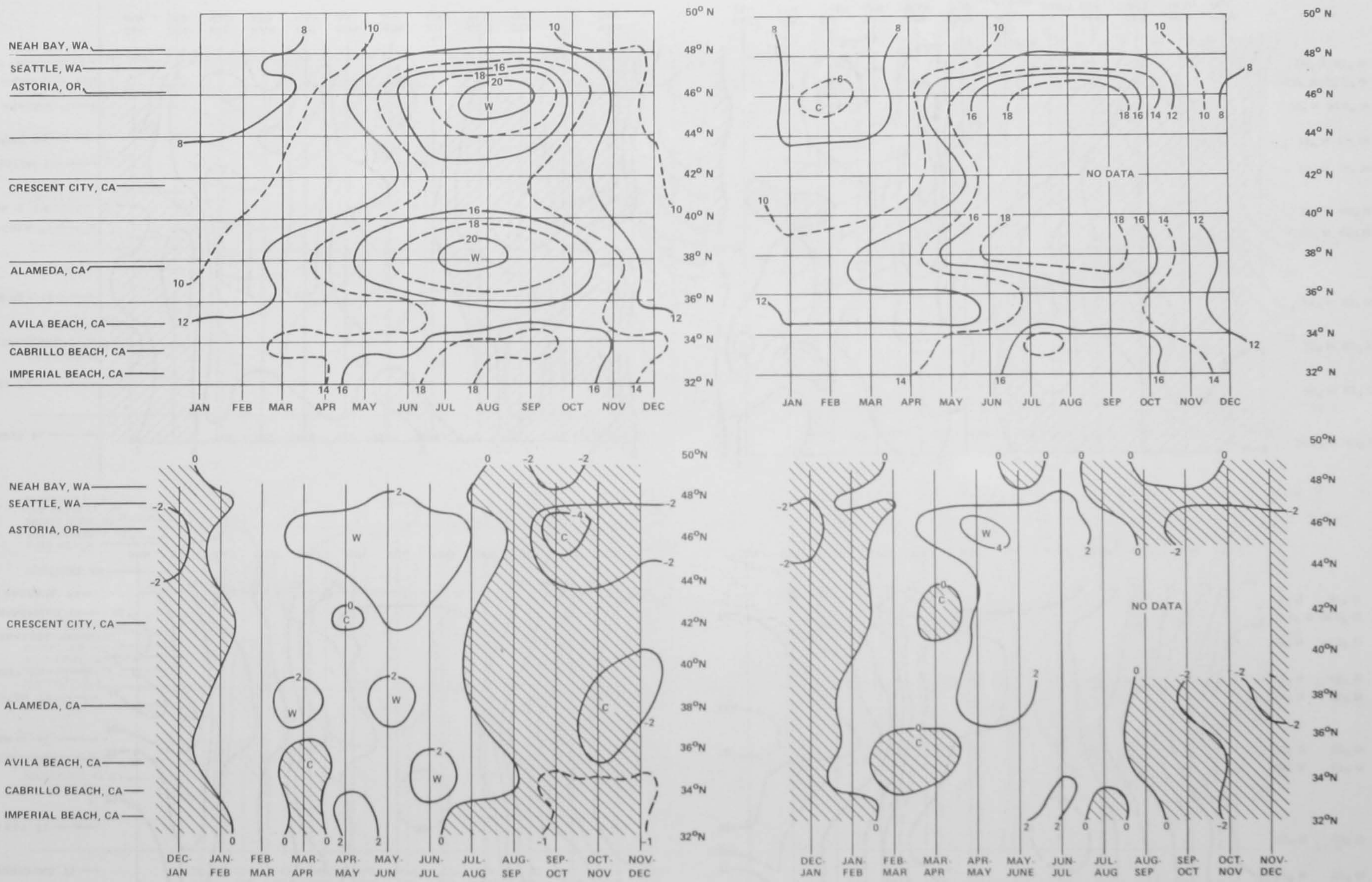


Figure 2.5.—West Coast: monthly mean sea surface temperatures (upper) and changes in monthly mean temperatures (lower) in degrees C for 1974 (left) and 1975 (right).

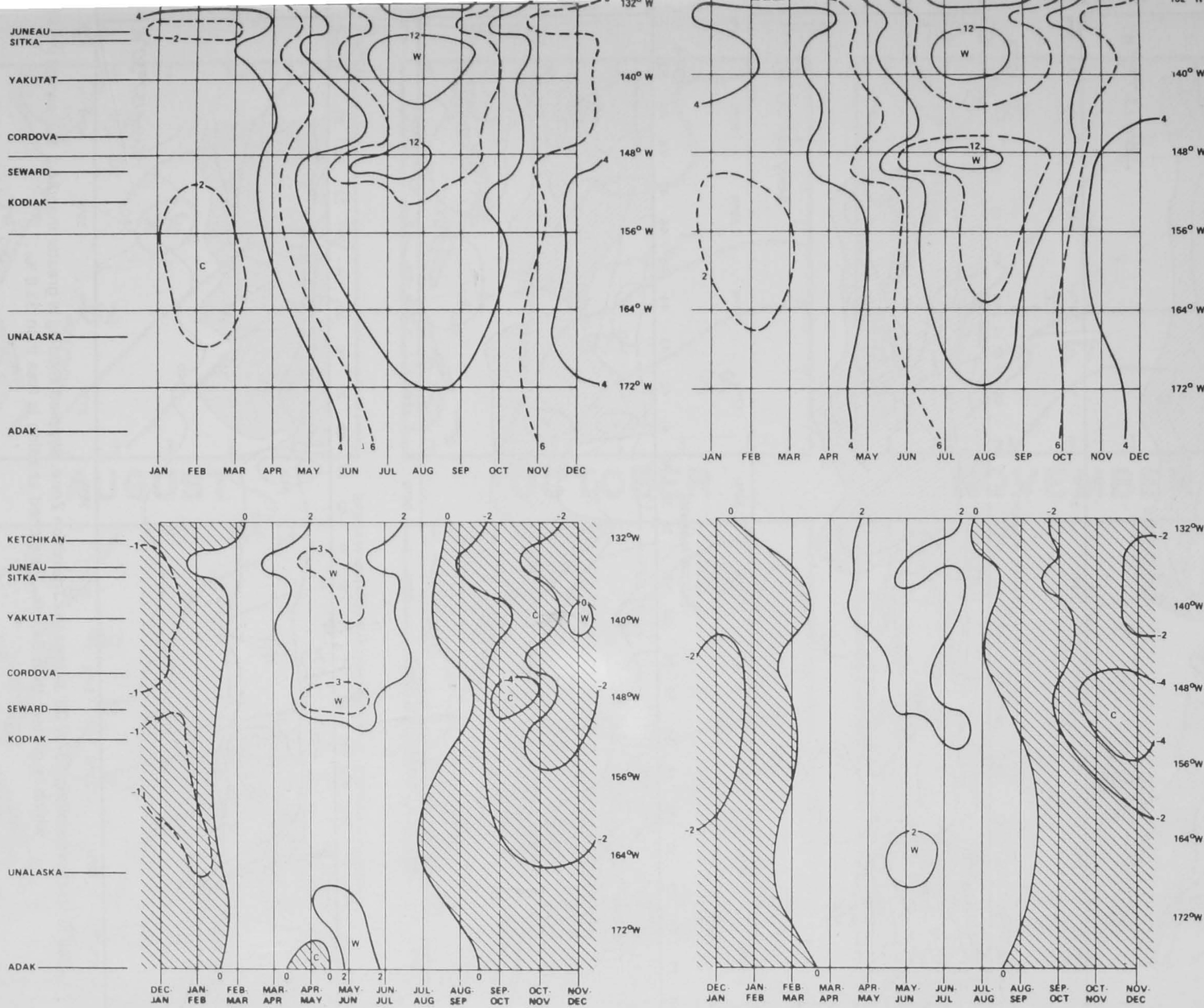


Figure 2.6.—Gulf of Alaska: monthly mean sea surface temperatures (upper) and changes in monthly mean temperatures (lower) in degrees C for 1974 (left) and 1975 (right).

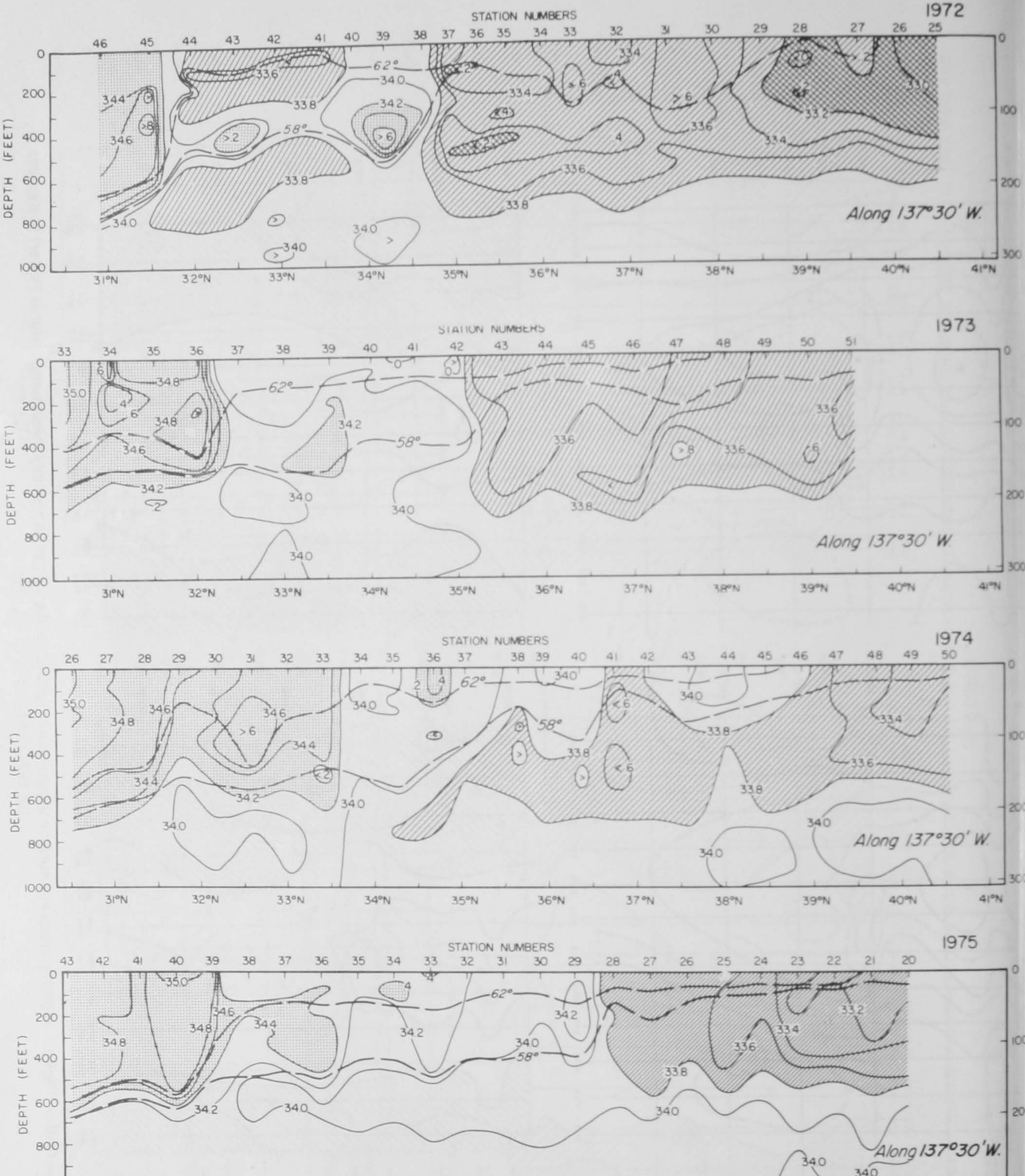


Figure 2.7.—Salinity transects along 137W 30′ across the Transition Zone. Stippled shading is greater than 34.2 ‰ except in 1975 which is greater than 34.4 ‰. Hatched shading is less than 33.8 ‰.

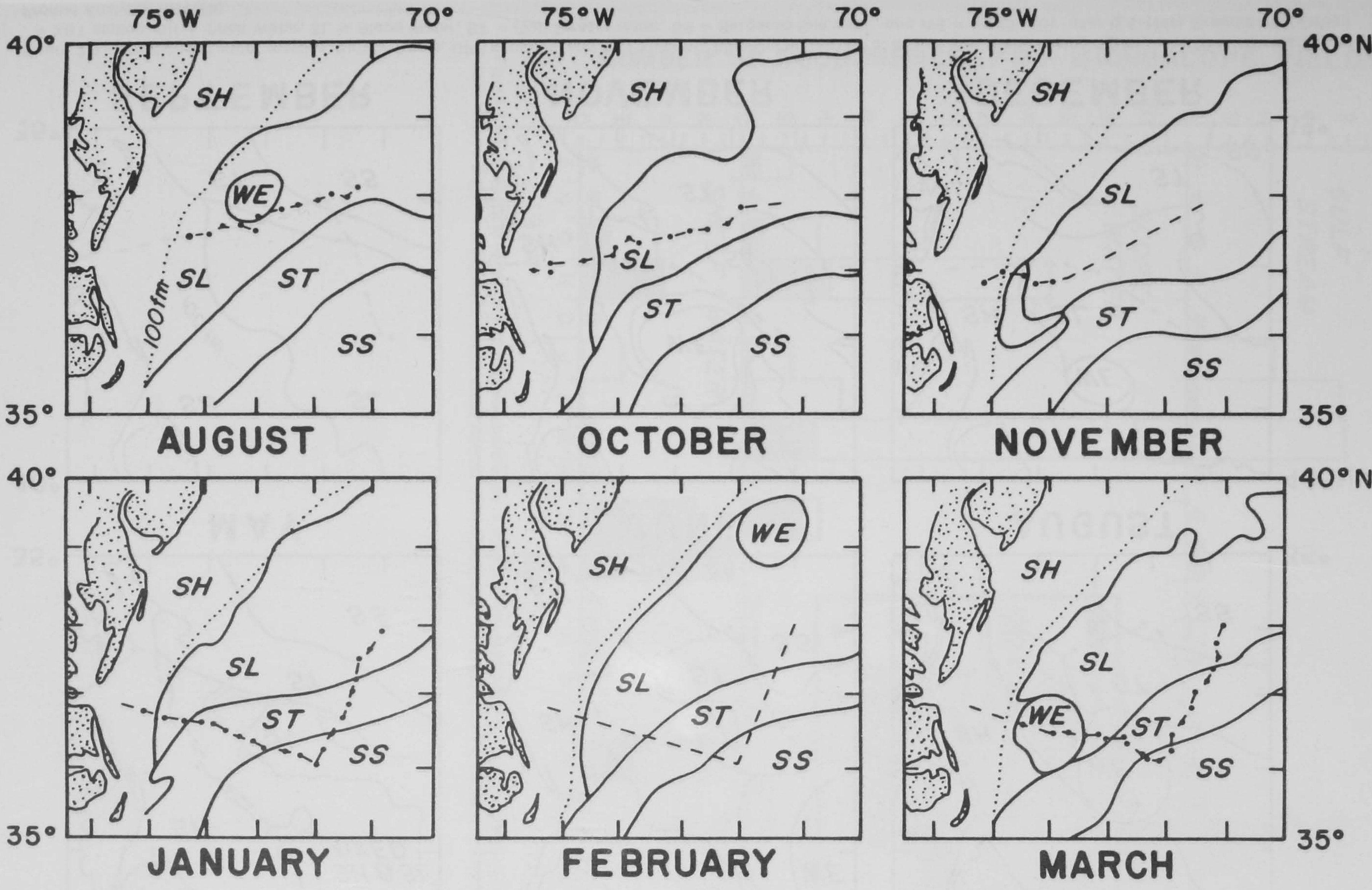


Figure 2.8.—Positions of water masses, surface fronts, CPR samples, and XBT stations, August 1974-March 1975. In this and the following figure, – = CPR/10-mile block, . = XBT station, SH = Shelf Water, SL = Slope Water, ST = Gulf Stream water, SS = Sargasso Sea water, and WE = warm eddy (after U.S. Navy Experimental Ocean Frontal Analysis 1974-75).

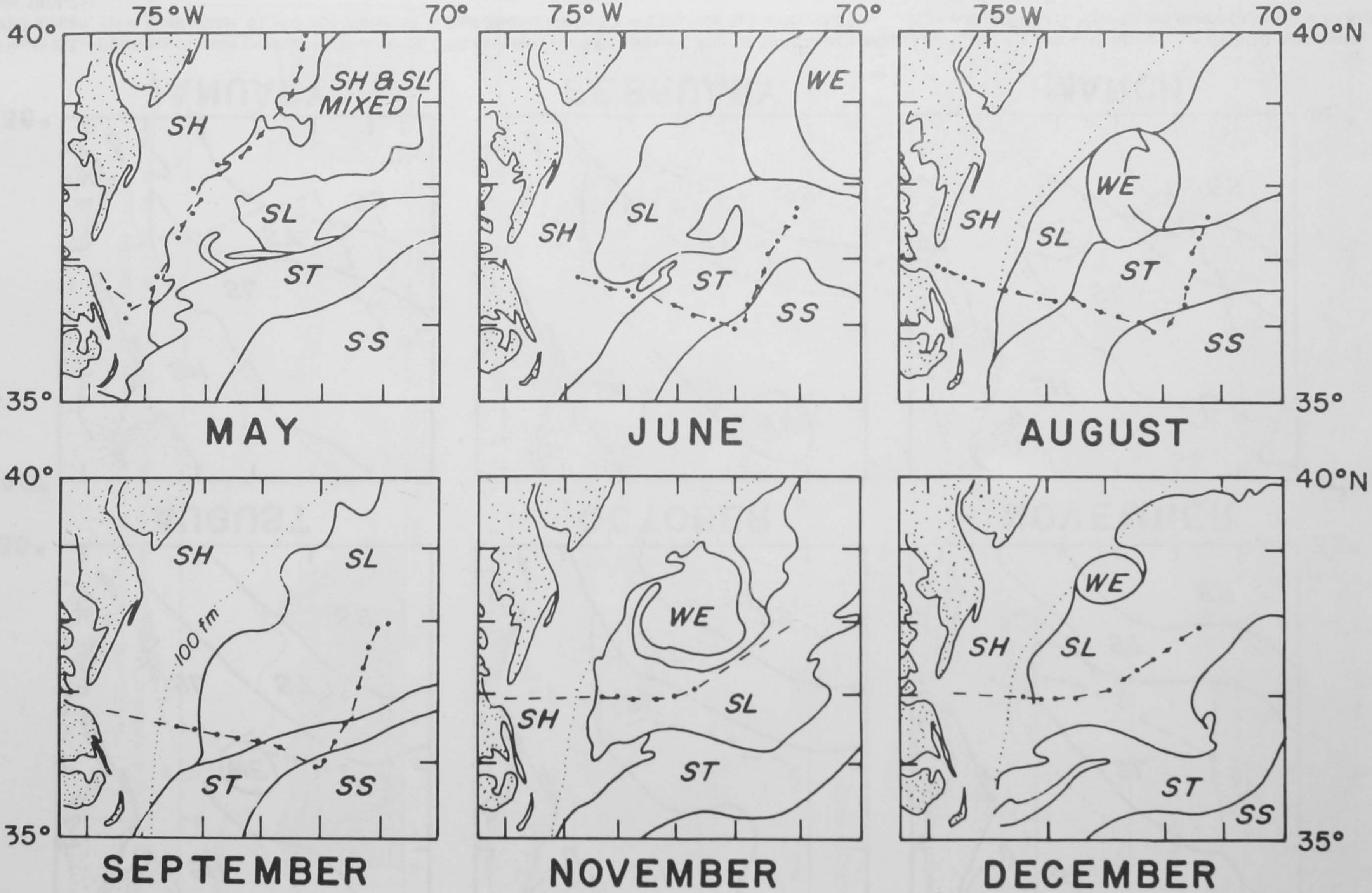


Figure 2.9.—Positions of water masses, furface fronts, CPR samples, and XBT stations, May-December 1975. In this and the following figure, ÷ = CPR/10-mile block, . = XBT station, SH = Shelf Water, SL = Slope Water, ST = Gulf Stream water, SS = Sargasso Sea water, and WE = warm eddy (after U.S. Navy Experimental Ocean Frontal Analysis 1974-75).

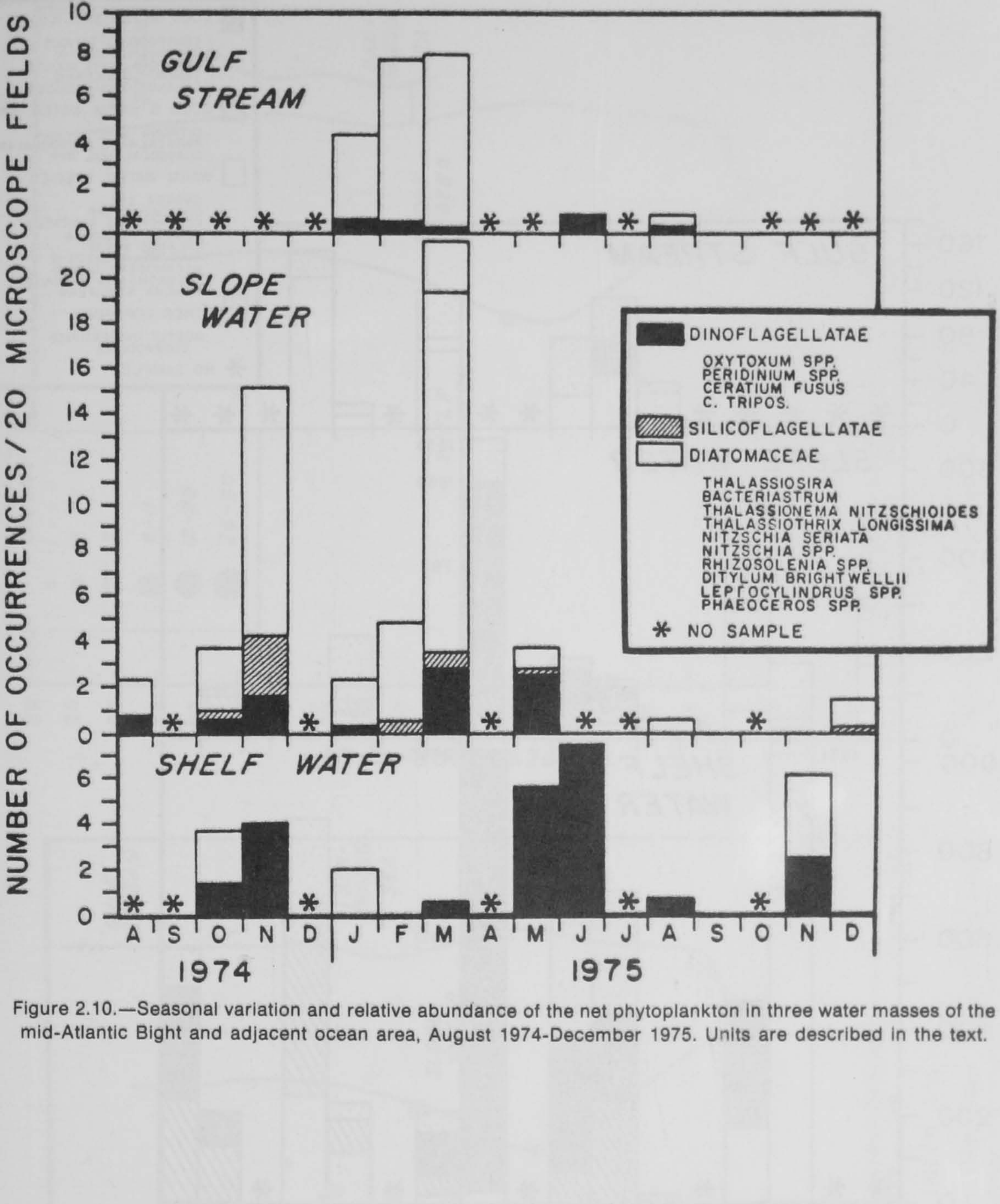


Figure 2.10.—Seasonal variation and relative abundance of the net phytoplankton in three water masses of the mid-Atlantic Bight and adjacent ocean area, August 1974-December 1975. Units are described in the text.

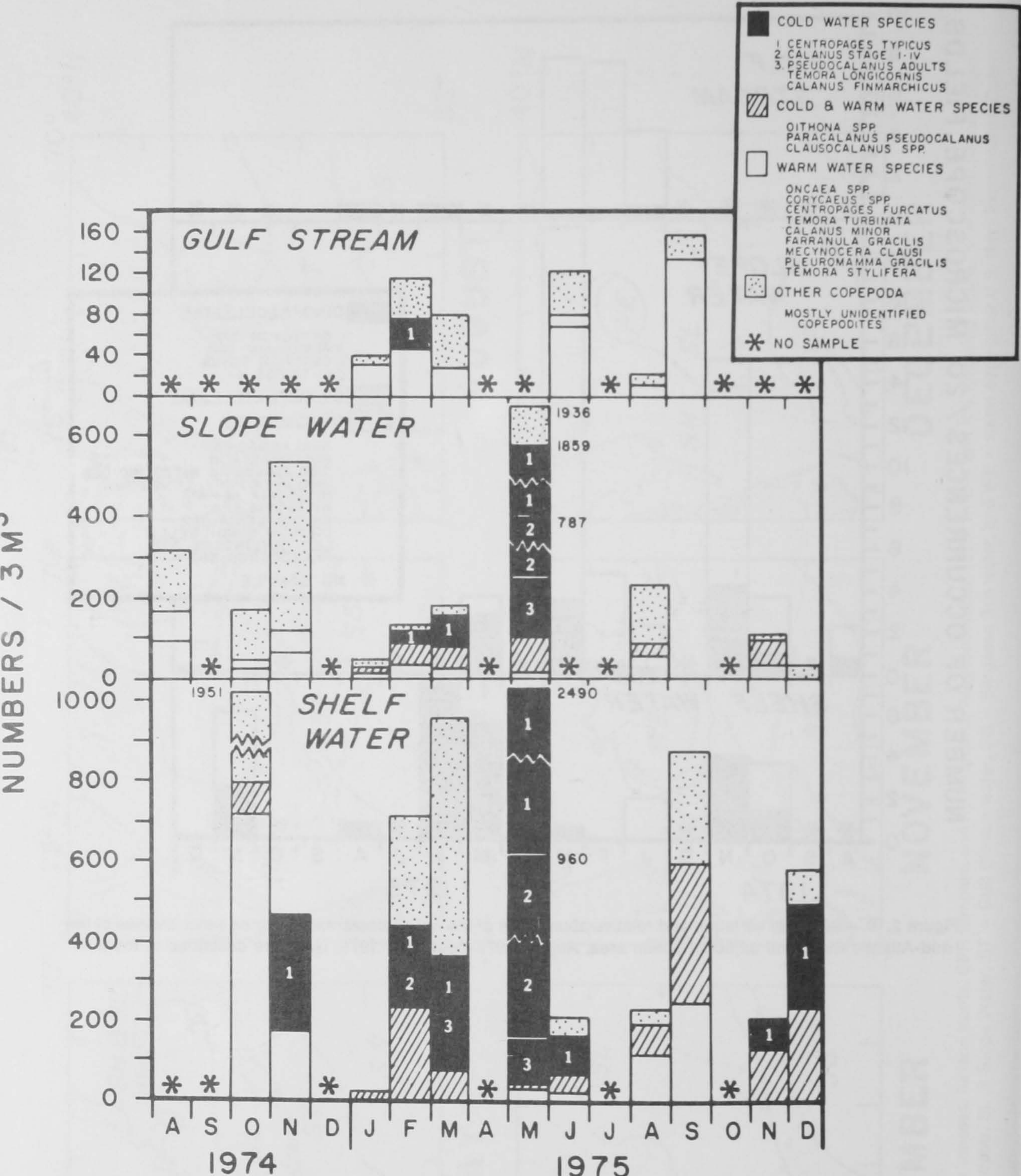


Figure 2.11.—Seasonal variation and abundance of epipelagic copepods in three water masses of the Middle Atlantic Bight and adjacent ocean area, August 1974-December 1975. Sampling depth = 10 m.

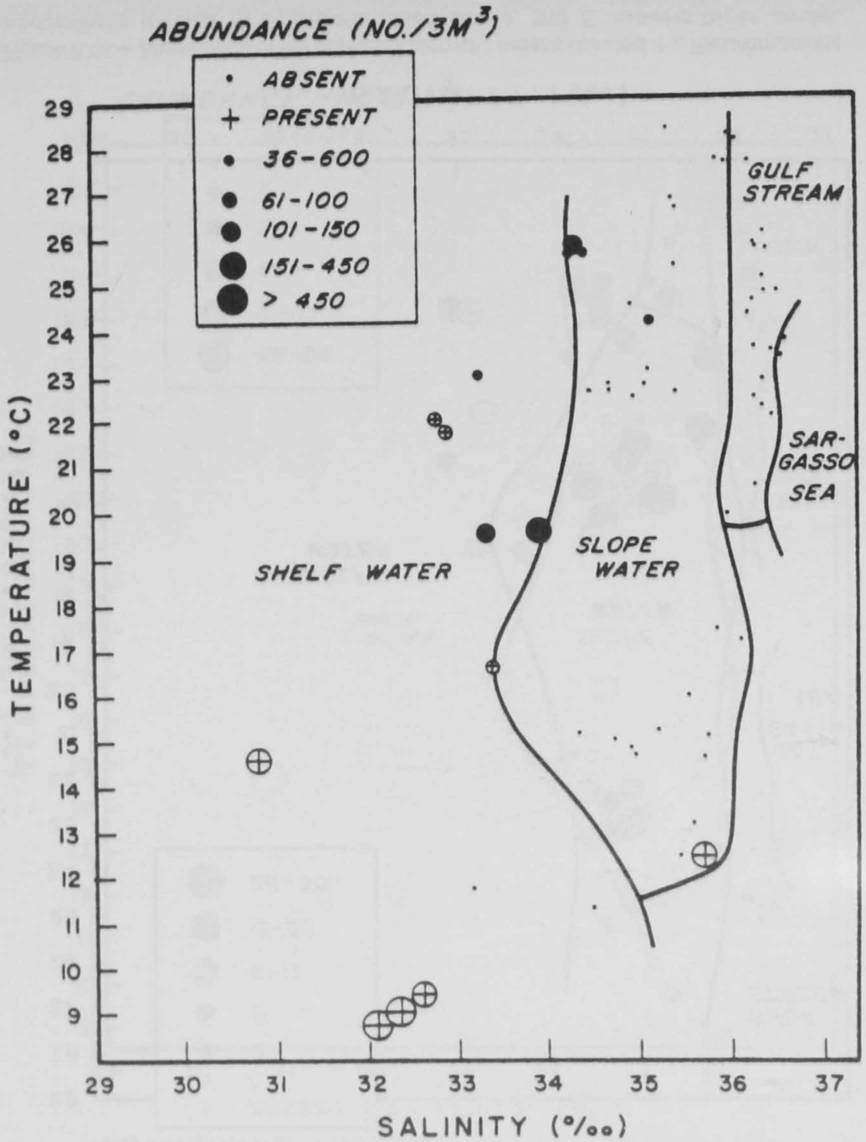


Figure 2.12.—Abundance of the copepod *Centropages velificatus* (filled circles) and *C. typicus* (open circles) in relation to temperature and salinity.

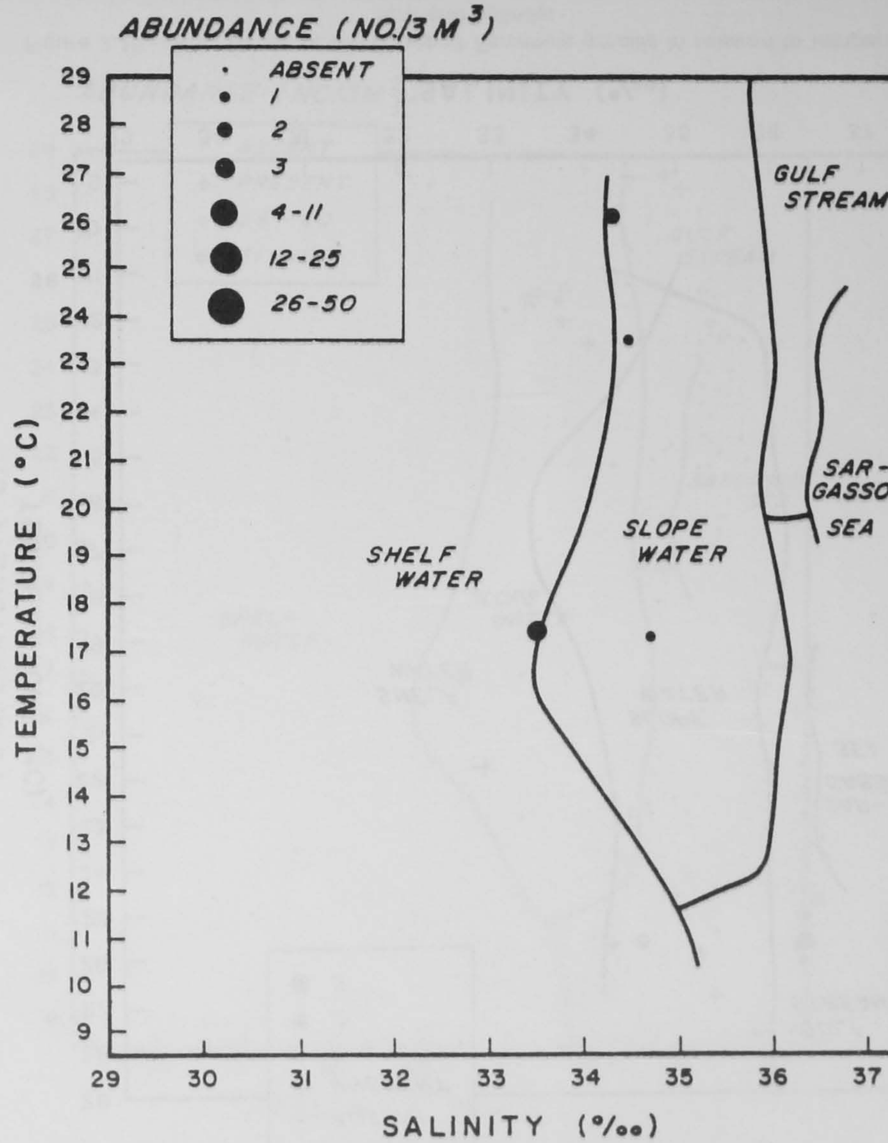


Figure 2.13.—Abundance of the copepod *Centropages bradyi* in relation to temperature and salinity.

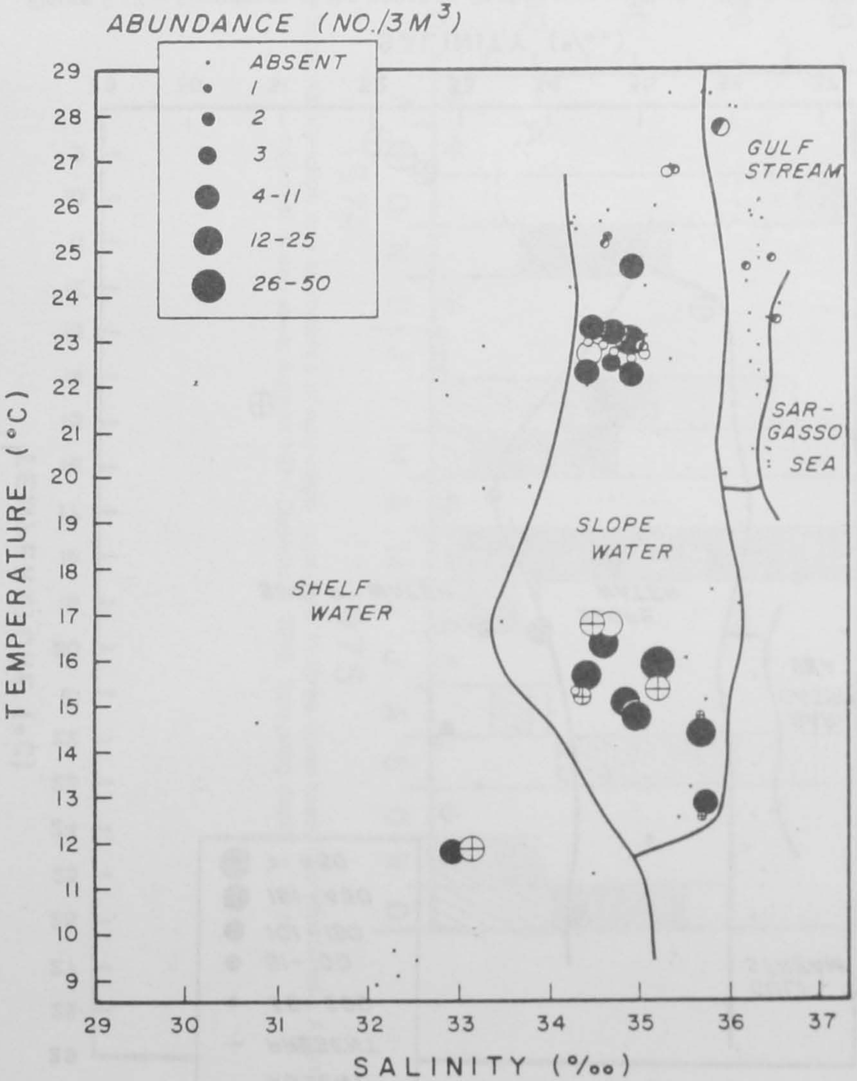


Figure 2.14.—Abundance of the copepod *Metridia lucens* (circled +), *Pleuromamma abdominalis* (circled /), *P. gracilis* (filled circle), and *P. robusta* (open circle).

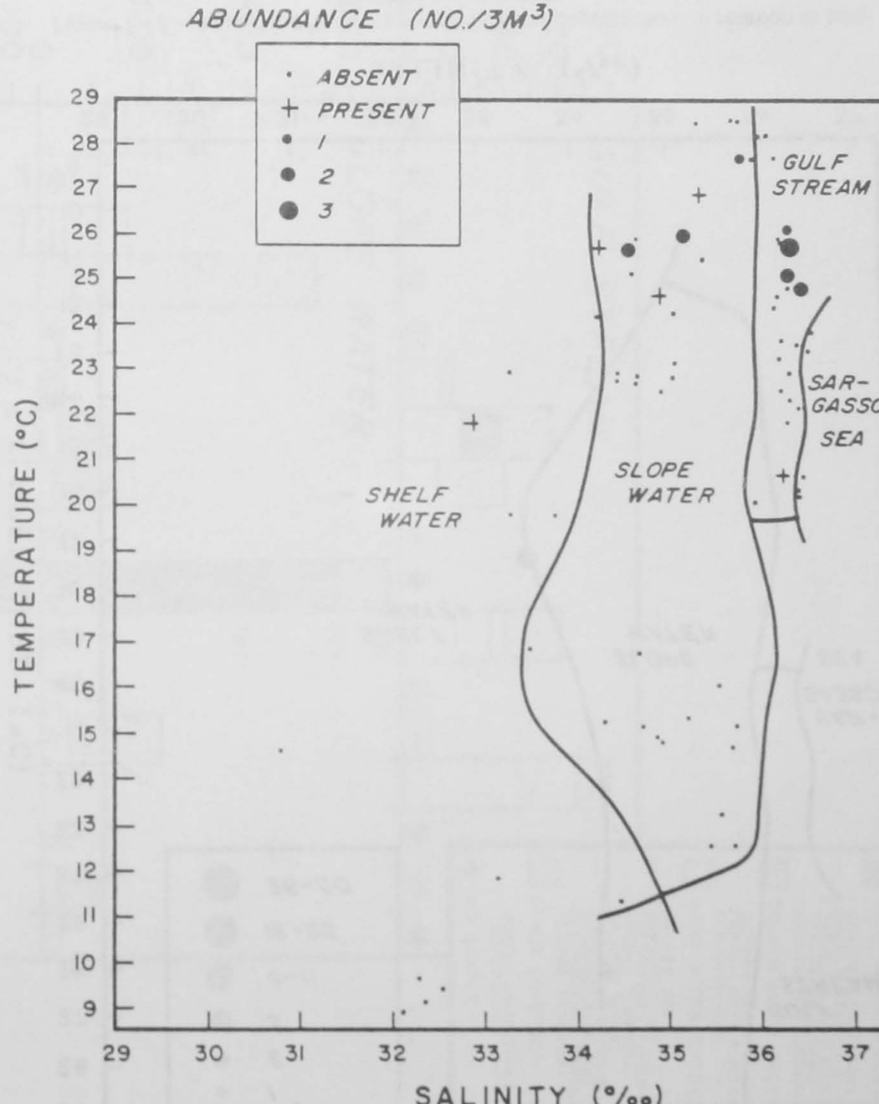


Figure 2.15.—Abundance of the copepod *Farranula gracilis* in relation to temperature and salinity.

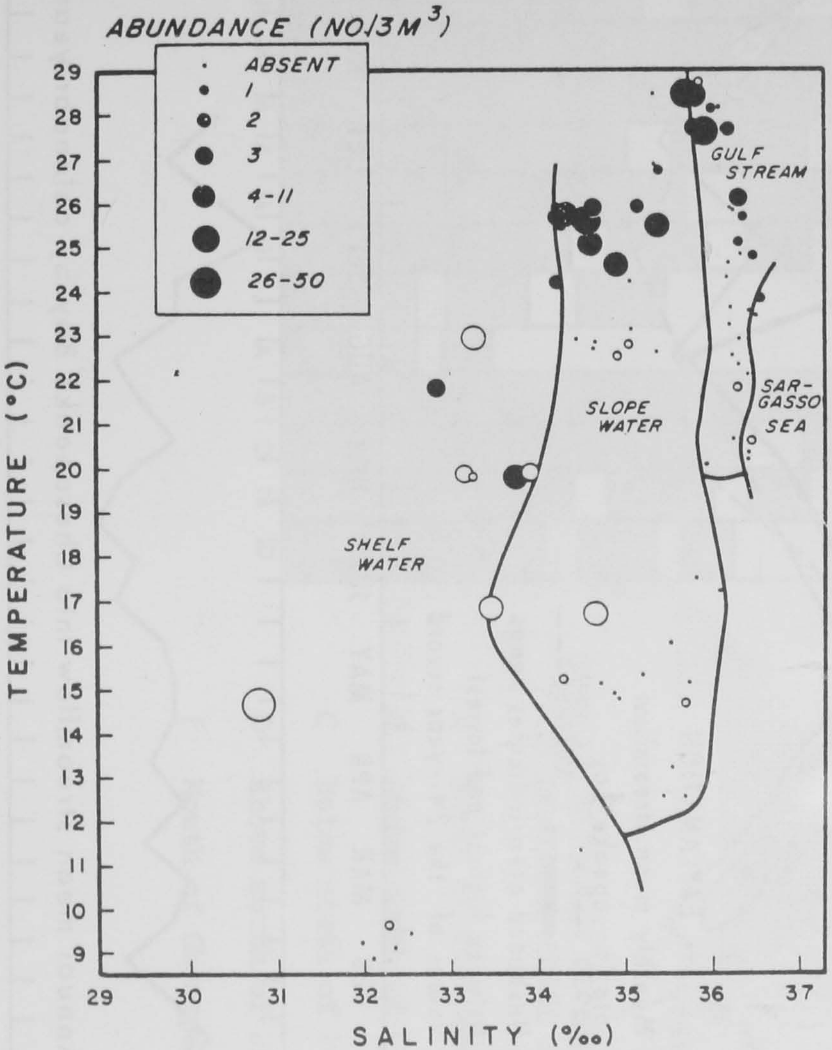


Figure 2.16.—Abundance of the copepod *Calanus minor* (filled circle) and *Undinula vulgaris* (open circle) in relation to temperature and salinity.

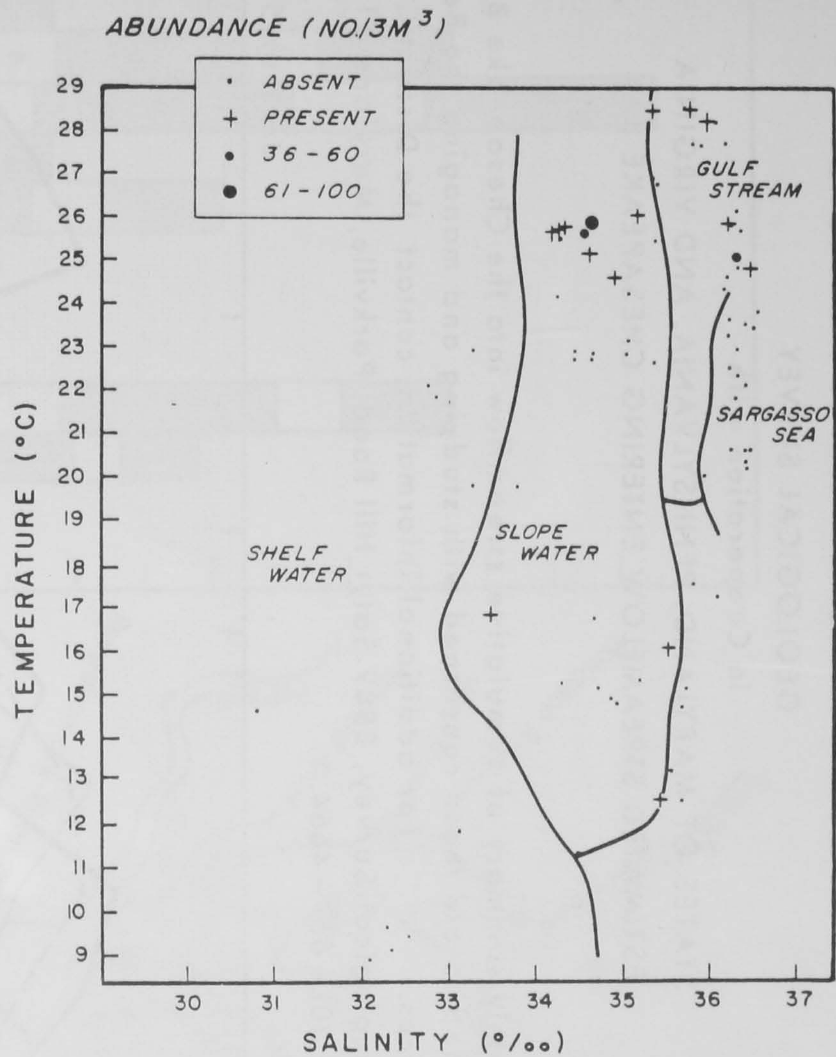
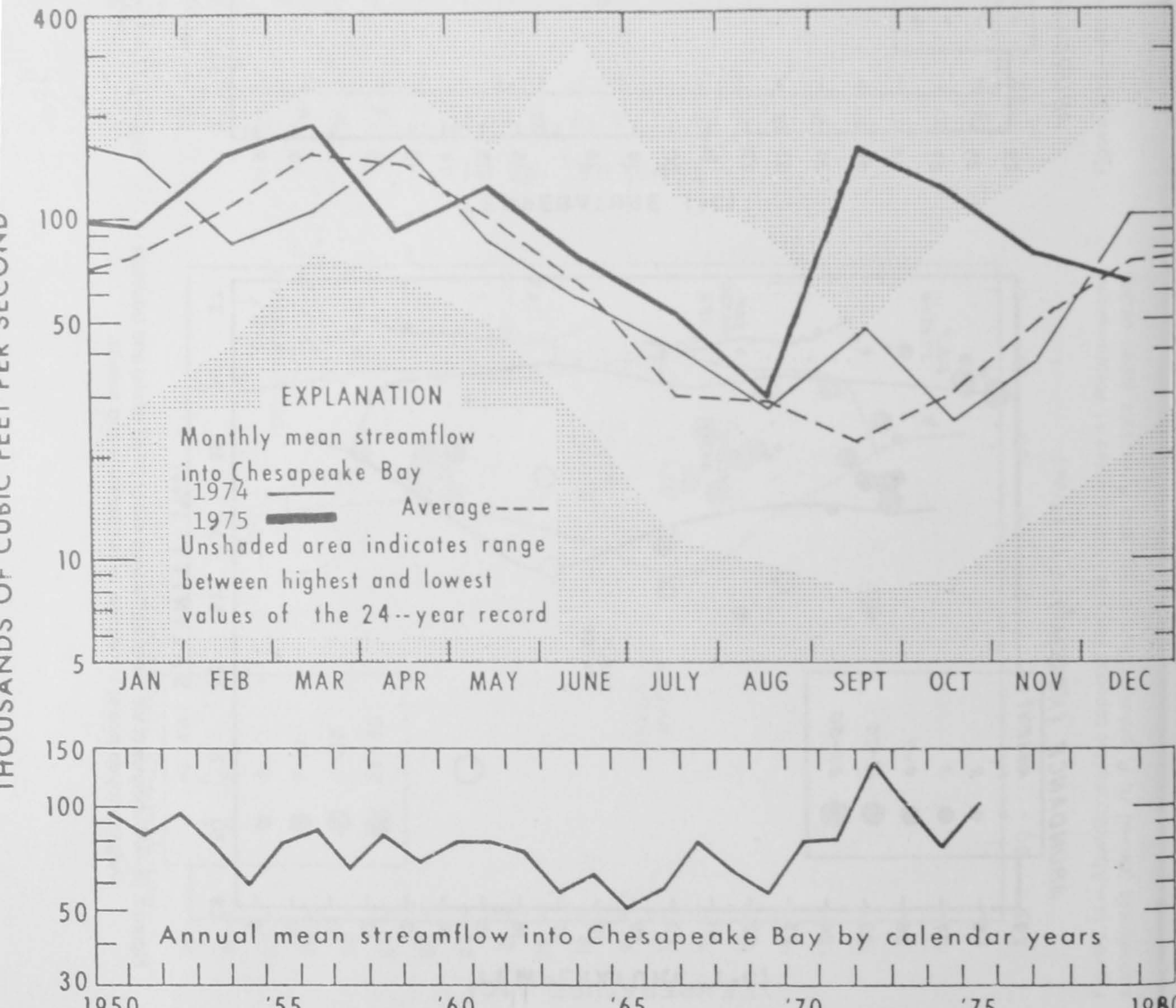


Figure 2.17.—Abundance of the copepod *Temora stylifera* in relation to temperature and salinity.

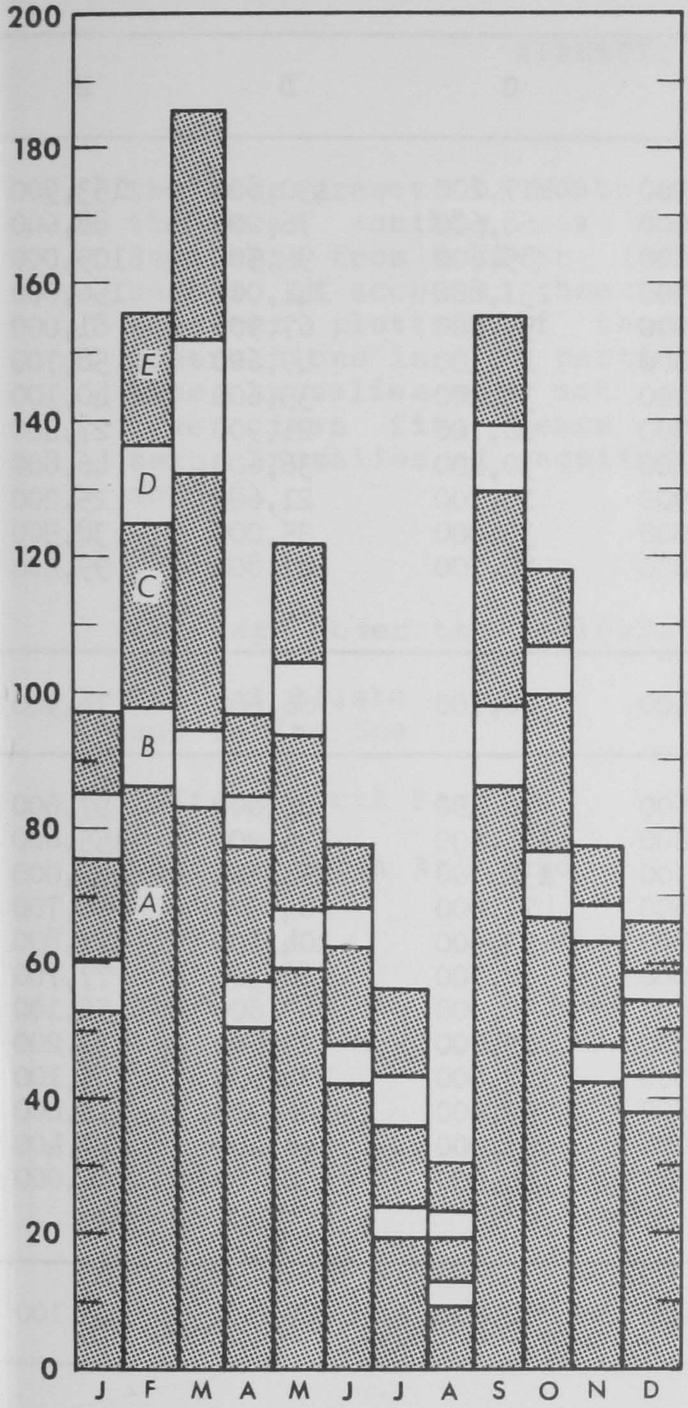
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
in Cooperation with
STATES OF MARYLAND, PENNSYLVANIA, AND VIRGINIA
ESTIMATED STREAMFLOW ENTERING CHESAPEAKE BAY

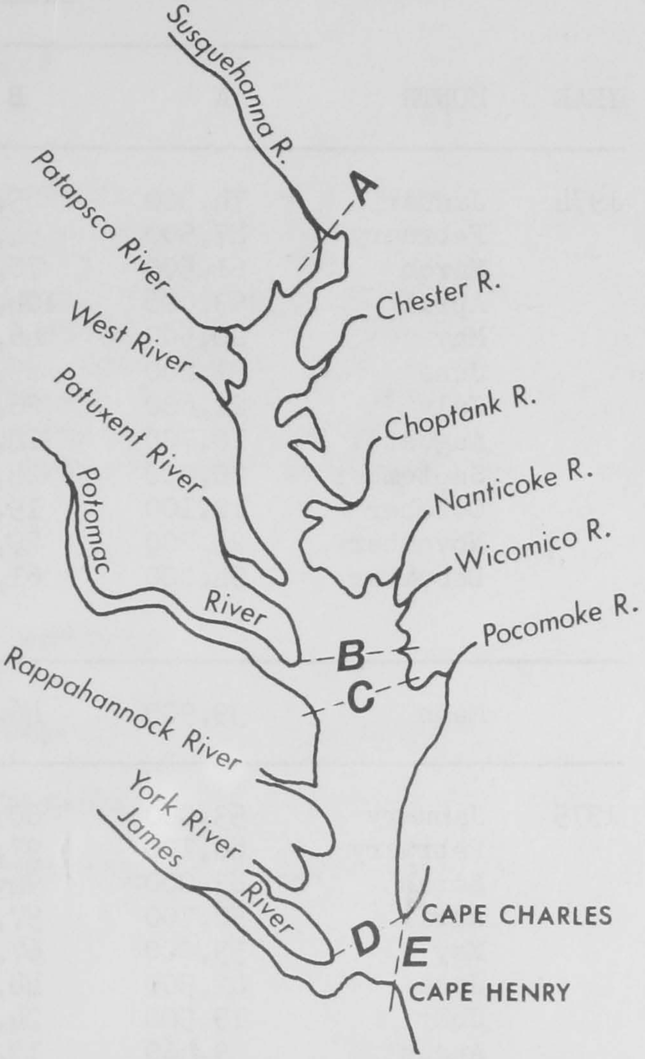
A monthly summary of cumulative streamflow into the Chesapeake Bay designed to aid those concerned with studying and managing the Bay's resources. For additional information, contact the District Chief, U.S. Geological Survey, 8809 Satyr Hill Road, Parkville, Maryland 21234, Phone 301 – 661 – 4664.

January 5, 1976



ESTIMATED CUMULATIVE STREAMFLOW ENTERING CHESAPEAKE BAY
ABOVE INDICATED SECTIONS BY MONTHS, DURING 1975





CUMULATIVE INFLOW TO CHESAPEAKE BAY
AT INDICATED CROSS SECTIONS

A Mouth of Susquehanna R.

B Above mouth of Potomac R.

C Below mouth of Potomac R.

D Above mouth of James R.

E Mouth of Chesapeake Bay

ESTIMATED CUMULATIVE STREAMFLOW ENTERING CHESAPEAKE BAY

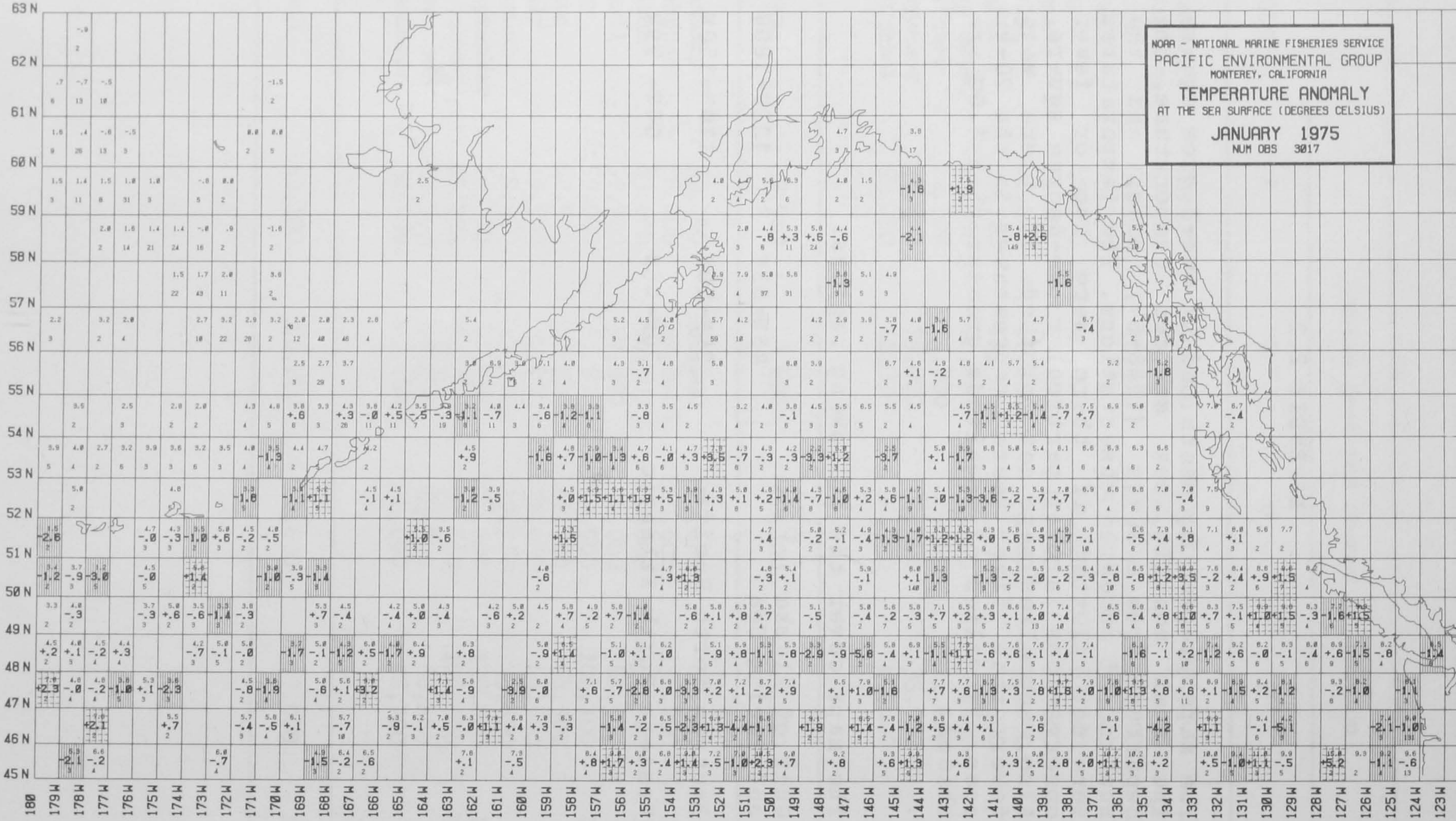
YEAR	MONTH	Cubic feet per second at section A	B	C	D	E
1974	January	74,300	85,300	117,200	130,800	153,900
	February	47,500	54,000	68,600	76,200	88,600
	March	61,500	70,800	85,600	94,500	109,000
	April	93,000	104,900	131,800	141,000	156,000
	May	40,500	46,000	59,800	67,900	81,000
	June	21,200	25,800	44,100	49,600	58,700
	July	21,600	26,200	33,200	35,600	40,100
	August	10,700	14,300	18,700	21,900	27,400
	September	20,000	24,600	30,400	36,600	46,800
	October	12,100	15,900	19,700	21,600	25,200
	November	24,200	29,000	33,000	35,000	38,500
	December	54,000	61,800	80,700	87,800	99,400
	Mean	39,900	46,400	60,100	66,400	76,900
1975	January	53,000	60,600	76,400	85,000	97,600
	February	86,100	97,800	124,600	136,200	155,600
	March	83,000	94,500	132,000	151,300	185,000
	April	50,700	57,800	77,000	84,500	96,700
	May	59,000	67,800	93,500	104,100	121,800
	June	42,500	48,000	62,700	68,300	77,700
	July	19,500	24,000	36,000	43,600	56,100
	August	9,460	13,000	19,700	23,600	30,200
	September	86,100	97,800	128,600	138,600	155,100
	October	66,700	76,800	99,600	106,000	118,000
	November	42,500	48,000	63,000	68,400	77,400
	December	38,100	43,600	54,400	58,700	66,000
	Mean	53,100	60,800	80,600	89,000	103,100

APPENDIX 2.2

The maps present by month and by one-degree square the mean monthly sea surface temperature, the departure from a 20-yr (1948-67) mean, and the number of accepted observations. The temperatures were not plotted if there were two or fewer observations in that particular one-degree square. Also, anomalies were not plotted if there were fewer than five years represented in the 20-yr mean. Anomalies of magnitude greater than 1.0C are shaded.

The maps cover the following regions:

Gulf of Alaska and Bering Sea	45N-63N	122W-180W
Eastern North Pacific	25N-50N	110W-150W
Western North Atlantic	20N-46N	60W- 99W


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JANUARY 1975
NUM OBS 3017
63 N
62 N
61 N
60 N
59 N
58 N
57 N
56 N
55 N
54 N
53 N
52 N
51 N
50 N
49 N
48 N
47 N
46 N
45 N
180
179 W
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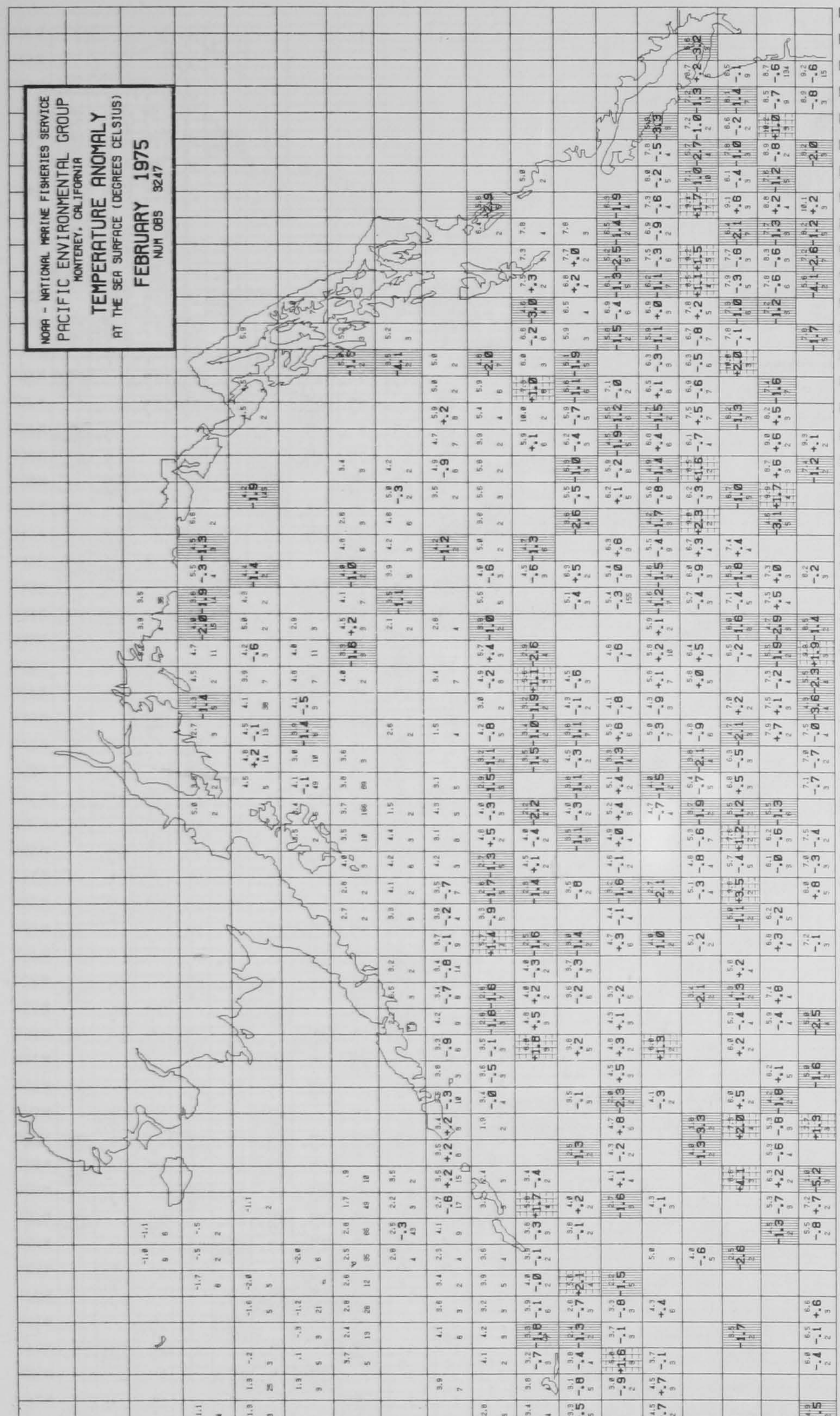
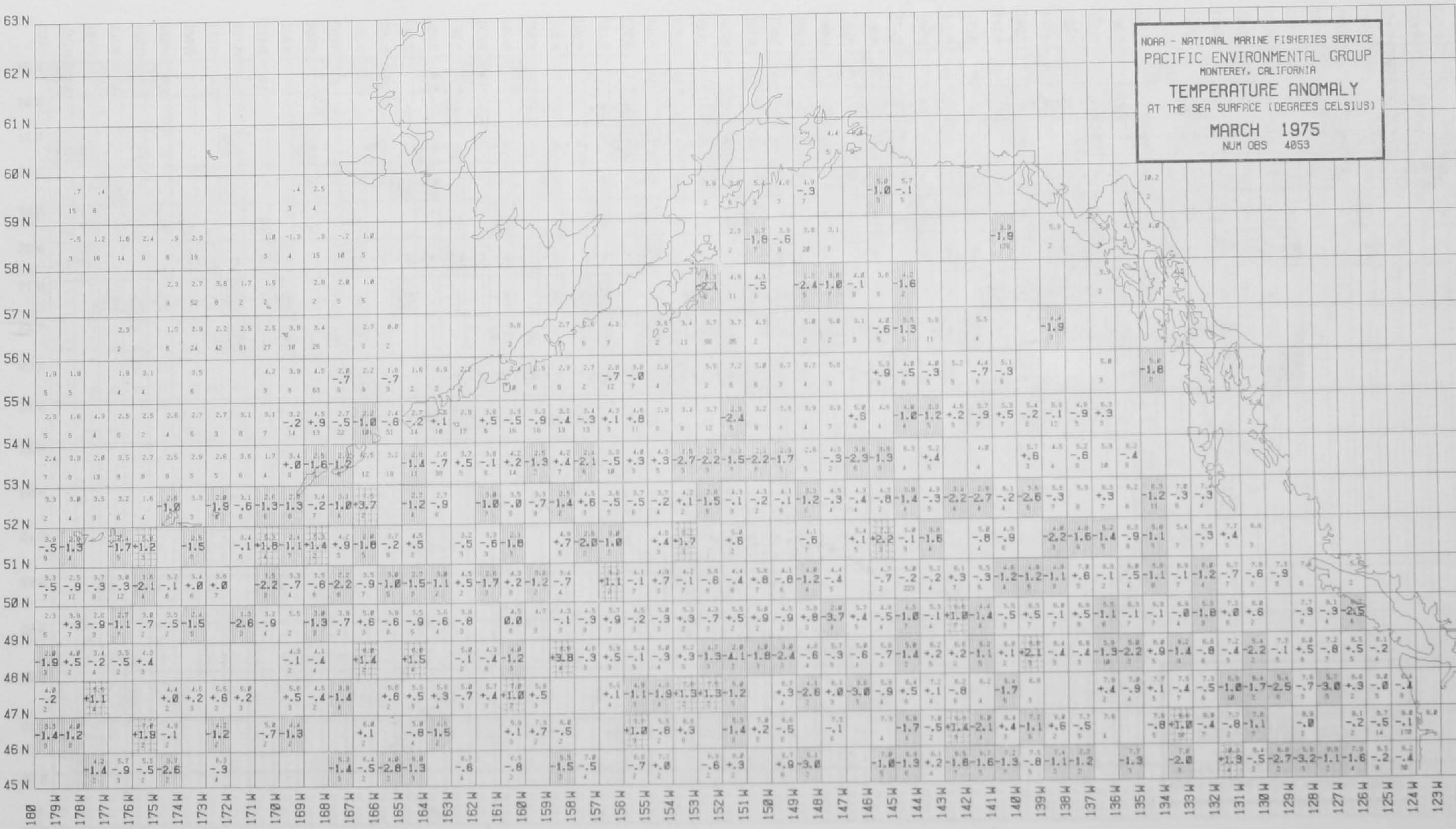
122 W


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
FEBRUARY 1975
NUM OBS 3247


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
MARCH 1975
NUM OBS 4053
63 N
62 N
61 N
60 N
59 N
58 N
57 N
56 N
55 N
54 N
53 N
52 N
51 N
50 N
49 N
48 N
47 N
46 N
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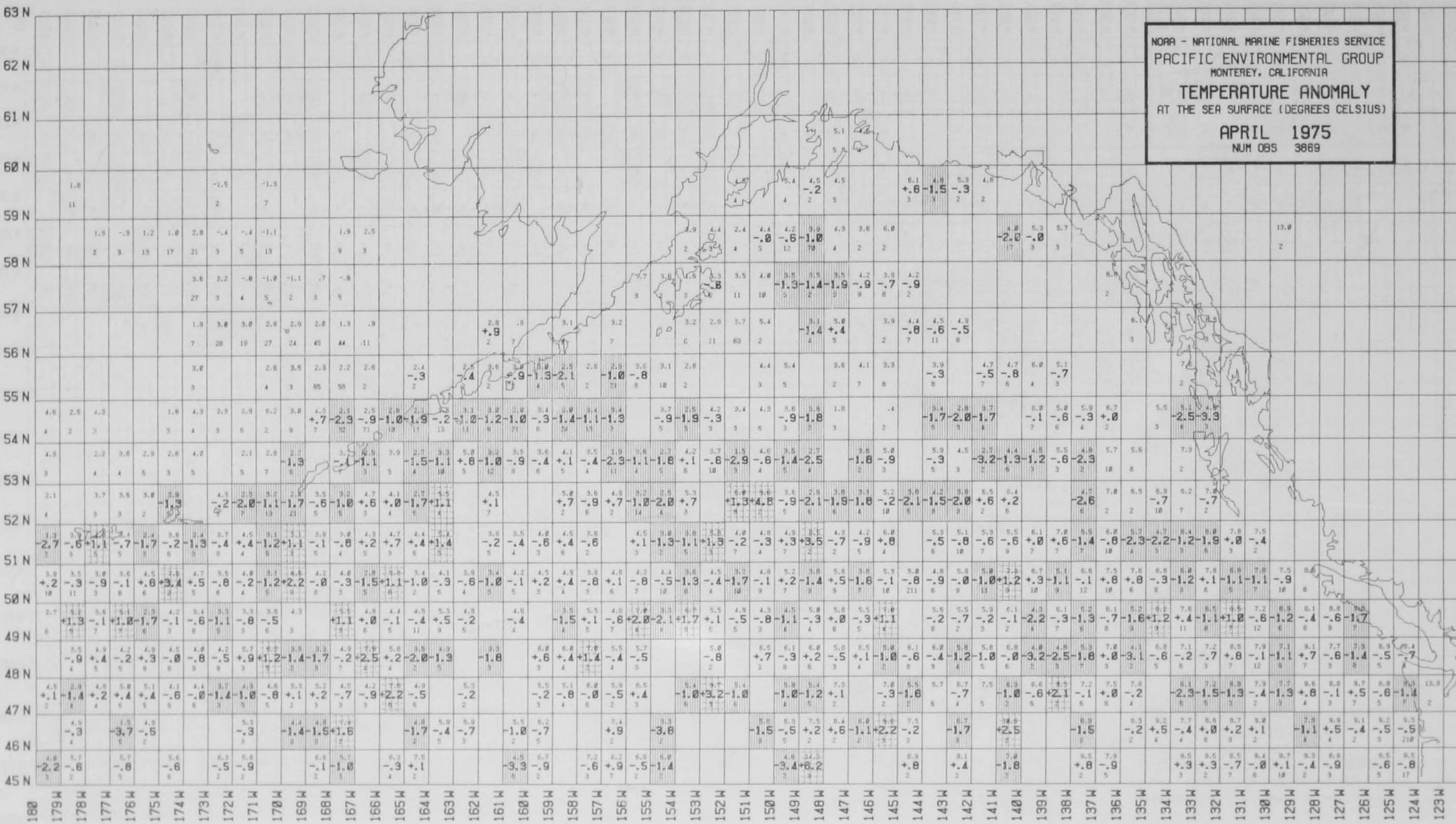
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
APRIL 1975
NUM OBS 3869
63 N
62 N
61 N
60 N
59 N
58 N
57 N
56 N
55 N
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53 N
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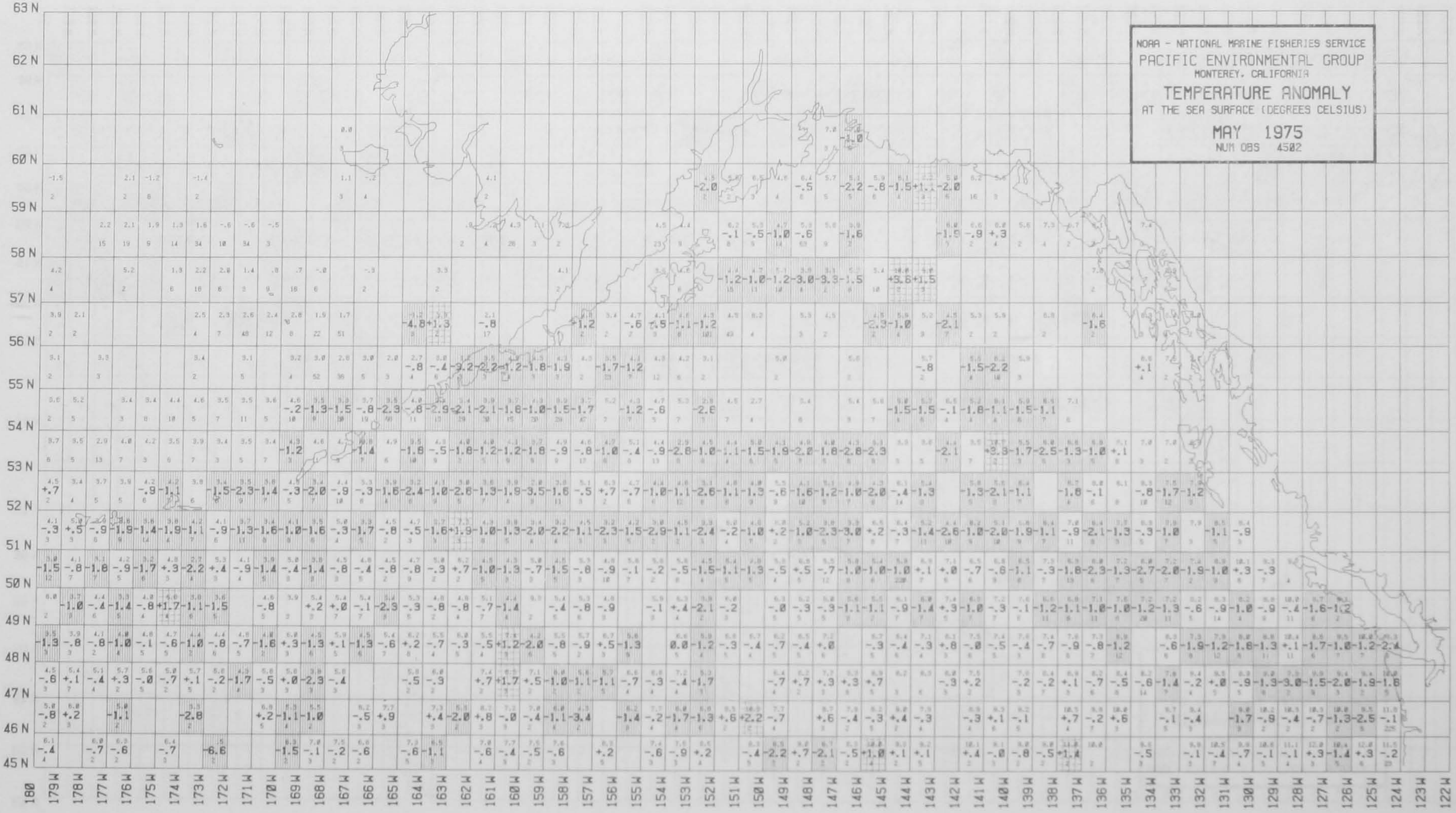
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
MAY 1975
NUM OBS 4502
63 N
62 N
61 N
60 N
59 N
58 N
57 N
56 N
55 N
54 N
53 N
52 N
51 N
50 N
49 N
48 N
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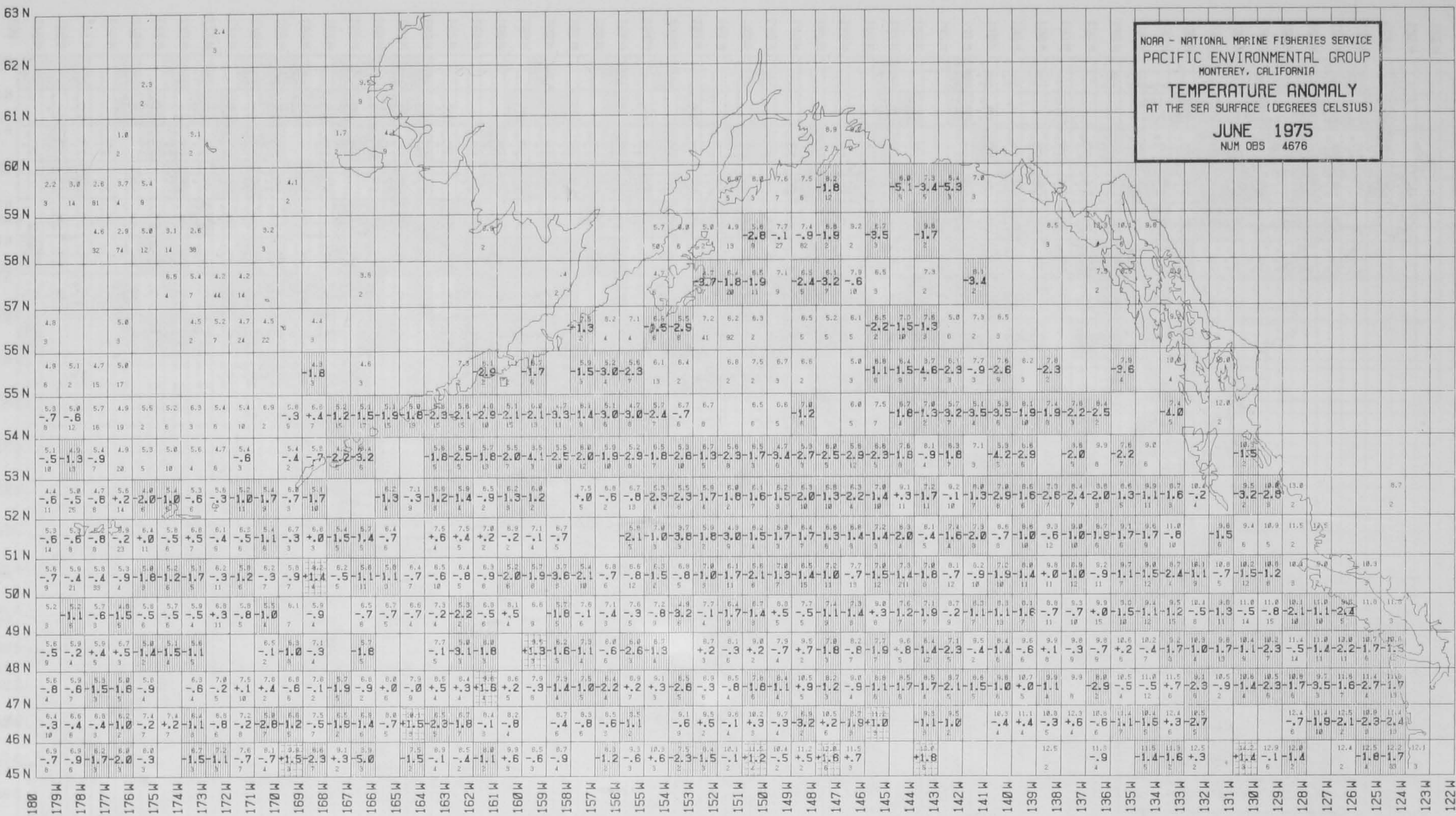
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JUNE 1975
NUM OBS 4676
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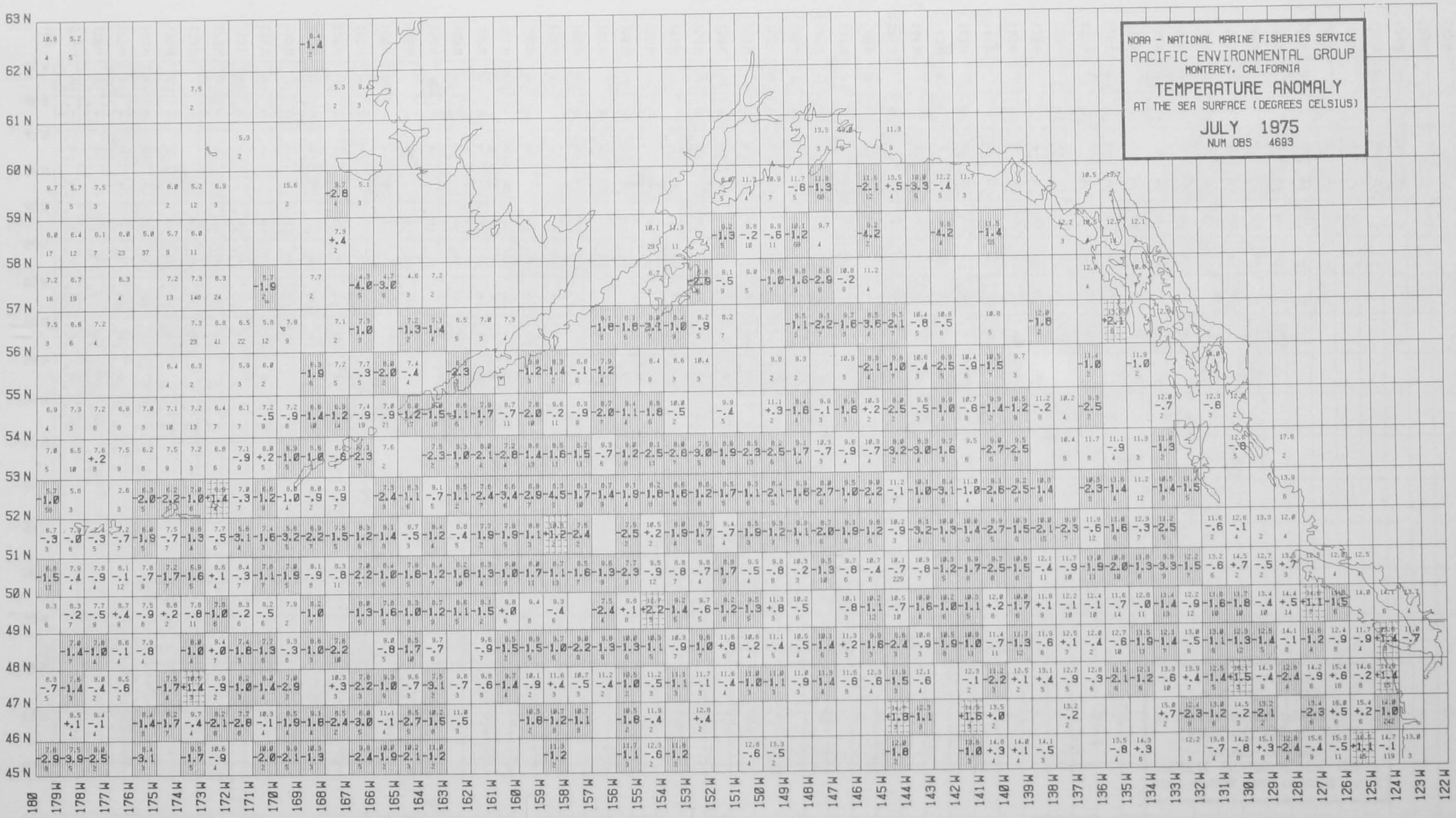
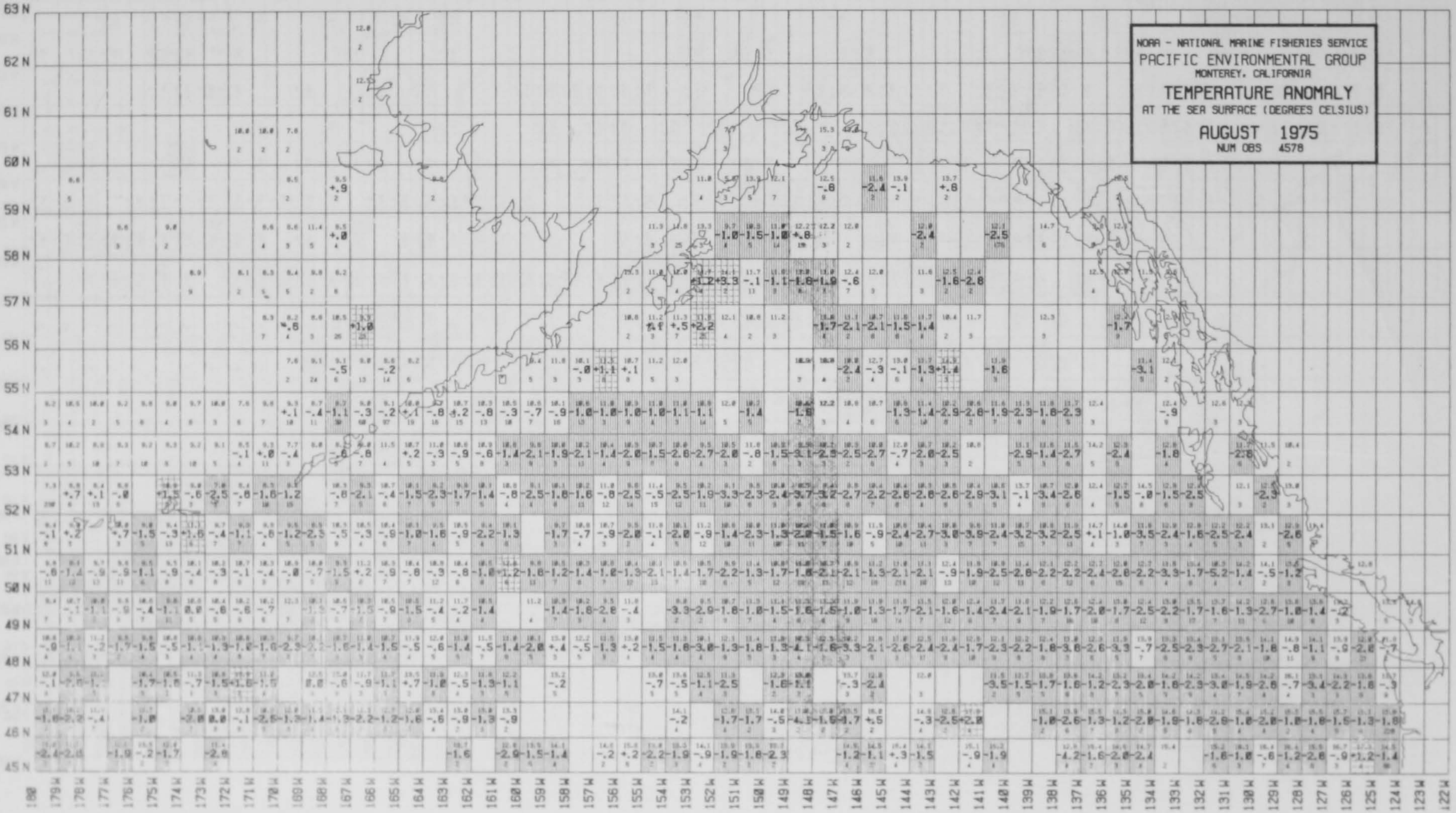
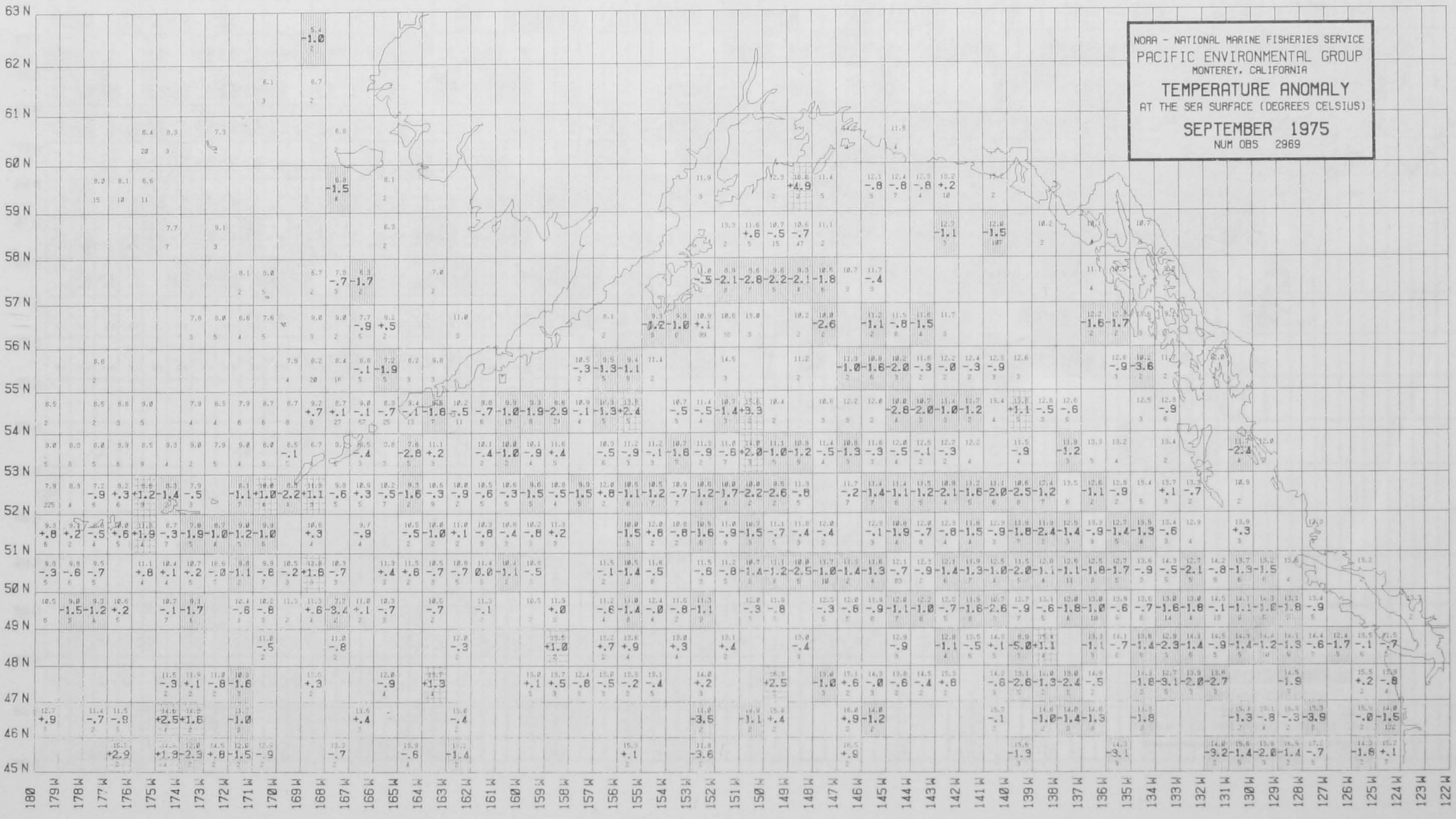
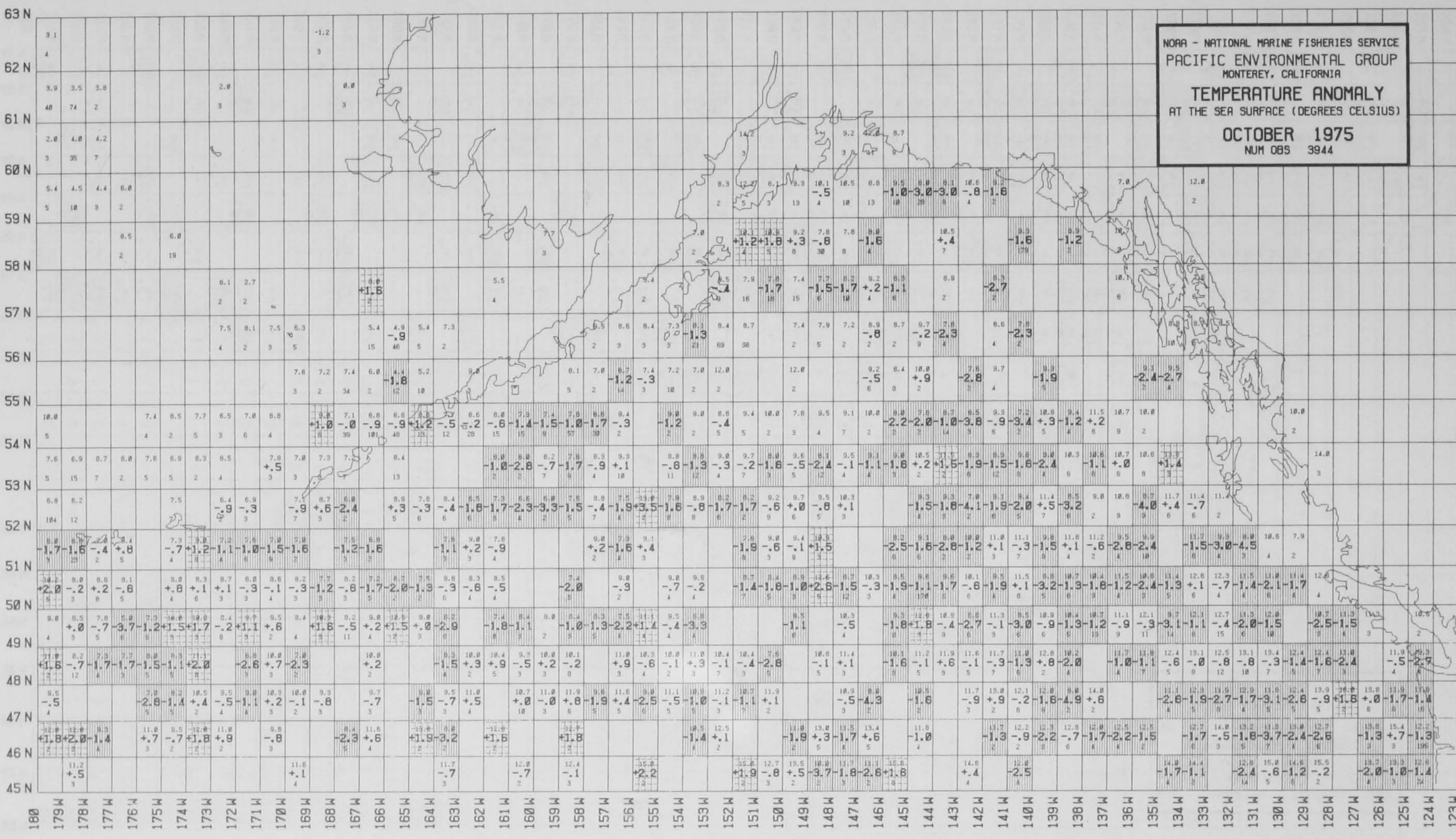
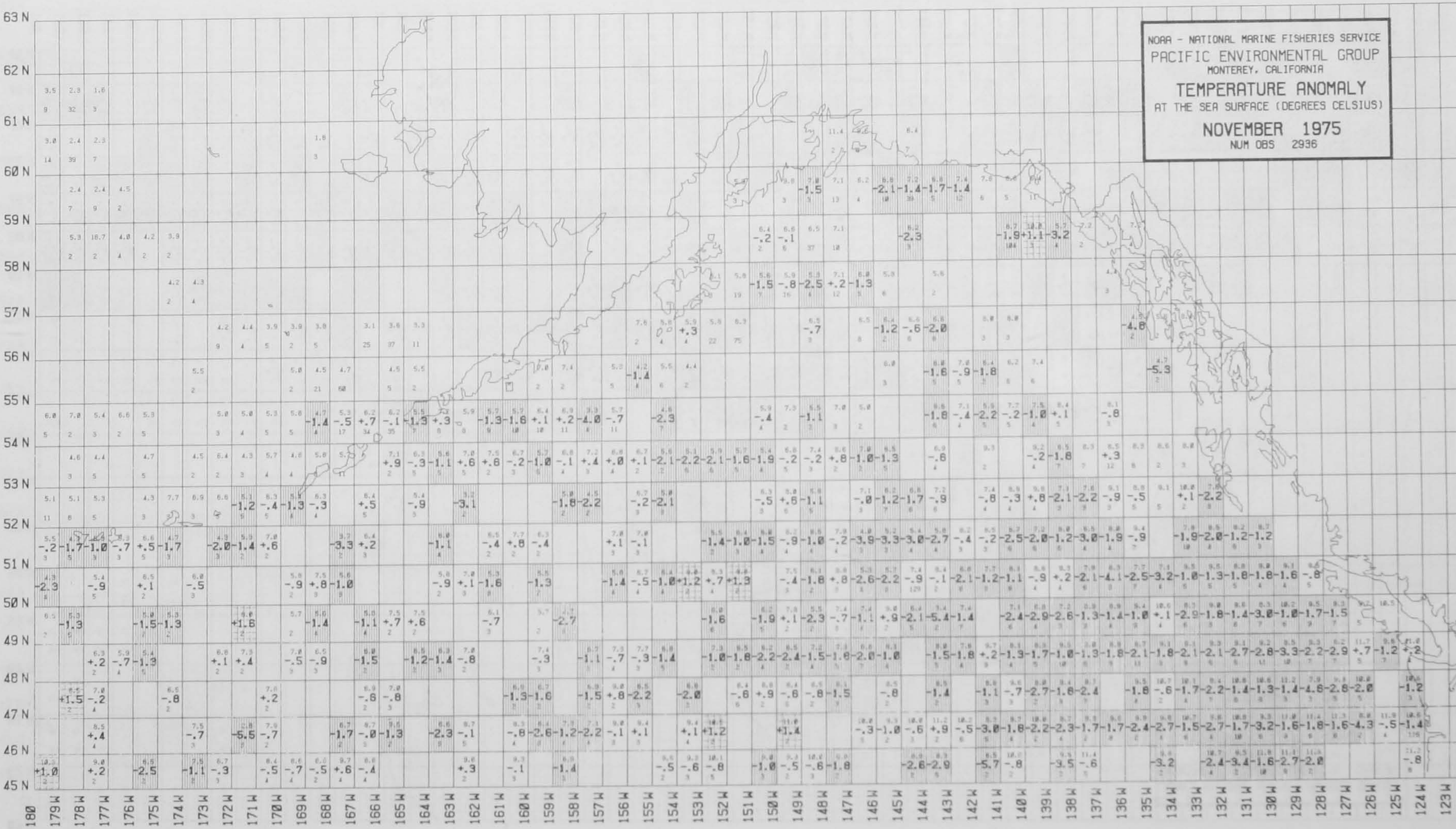
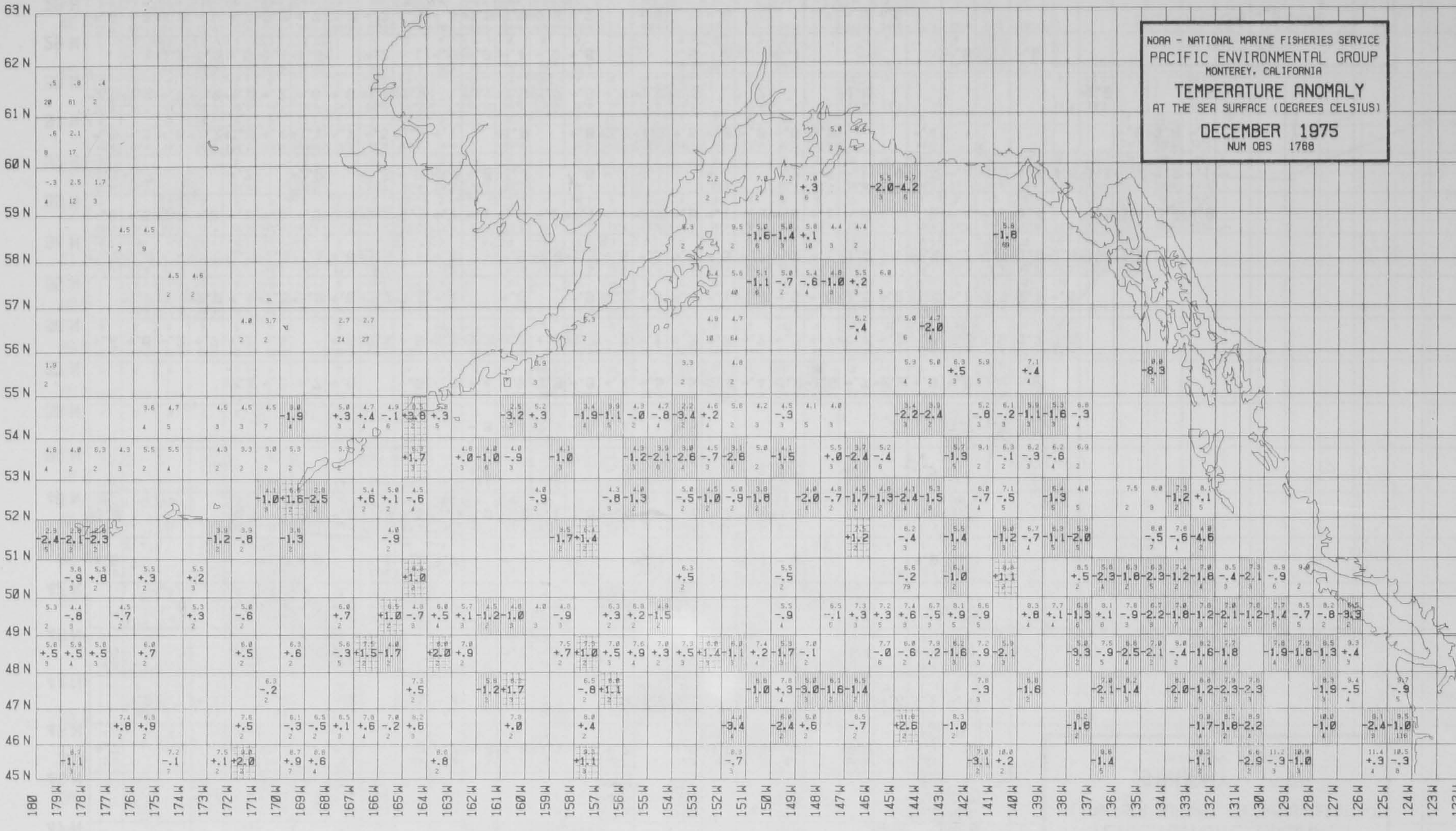

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JULY 1975
NUM OBS 4693

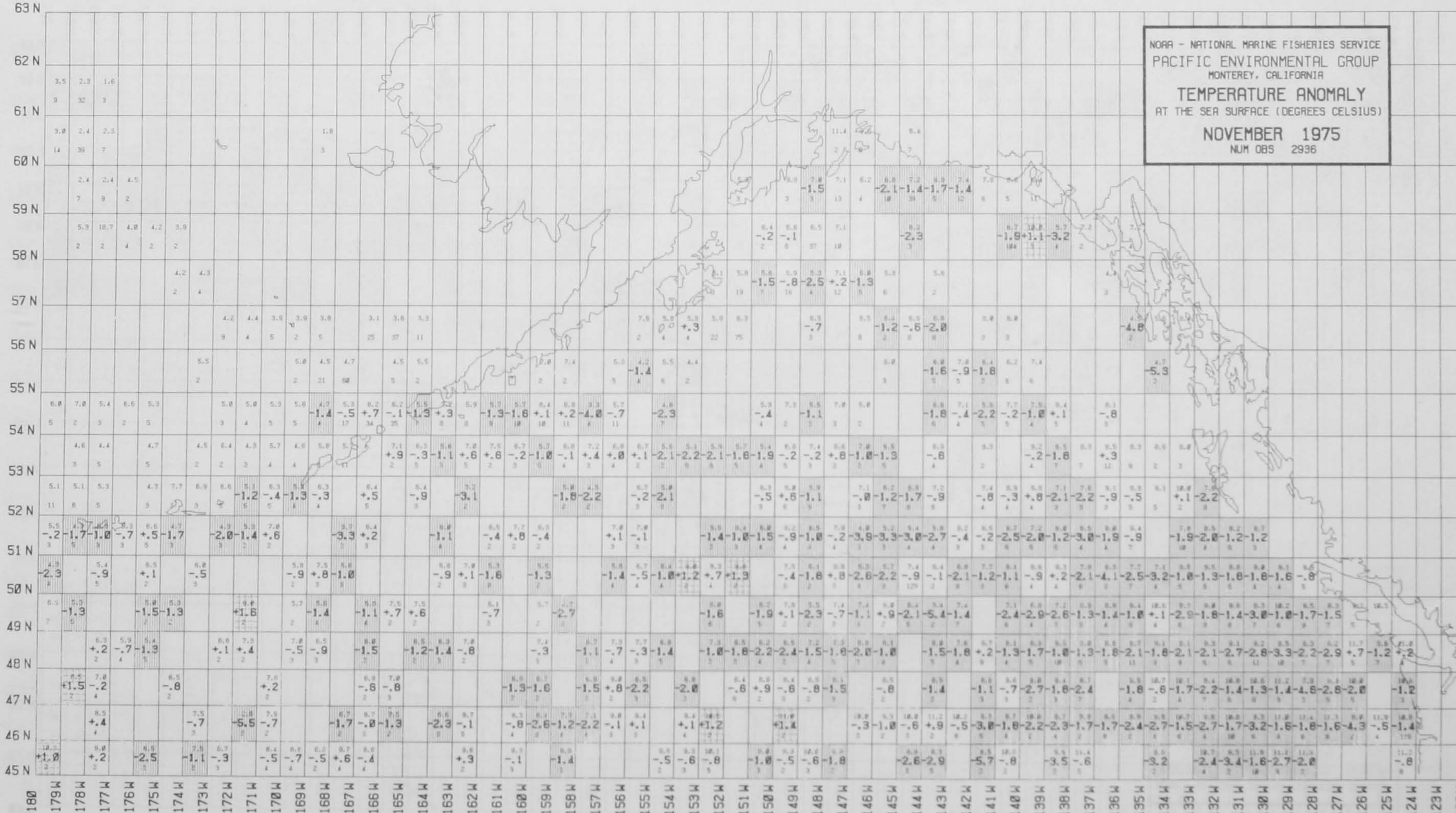

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
AUGUST 1975
NUM OBS 4578

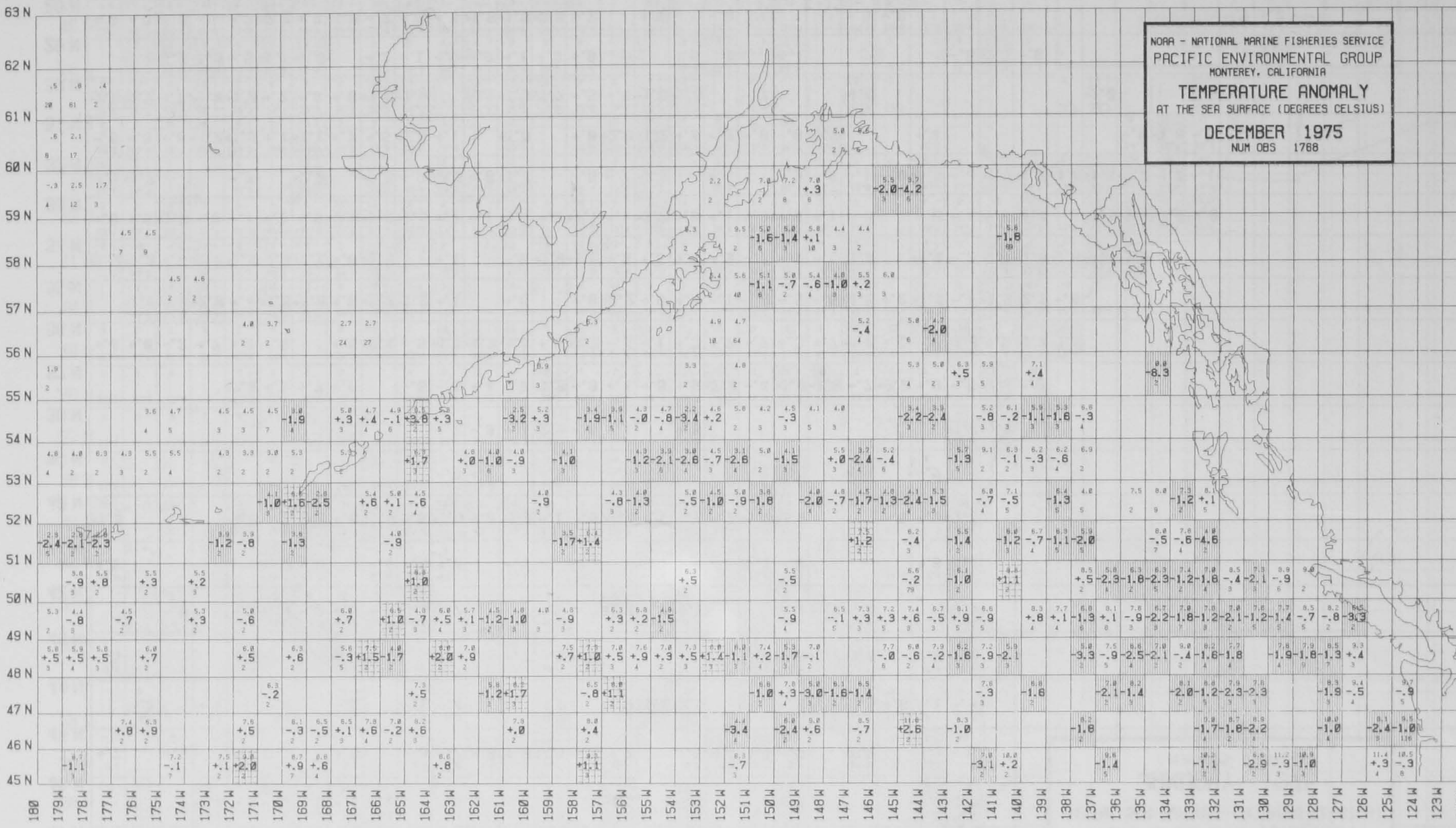

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
SEPTEMBER 1975
NUM OBS 2969


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
OCTOBER 1975
NUM OBS 3944


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
NOVEMBER 1975
NUM OBS 2936


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
DECEMBER 1975
NUM OBS 1768


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
NOVEMBER 1975
NUM OBS 2936


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
DECEMBER 1975
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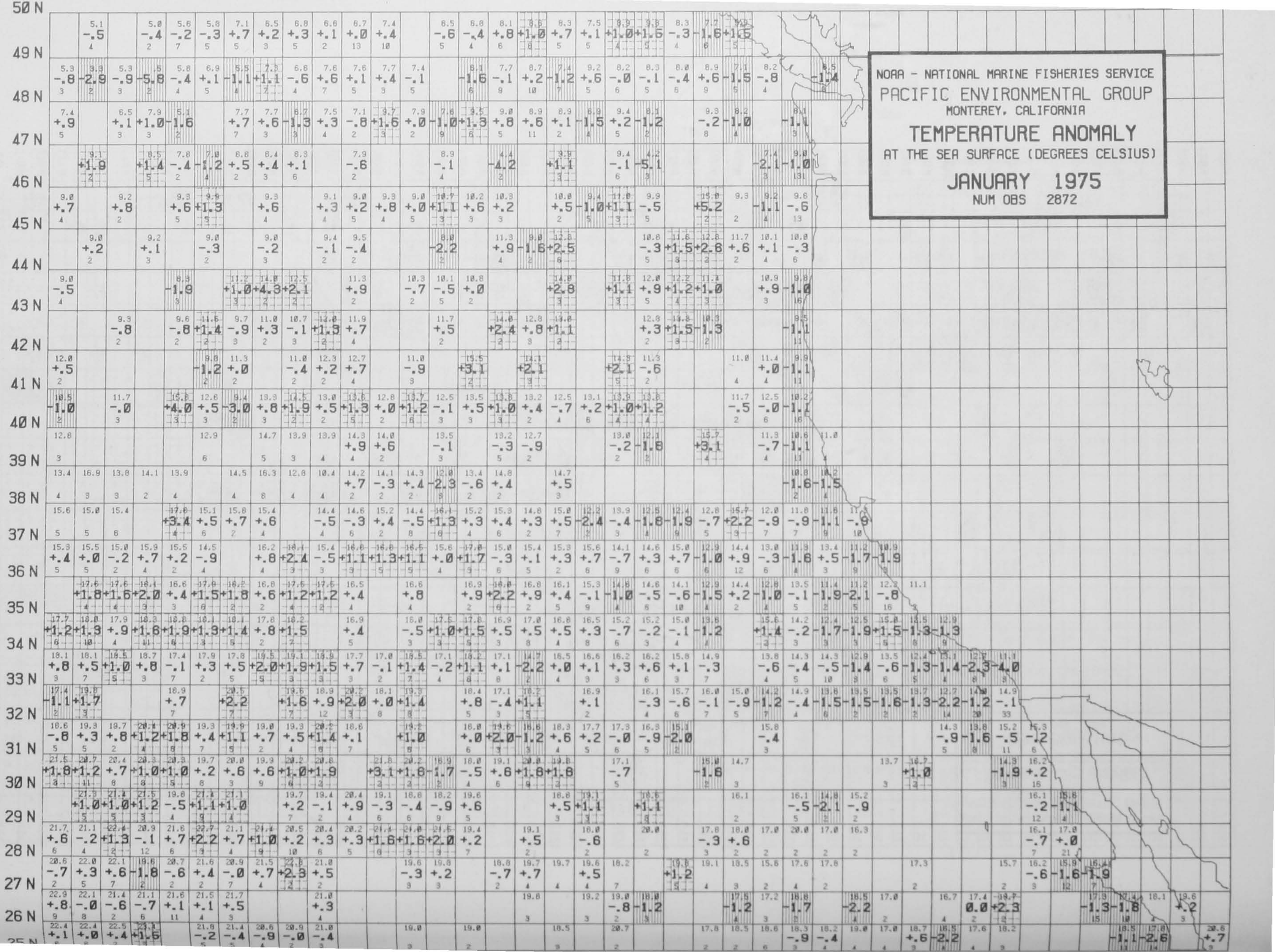
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JANUARY 1975
NUM OBS 2872
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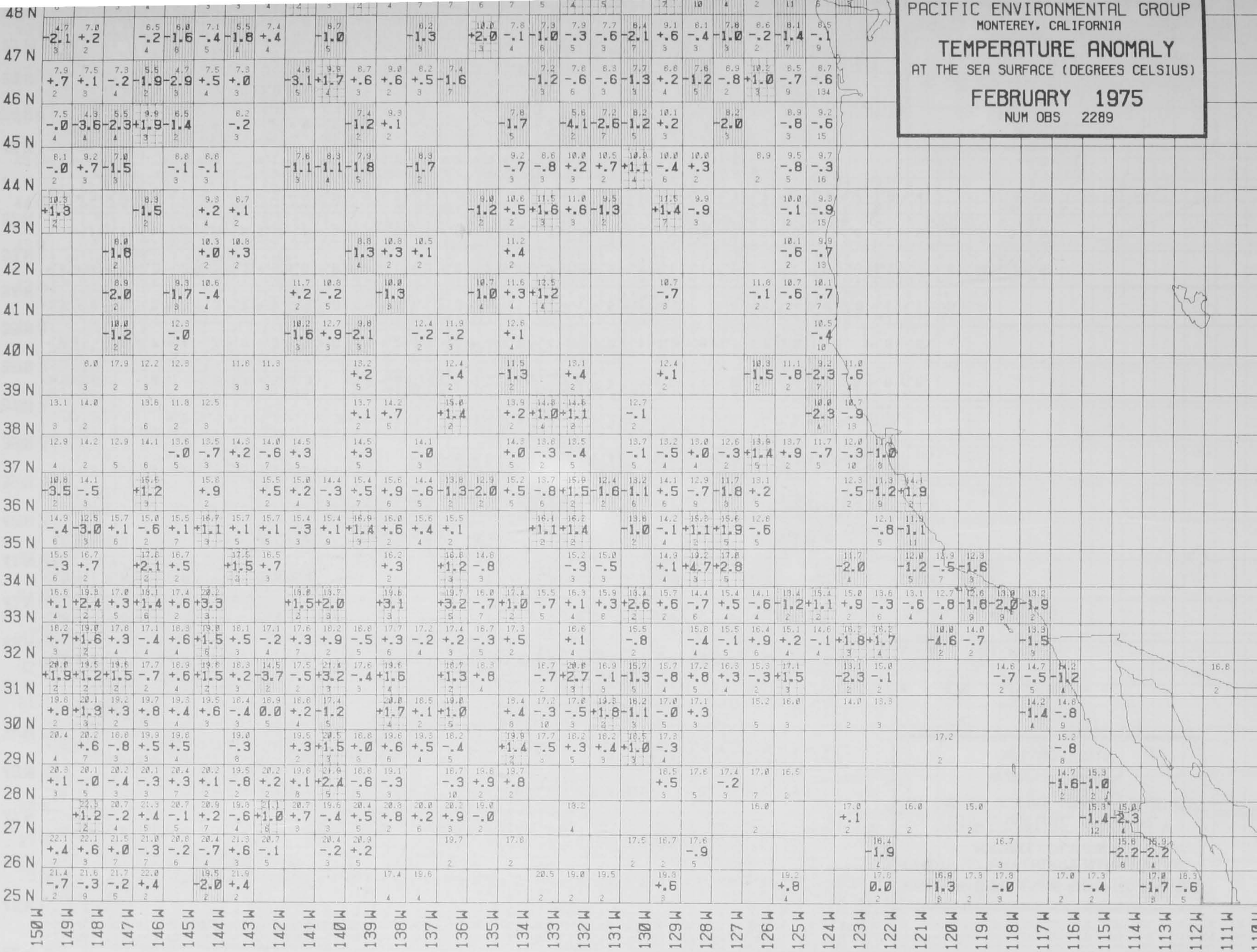
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
FEBRUARY 1975
NUM OBS 2289
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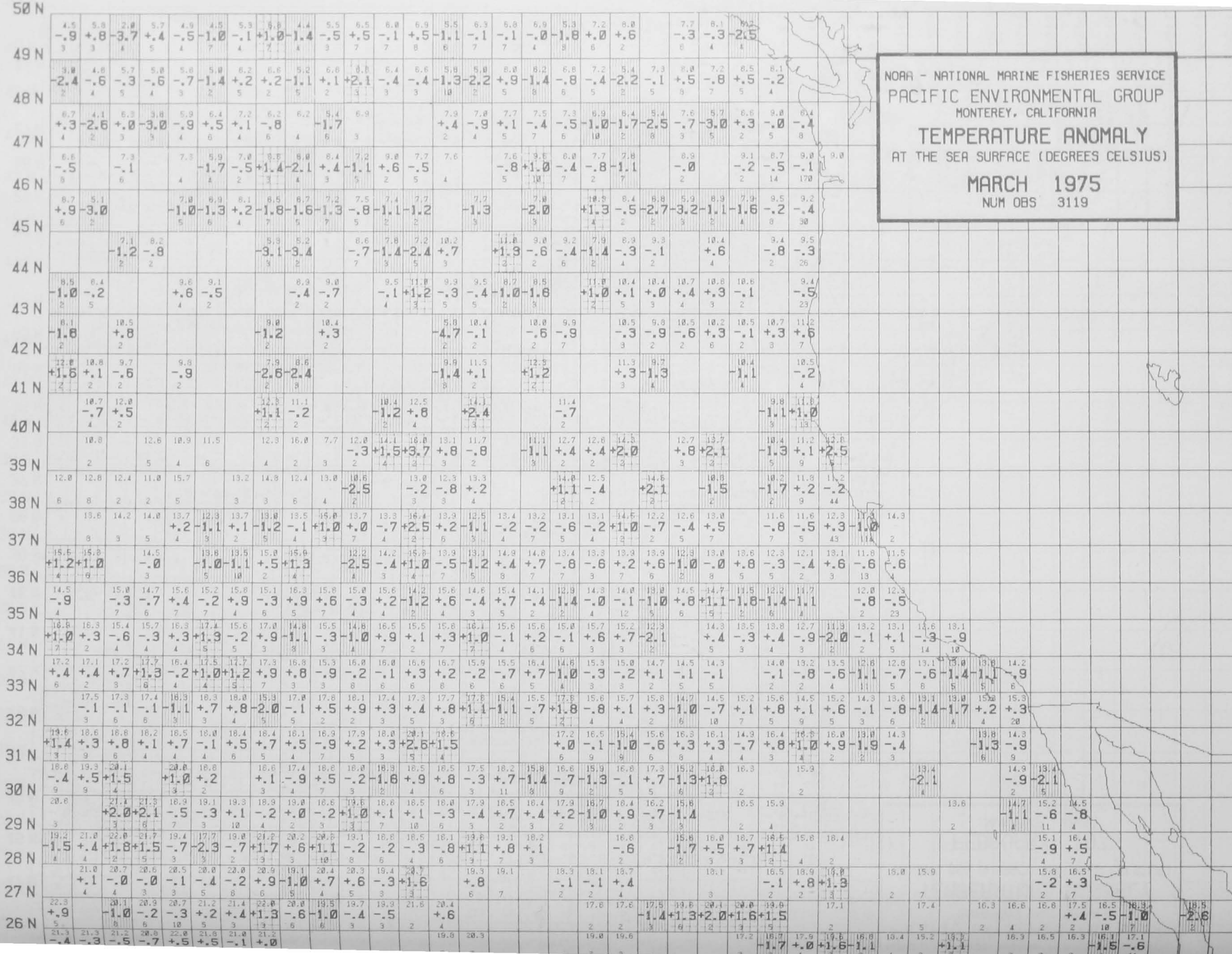
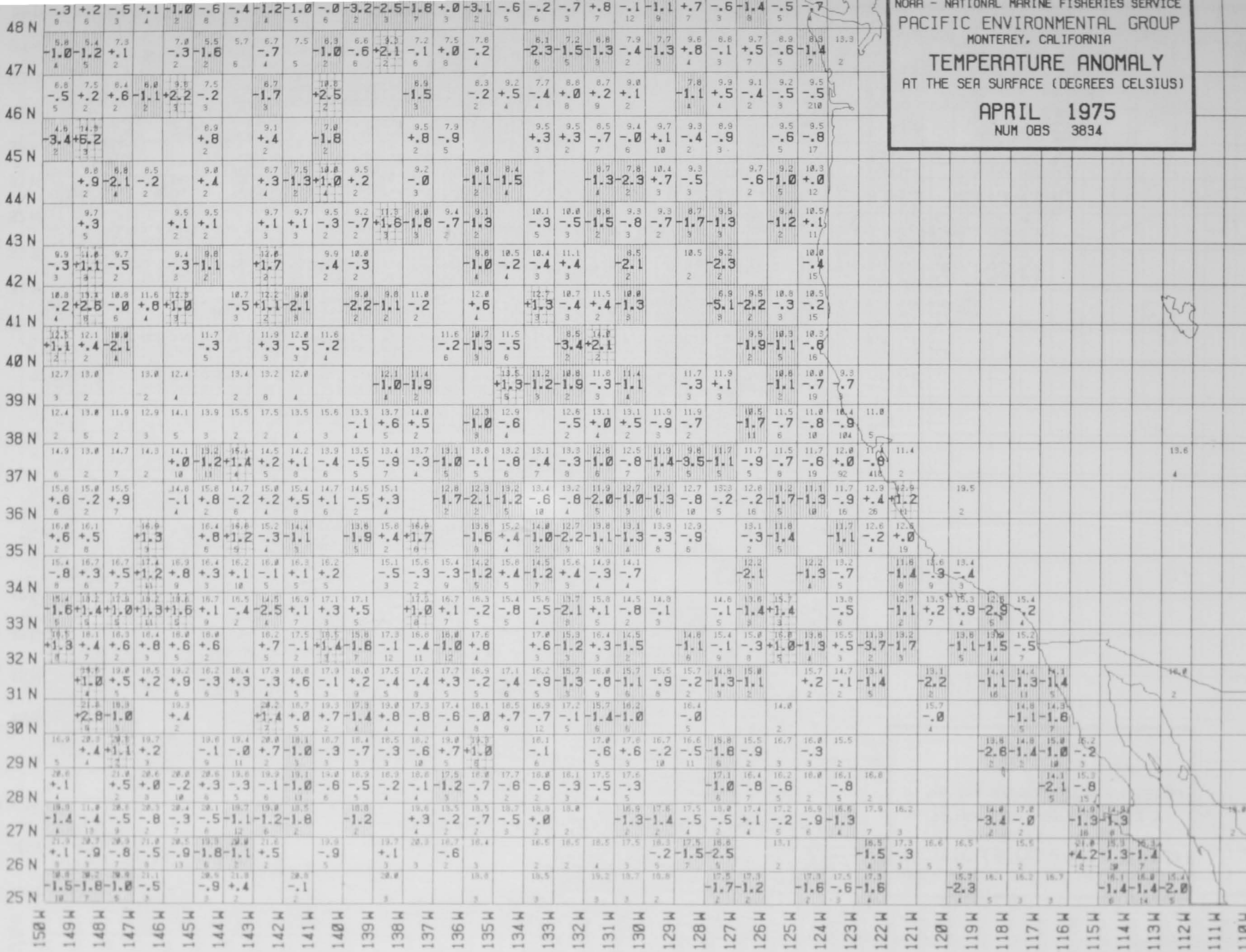

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
MARCH 1975
NUM OBS 3119


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
APRIL 1975
NUM OBS 3834
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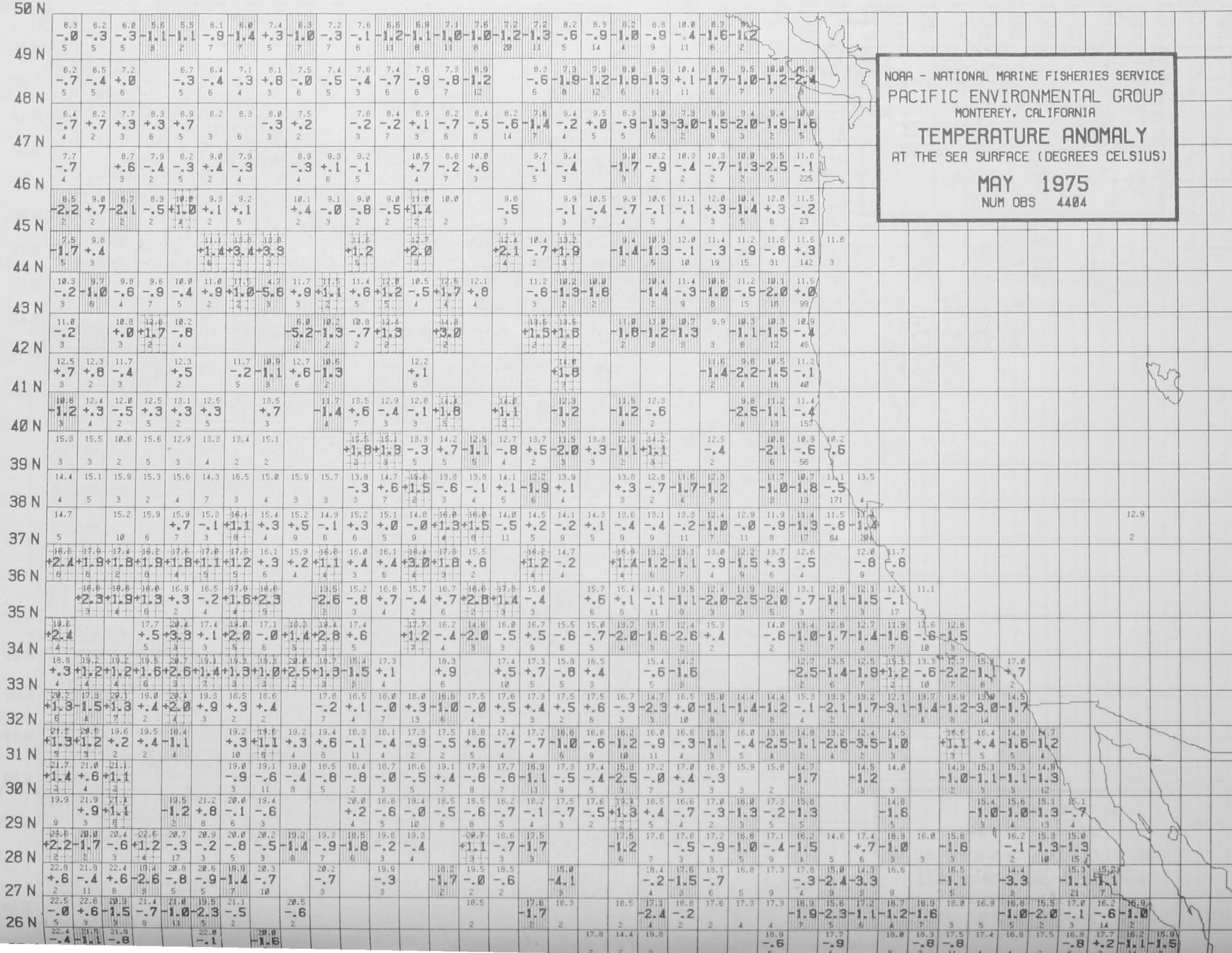
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
MAY 1975
NUM OBS 4404
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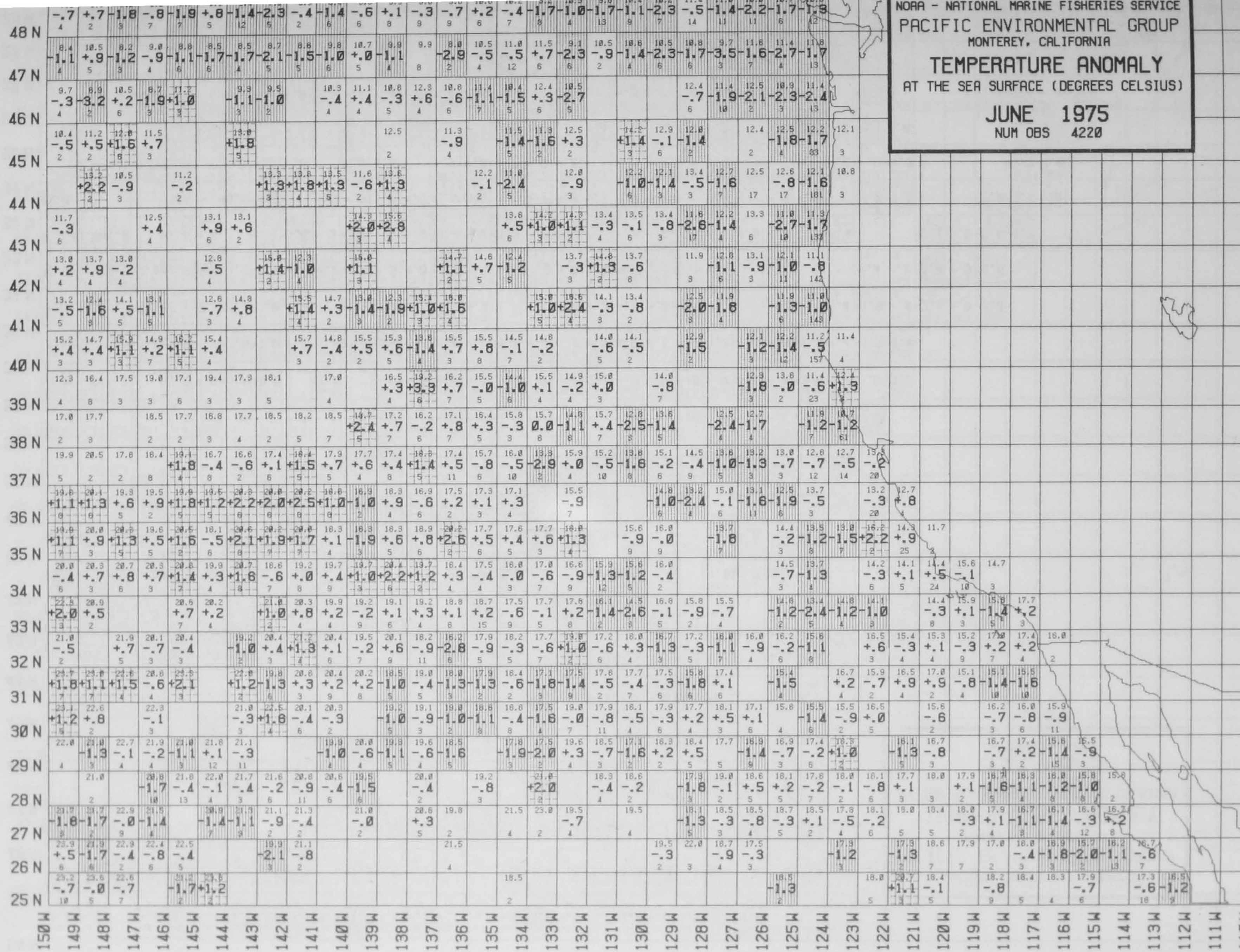
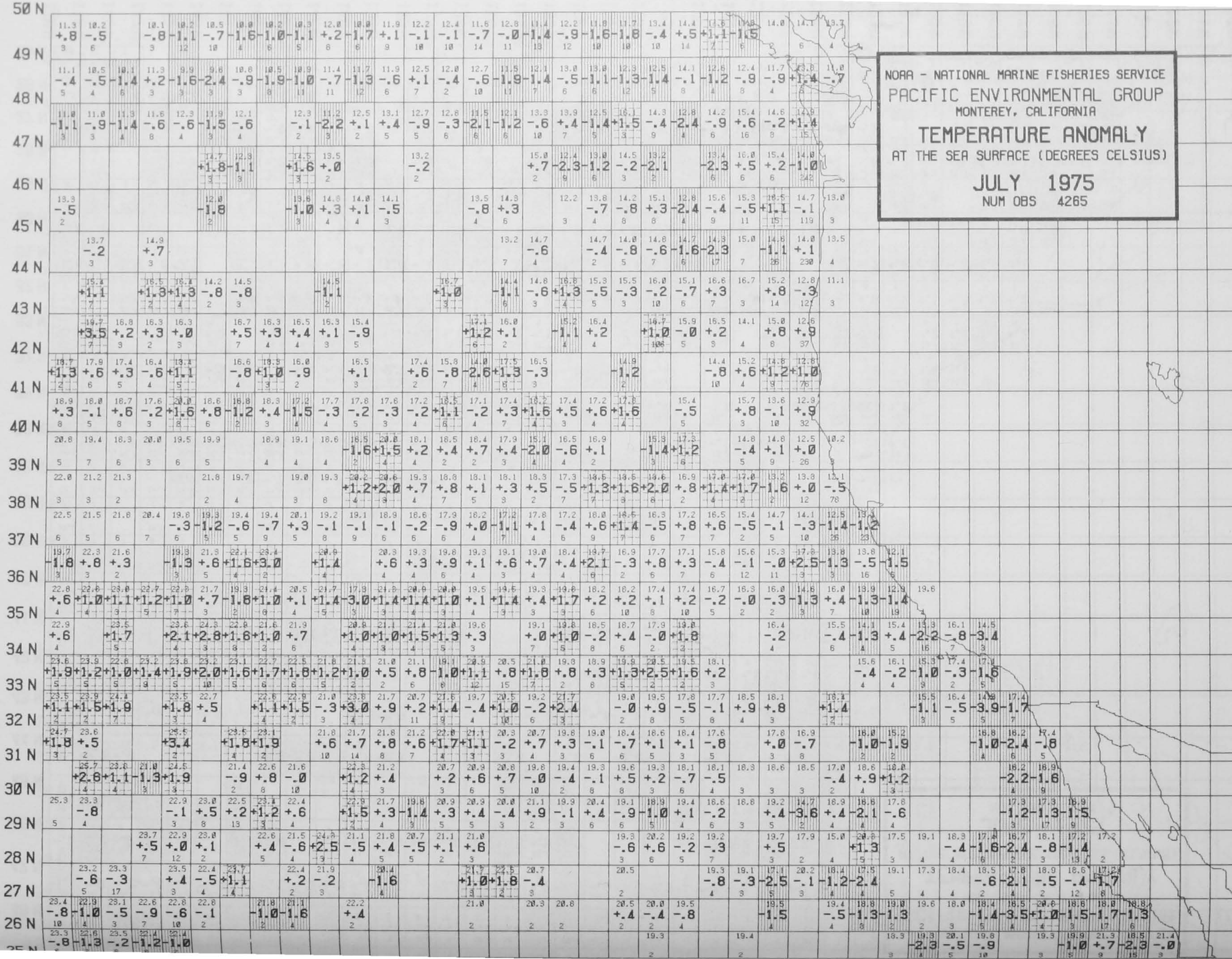

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JUNE 1975
NUM OBS 4220


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JULY 1975
NUM OBS 4265
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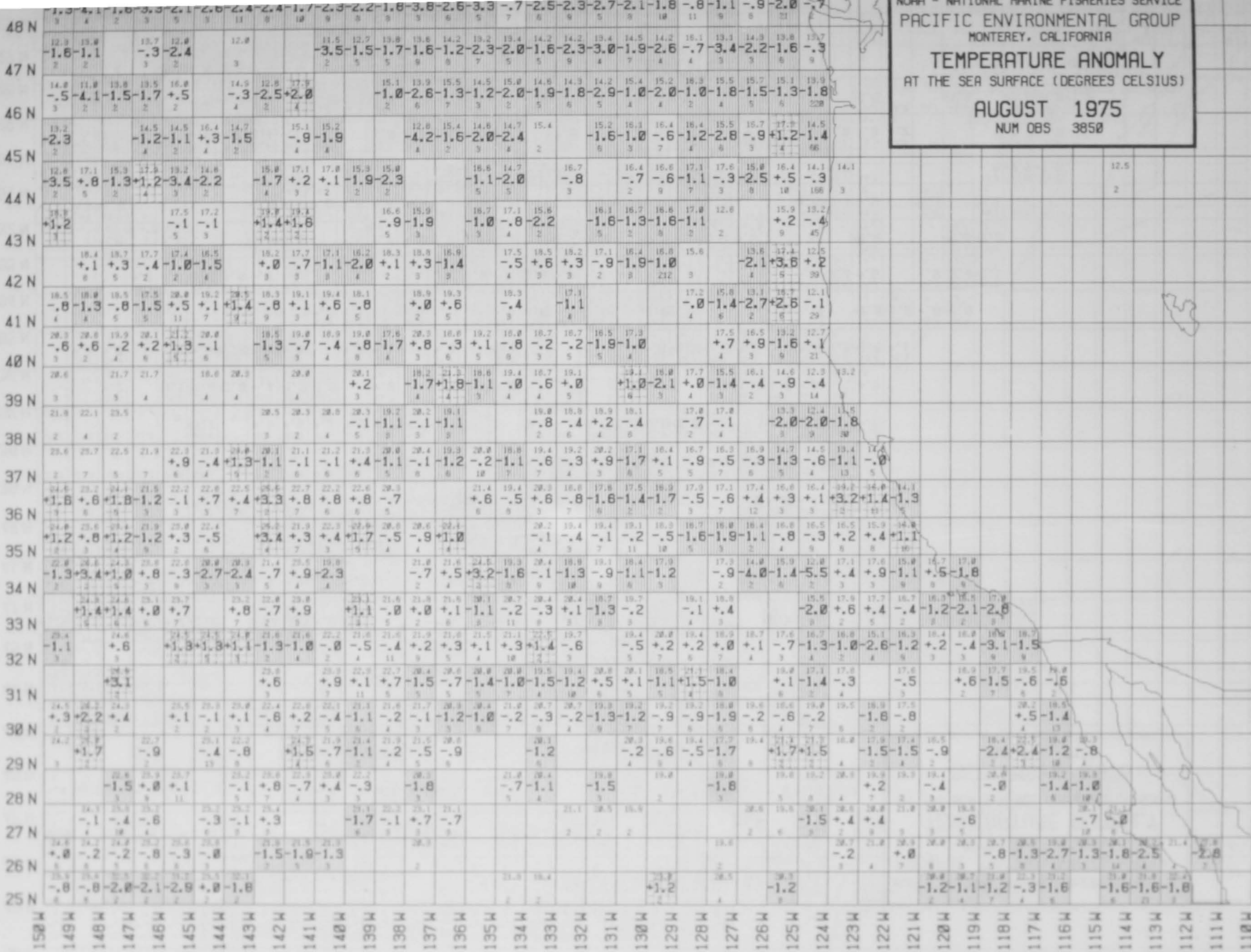
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
AUGUST 1975
NUM OBS 3850
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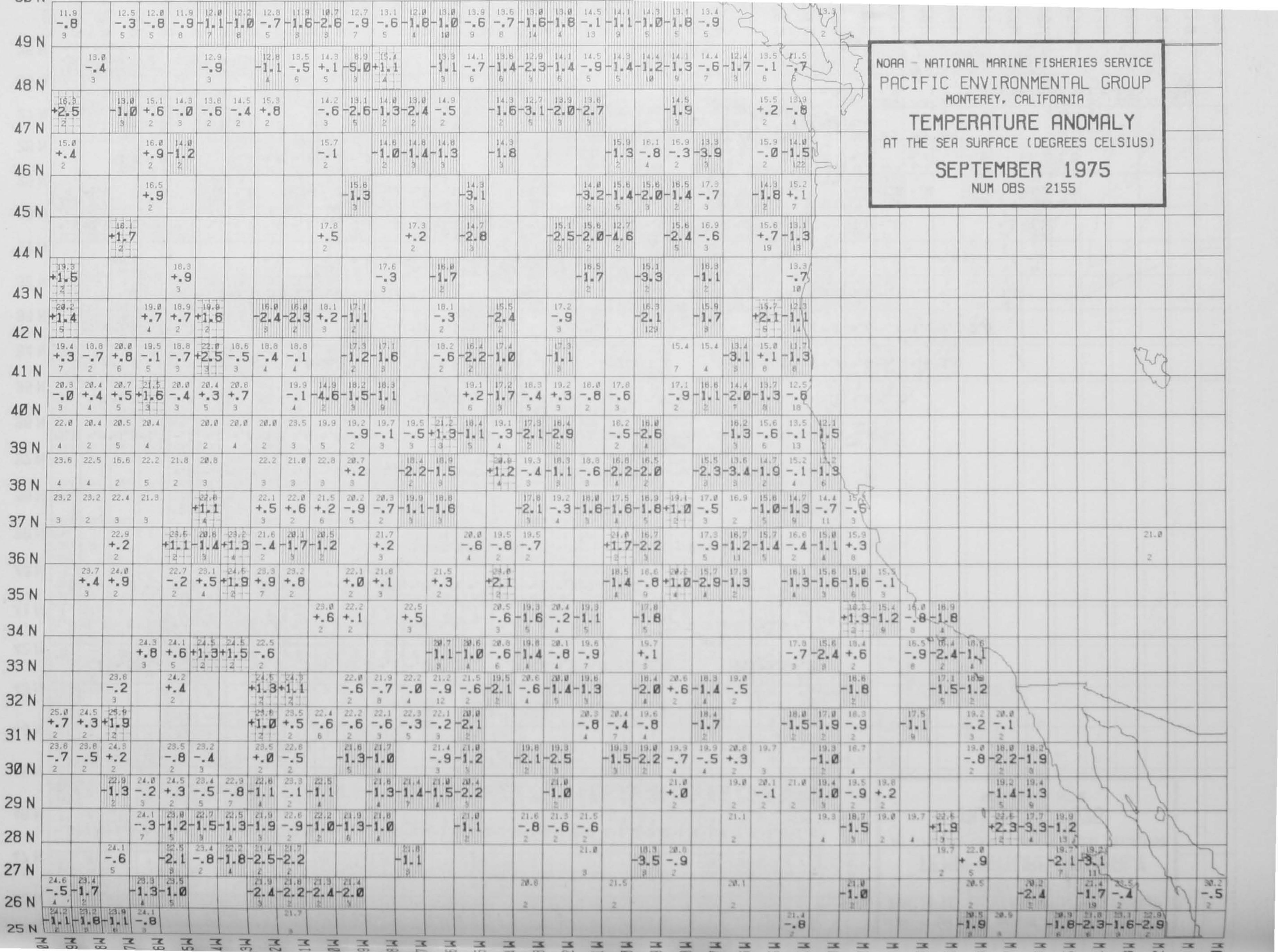
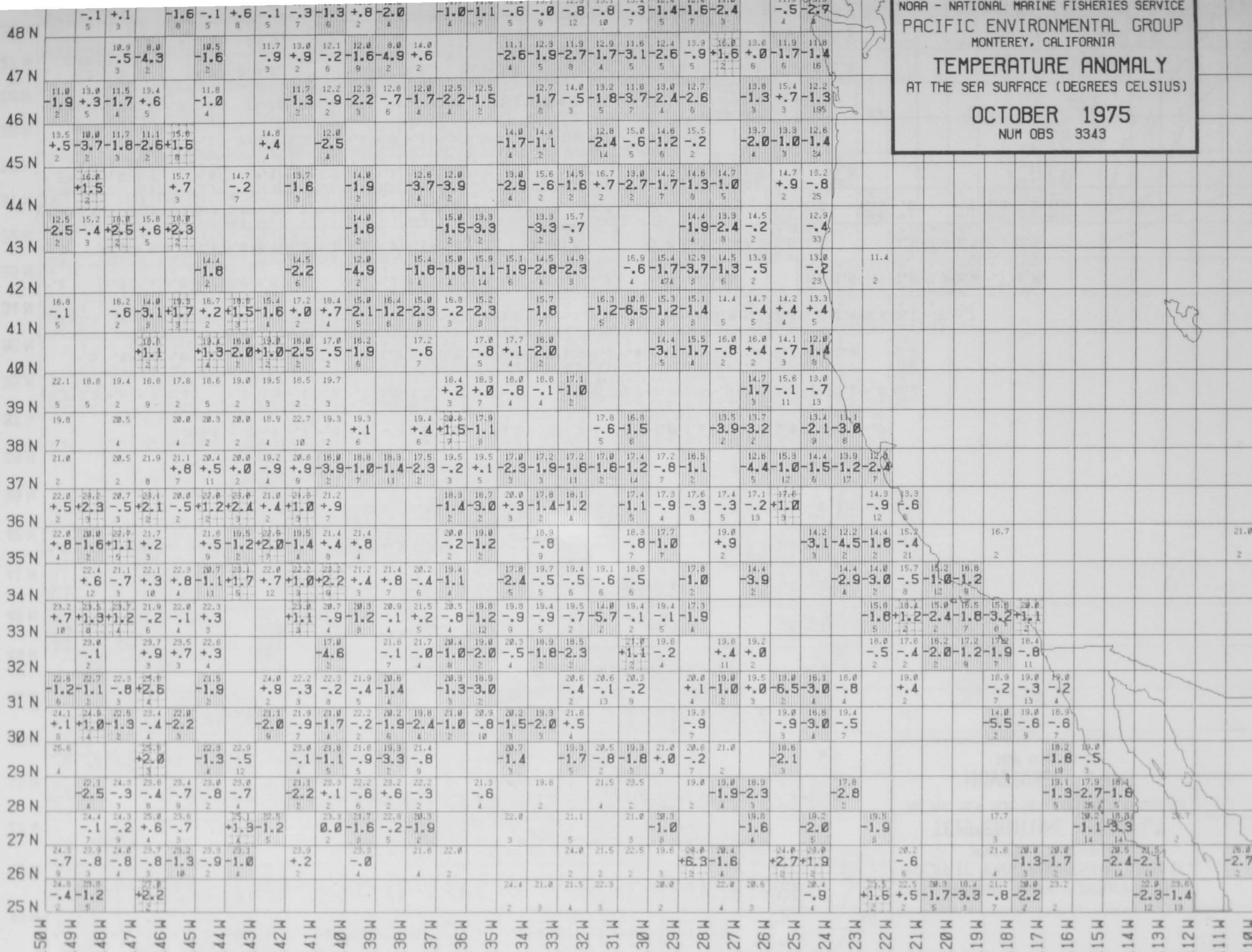

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
SEPTEMBER 1975
NUM OBS 2155


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
OCTOBER 1975
NUM OBS 3343
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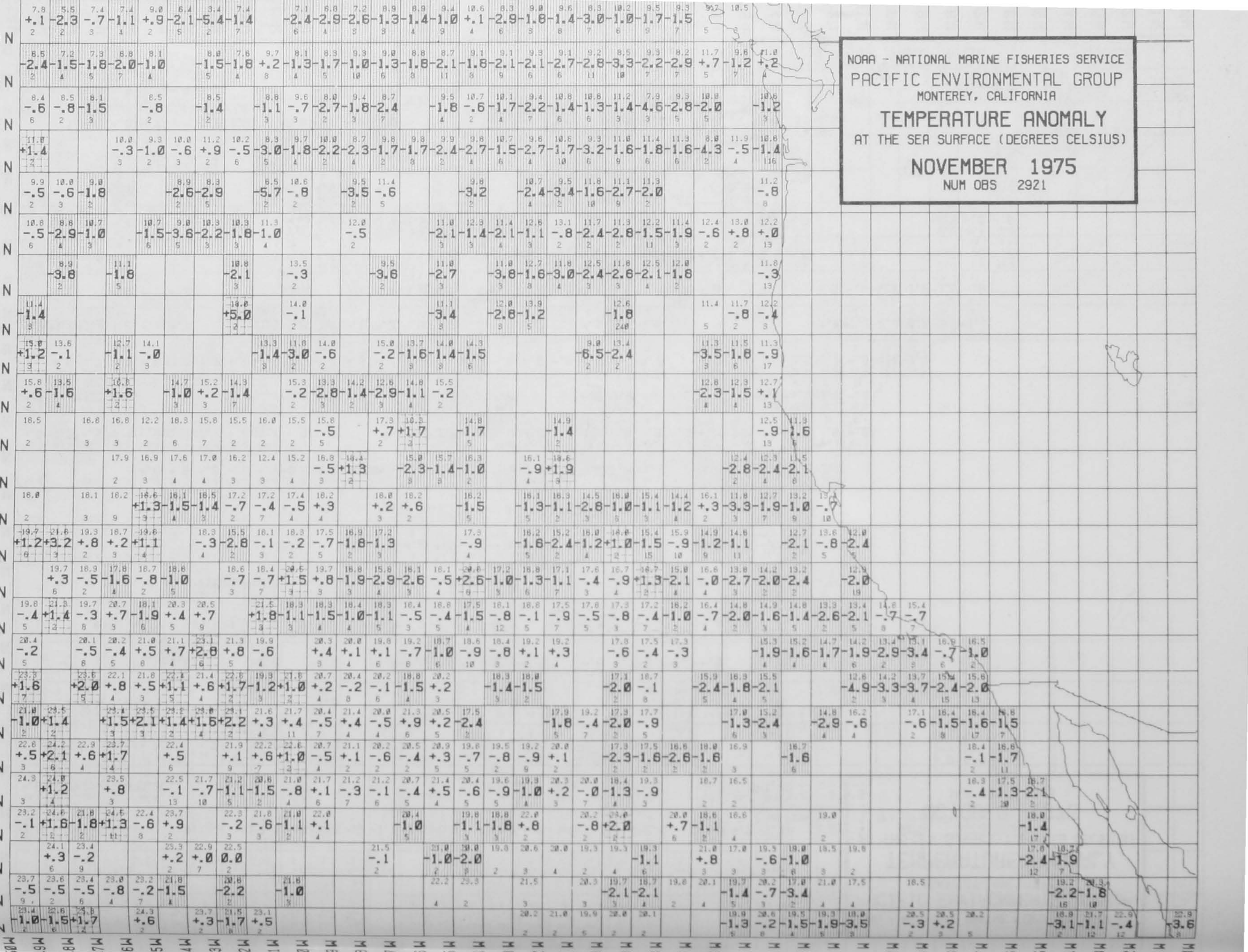
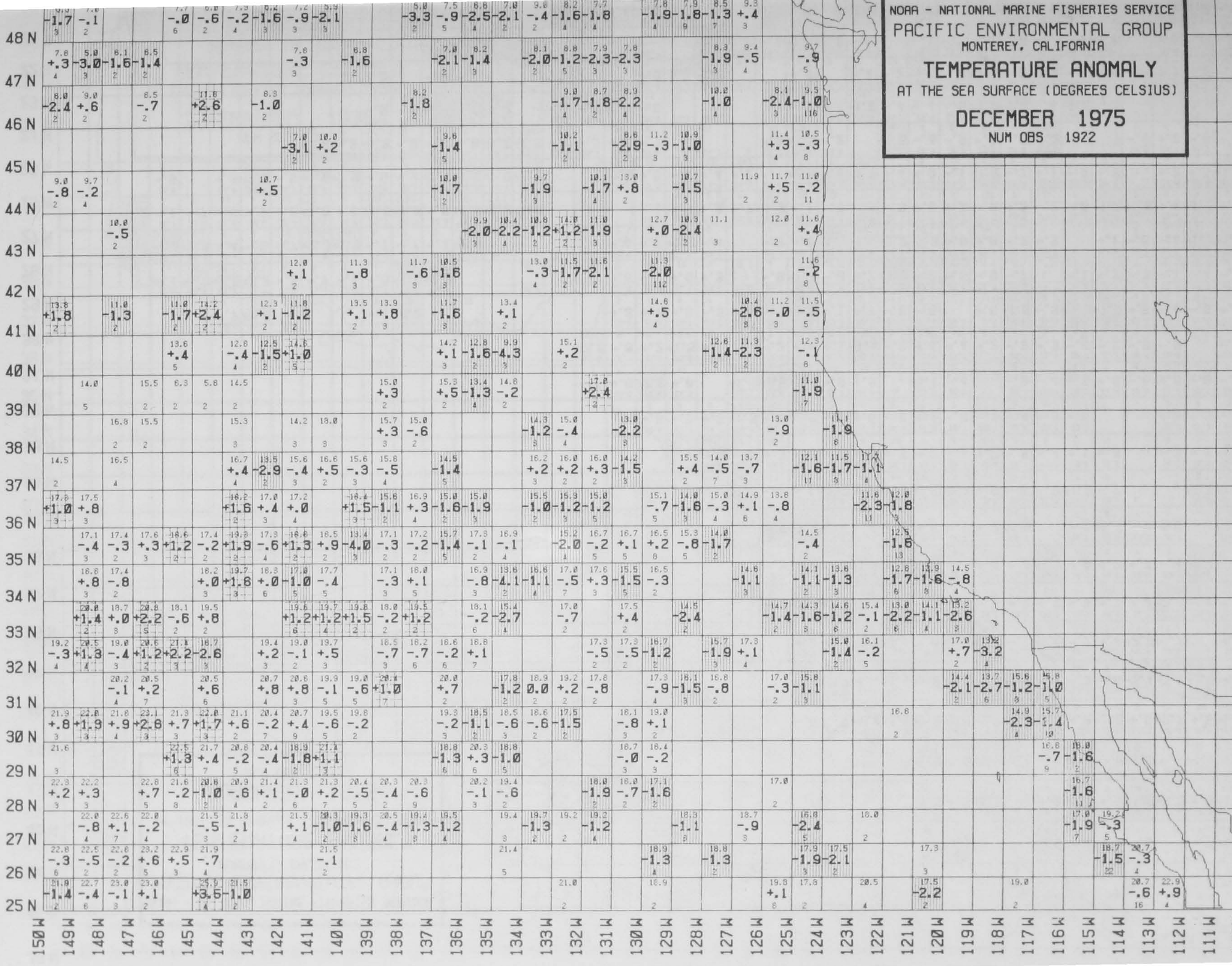

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
NOVEMBER 1975
NUM OBS 2921


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
DECEMBER 1975
NUM OBS 1922
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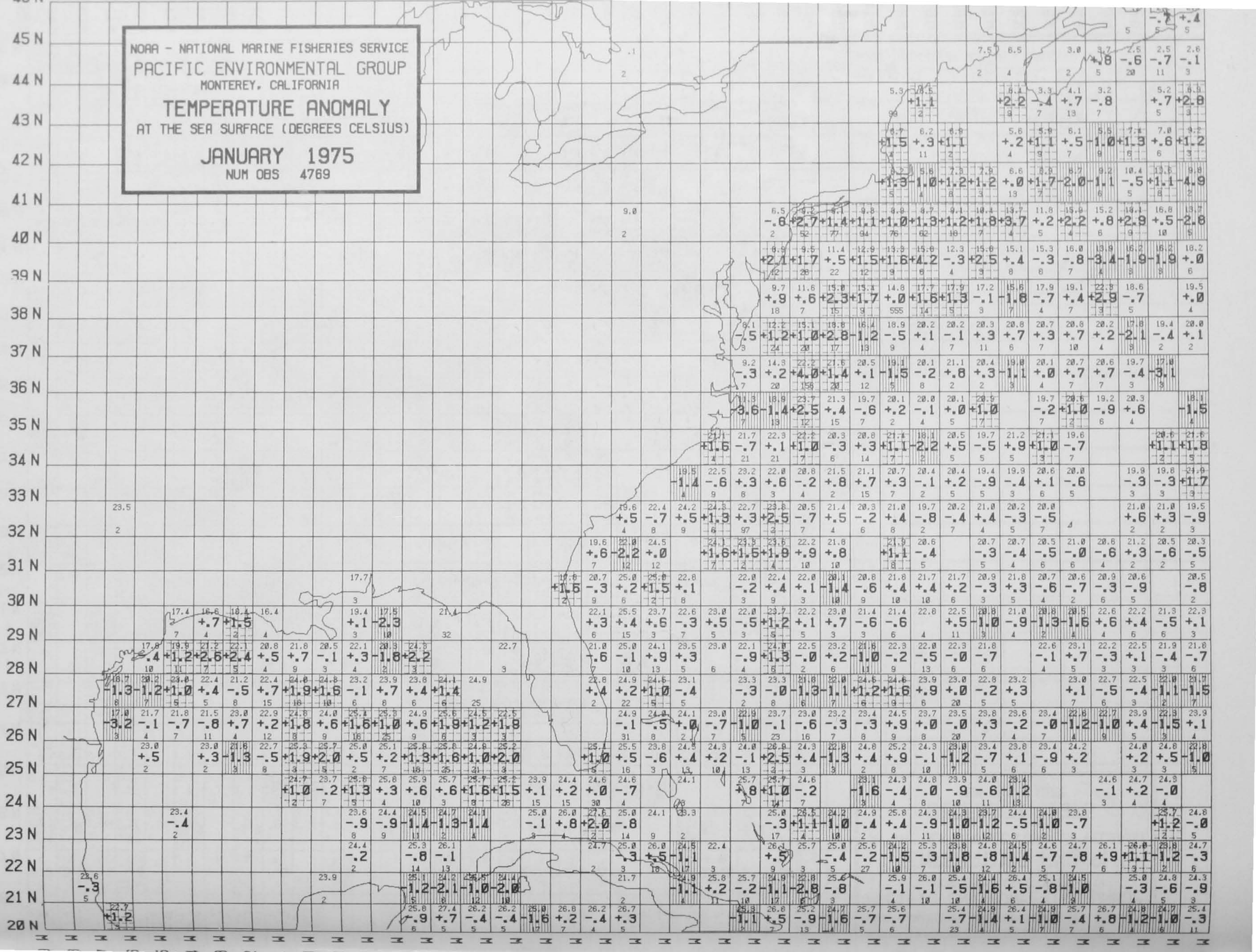
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JANUARY 1975
NUM OBS 4769
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NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
FEBRUARY 1975
NUM OBS 4284
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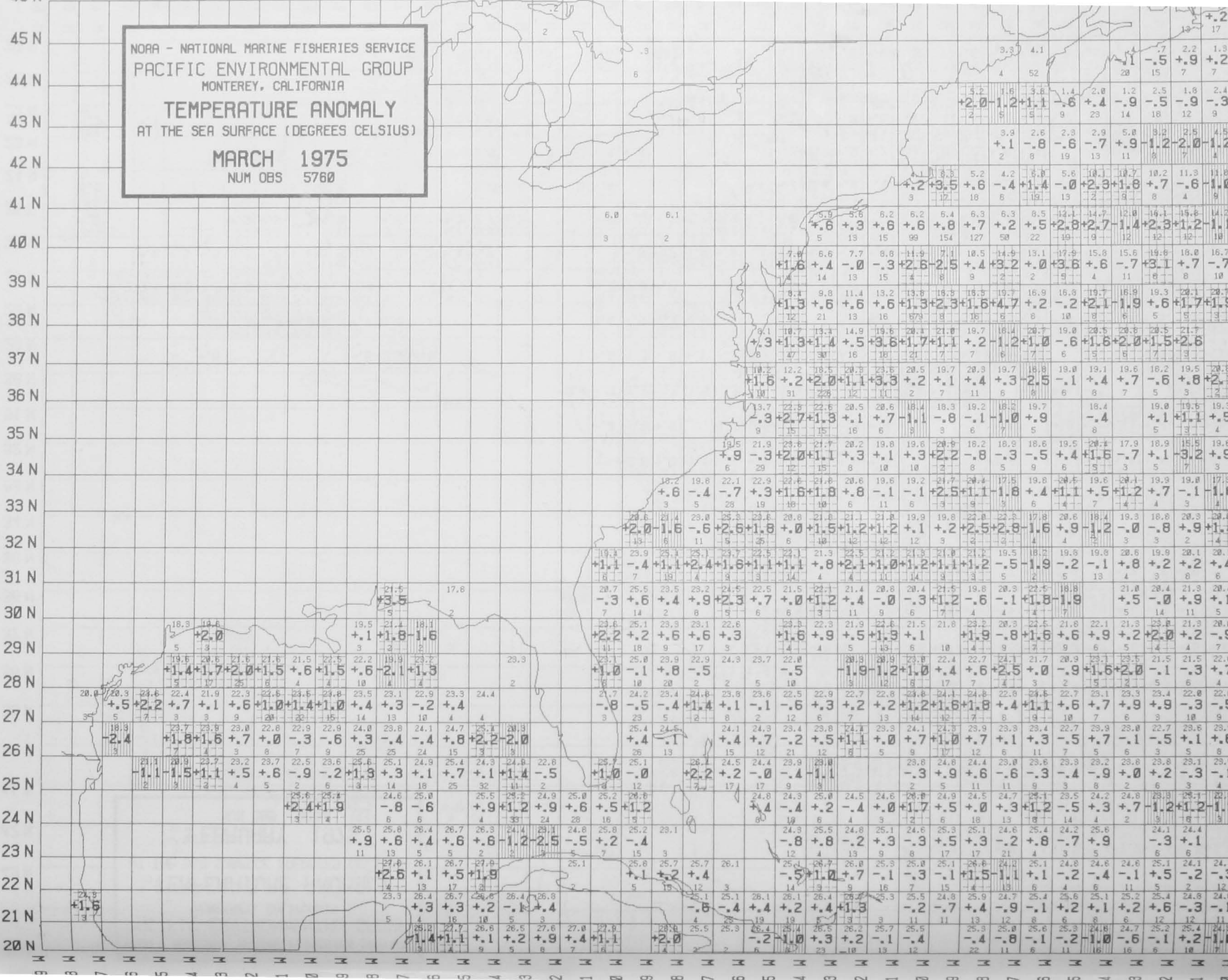
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
MARCH 1975
NUM OBS 5760
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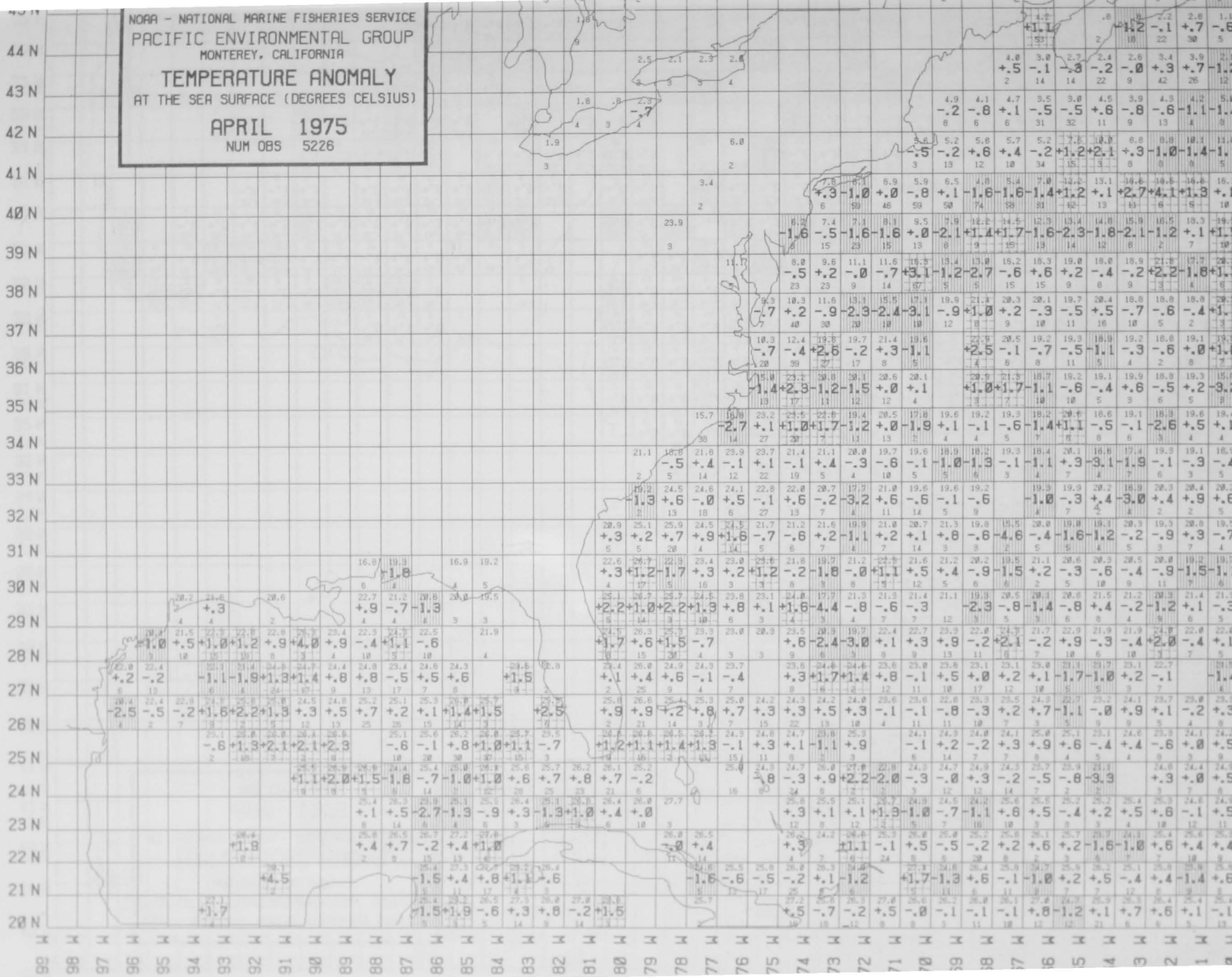
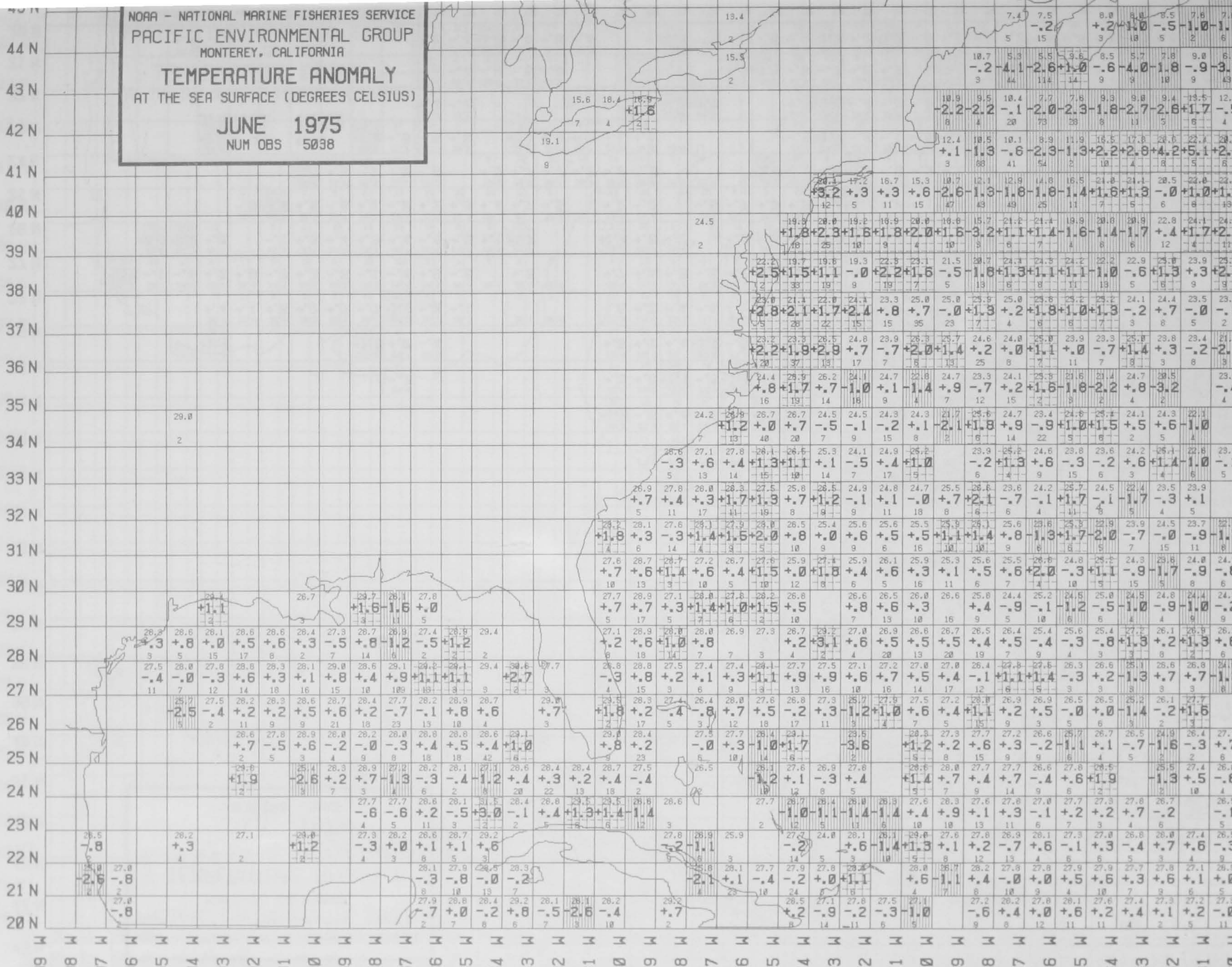

NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
APRIL 1975
NUM OBS 5226


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
MAY 1975
NUM OBS 5169


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JUNE 1975
NUM OBS 5038
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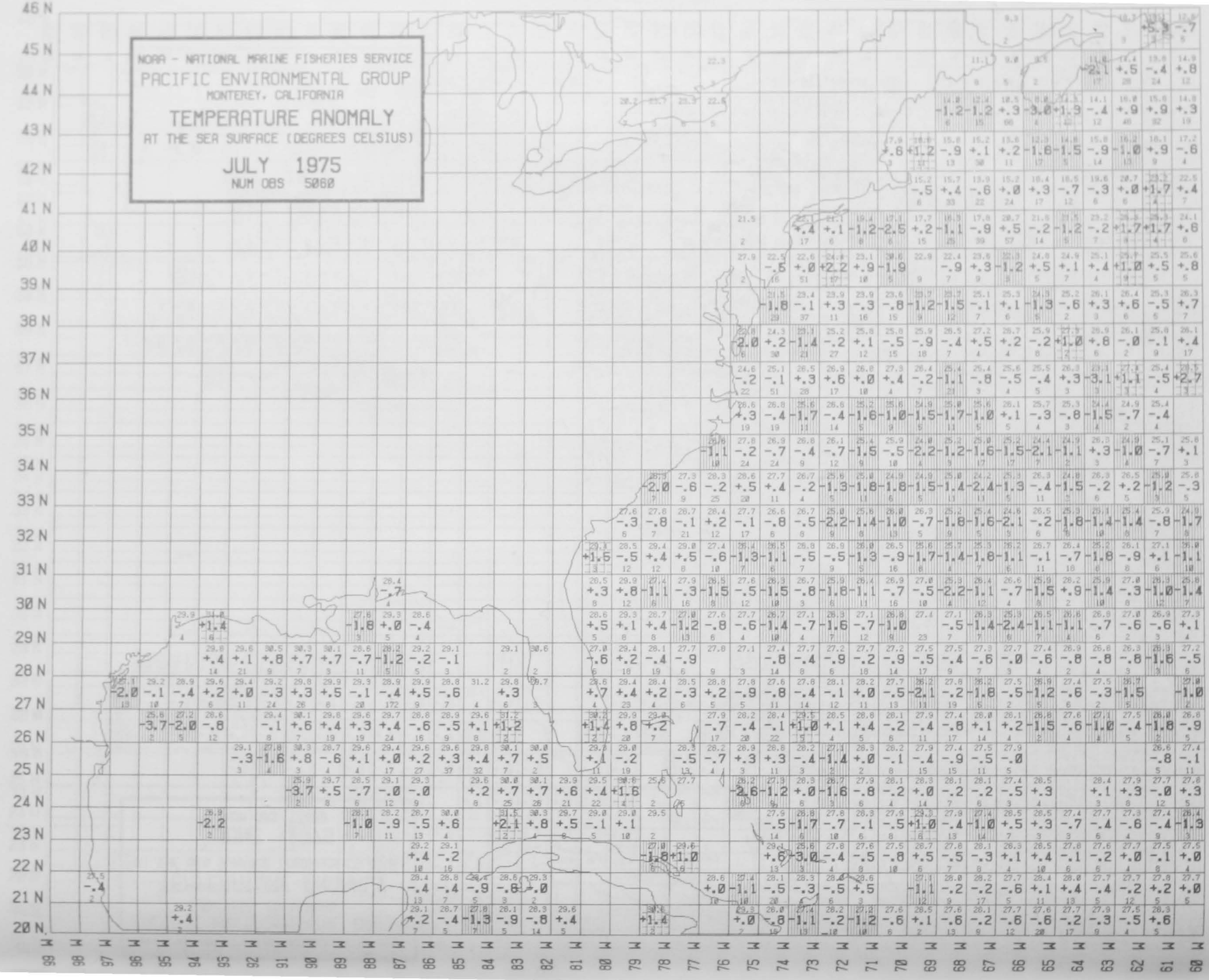
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
JULY 1975
NUM OBS 5060
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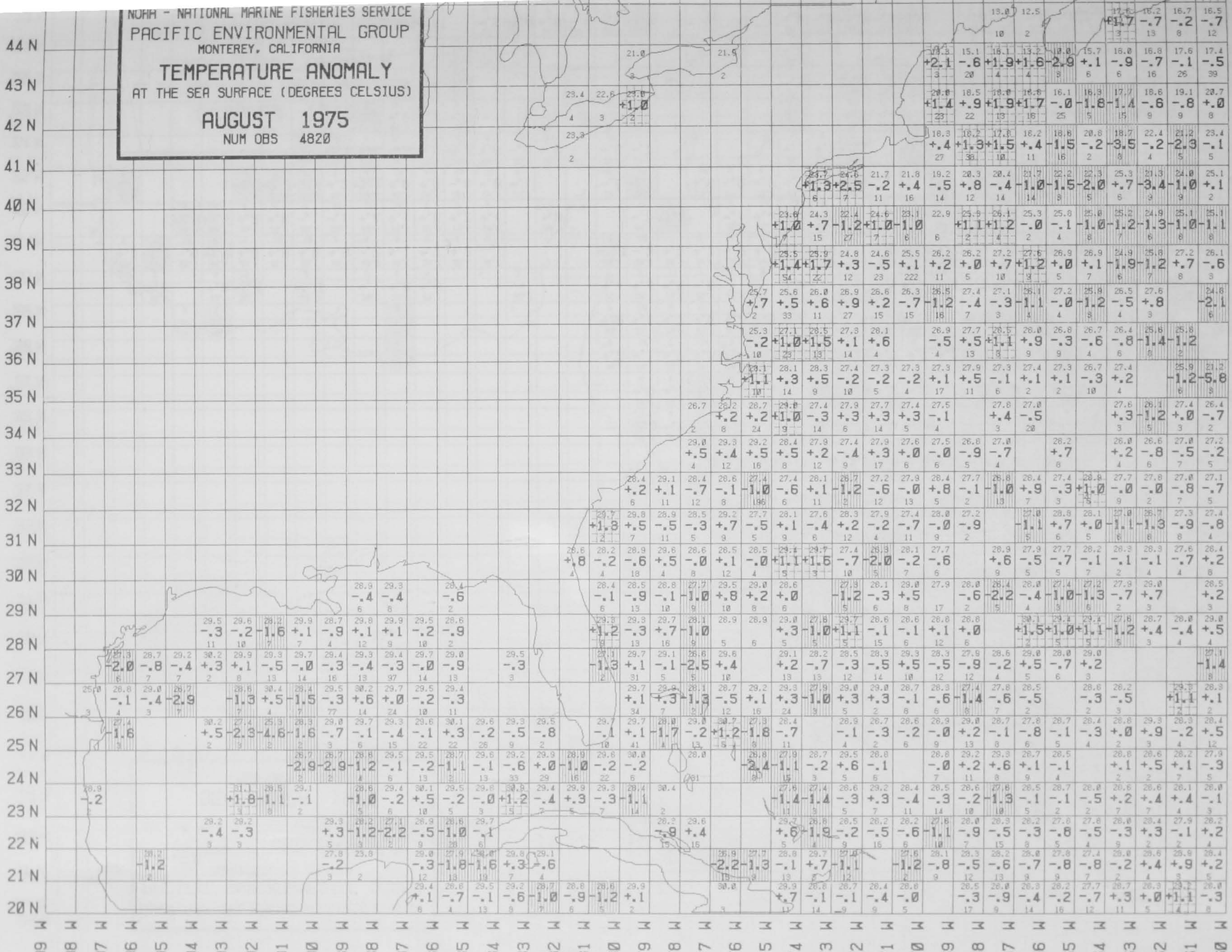
NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
AUGUST 1975
NUM OBS 4820
44 N
43 N
42 N
41 N
40 N
39 N
38 N
37 N
36 N
35 N
34 N
33 N
32 N
31 N
30 N
29 N
28 N
27 N
26 N
25 N
24 N
23 N
22 N
21 N
20 N
99 W
98 W
97 W
96 W
95 W
94 W
93 W
92 W
91 W
90 W
89 W
88 W
87 W
86 W
85 W
84 W
83 W
82 W
81 W
80 W
79 W
78 W
77 W
76 W
75 W
74 W
73 W
72 W
71 W
70 W
69 W
68 W
67 W
66 W
65 W
64 W
63 W
62 W
61 W
60 W


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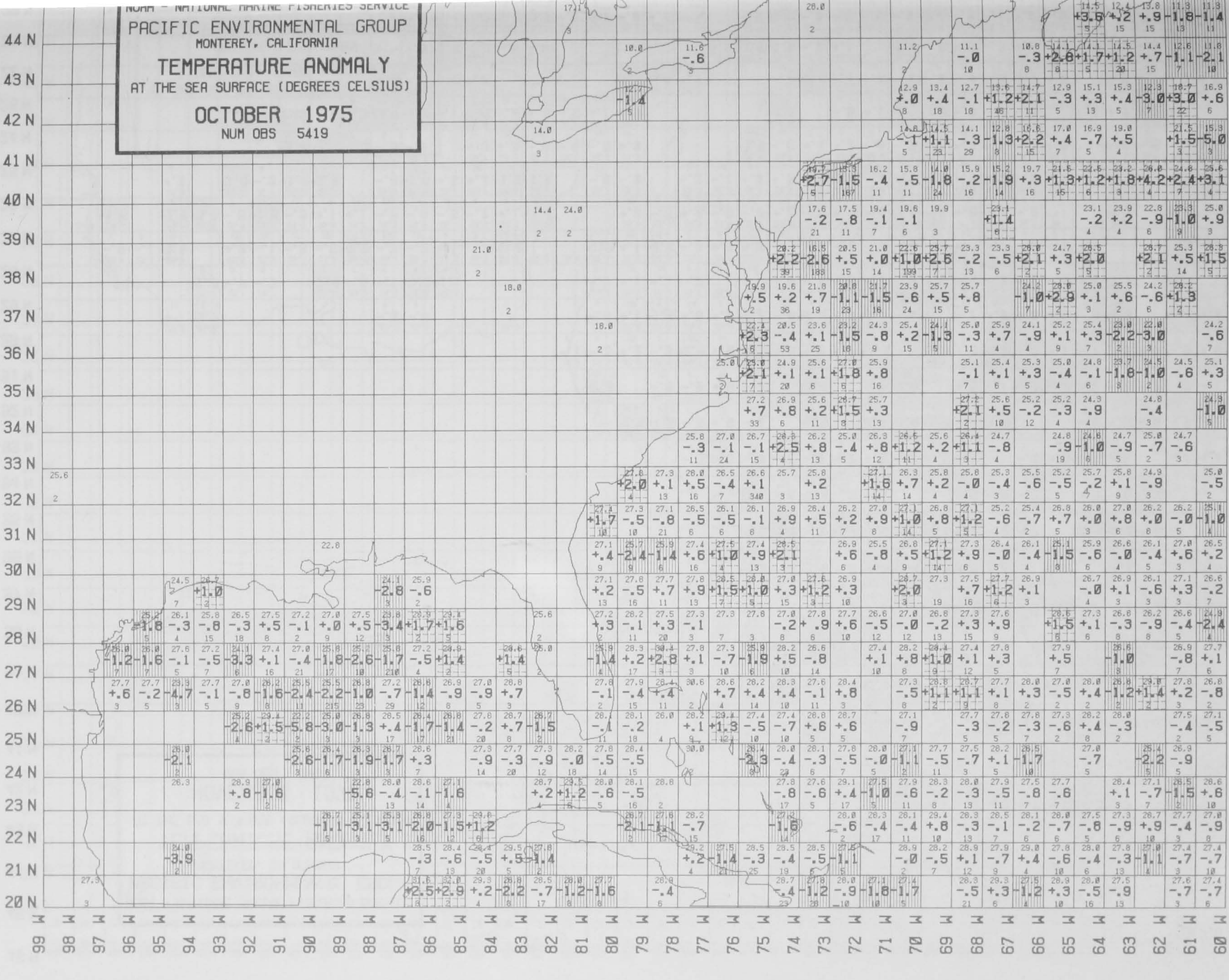
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
SEPTEMBER 1975
NUM OBS 3092
46 N
45 N
44 N
43 N
42 N
41 N
40 N
39 N
38 N
37 N
36 N
35 N
34 N
33 N
32 N
31 N
30 N
29 N
28 N
27 N
26 N
25 N
24 N
23 N
22 N
21 N
20 N


NOAA - NATIONAL MARINE FISHERIES SERVICE
PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
OCTOBER 1975
NUM OBS 5419
44 N
43 N
42 N
41 N
40 N
39 N
38 N
37 N
36 N
35 N
34 N
33 N
32 N
31 N
30 N
29 N
28 N
27 N
26 N
25 N
24 N
23 N
22 N
21 N
20 N
99 W
98 W
97 W
96 W
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92 W
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76 W
75 W
74 W
73 W
72 W
71 W
70 W
69 W
68 W
67 W
66 W
65 W
64 W
63 W
62 W
61 W
60 W


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PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
NOVEMBER 1975
NUM OBS 5067
46 N
45 N
44 N
43 N
42 N
41 N
40 N
39 N
38 N
37 N
36 N
35 N
34 N
33 N
32 N
31 N
30 N
29 N
28 N
27 N
26 N
25 N
24 N
23 N
22 N
21 N
20 N


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PACIFIC ENVIRONMENTAL GROUP
MONTEREY, CALIFORNIA
TEMPERATURE ANOMALY
AT THE SEA SURFACE (DEGREES CELSIUS)
DECEMBER 1975
NUM OBS 3306
44 N
43 N
42 N
41 N
40 N
39 N
38 N
37 N
36 N
35 N
34 N
33 N
32 N
31 N
30 N
29 N
28 N
27 N
26 N
25 N
24 N
23 N
22 N
21 N
20 N
99 W 98 W 97 W 96 W 95 W 94 W 93 W 92 W 91 W 90 W 89 W 88 W 87 W 86 W 85 W 84 W 83 W 82 W 81 W 80 W 79 W 78 W 77 W 76 W 75 W 74 W 73 W 72 W 71 W 70 W 69 W 68 W 67 W 66 W 65 W 64 W 63 W 62 W 61 W 60 W

Section 3

ATMOSPHERIC CLIMATOLOGY AND ITS EFFECT ON SEA SURFACE TEMPERATURE - 1975

Robert R. Dickson[1] and Jerome Namias[2]

uring 1975, stronger than normal westerly flow continued to ominate much of the Northern Hemisphere at middle and high atitudes, in keeping with the general circulation tendency of he previous four years (Namias and Dickson 1976). However, lthough this general tendency may have been maintained, there ere also marked differences in the strength, axial position, and easonal occurrences of these westerlies, compared with earlier ears.

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[2]Scripps Institution of Oceanography, La Jolla, CA 92037.

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Section 3

ATMOSPHERIC CLIMATOLOGY AND ITS EFFECT ON SEA SURFACE TEMPERATURE - 1975

Robert R. Dickson[1] and Jerome Namias[2]

During 1975, stronger than normal westerly flow continued to dominate much of the Northern Hemisphere at middle and high latitudes, in keeping with the general circulation tendency of the previous four years (Namias and Dickson 1976). However, although this general tendency may have been maintained, there were also marked differences in the strength, axial position, and seasonal occurrences of these westerlies, compared with earlier years.

Figure 3.1 illustrates the mean annual distribution of 700 mb height and its anomaly during 1975. As in the previous high index years, the augmented westerlies are shown to be chiefly a feature of the oceanic areas, with a relatively slack flow over North America and Asia. Unlike these earlier years, however, the principal strengthening of the westerlies took place at relatively high latitudes. Over the North Pacific an extensive but low amplitude anomaly ridge at mid-latitudes [+90 ft (27 m) in the annual mean] combined with a weak upper level trough over the Beaufort and Bering Seas [-50 ft (-15 m)] to direct strengthened westerlies to the south of the Aleutians; along the eastern limb of the mid-latitude ridge, these turned to northwesterlies flowing along the western seaboard of North America. In the Atlantic sector extensive ridging was also observed at mid-latitudes but was split into two main cells over the west Atlantic and northwest Europe. The eastern cell was the more intense [+110 ft (32 m) in the annual mean] and combined with a deep upper level trough over the Barents Sea [-140 ft (-41 m)] to induce vigorous westerlies from South Greenland across the European subarctic seas to Norway and arctic Russia. Thus in contrast to preceding years (Namias and Dickson 1976), these strengthened westerlies were not the result of an in situ

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tandem intensification of subpolar lows and subtropical anticyclones (the North Pacific and North Atlantic oscillations), but were the product of coupling between intensified ridging at mid-latitudes and a single polar trough.

The seasonal and latitudinal variations in westerly wind strength in 1975 are shown in Figure 3.2 in the form of zonal averages of the westerly component of the mean geostrophic wind (m/sec) over the Northern Hemisphere from 25N to 85N and from 0W to 180W (from Wagner 1976b). A comparison of this figure with the similar figure for 1974 (Wagner 1975a) confirms the general tendency for a shift in the westerly wind belt towards slightly higher latitudes in the later year. As in 1974 the westerlies were at their most intense in the winter season (+4 m/sec at mid-latitudes during January and February) though this has not necessarily been a uniform feature of the five high-index years since 1971. Table 3.1 compares the mean westerly component of the geostrophic wind over the North Pacific sector (35-55N, 130E-110W) in each season of the period 1971-75 with that observed during the relatively low-index years 1947-1966. As shown, although the vigor of the circulation increased in all seasons, the greatest westerly intensification tended to occur in spring within this sector with a progressively smaller mean increase in summer, winter, and fall.

Table 3.1. Mean zonal component of the geostrophic wind at 700 mb level, 35-55N, 130E-110W, during 1947-66 and 1971-75 (m/s).

	1947-66	1971-75	Difference
Winter	9.83	10.13	+0.30
Spring	8.64	9.32	+0.68
Summer	6.00	6.45	+0.45
Fall	9.63	9.70	+0.07

The mean annual distribution of Pacific sea surface temperature (SST) anomaly in 1975 (Fig. 3.3b) was once again the expected reflection of the relatively high-index circulation in that sector. Across the northern North Pacific from Japan, south of the Aleutians to the British Columbia coast, the track of the strengthened westerlies is marked by a zonal belt of abnormally cold water with core anomalies of -1.6F (central ocean) and -2.5F (at the North American coast). In fact, this distribution shows a closer relationship to the circulation of the winter season, when the westerly circulation was most strongly developed, than to the mean circulation of the year as a whole, and it is envisaged that these cool oceanic conditions were maintained primarily through the enhanced westerlies, cyclonicity, cold-frontal activity, and Ekman divergence (with open-ocean upwelling) of the winter season. To the scuth a zonal pool of warm water was maintained across the central North Pacific with core anomalies exceeding +1.3F in the annual mean. Again this is the expected development under the light winds, clear skies, and horizontal cceanic convergence which would be associated with the high pressure anomaly cell at mid-latitudes. Throughout the year, northerlies running along the eastern flank of this cell were responsible for the regeneration and maintenance cf cool surface temperatures at the North American seaboard, presumably as a result of enhanced coastal upwelling and heat exchange (Bakun, Section 6).

The above discussion has purposely emphasized the "maintenance" or "regeneraticn" of surface temperature anomalies in 1975 rather than the establishment of these features. The circulation of the preceding year was one of even greater westerly vigor and as a result, the surface temperature ancmaly distribution of 1975 must reflect the antecedent condition of the ocean's thermal field as well as contemporary forcing. Comparing the mean annual SST anomaly distributions cf 1974 and 1975 (Fig. 3.3) it is clear that similar distributions of surface temperature characterized these twc high-index years with the northward displacement cf the SST anomaly pattern in 1975 arising through the slight poleward shift of winds and pressure belts in that year.

Equivalent mean annual surface temperature data for the North Atlantic as a whole are not yet conveniently available; however, variations in surface temperature anomaly over the west Atlantic are described below in the discussion of seasonal changes.

The seasonal changes of 700 mb height anomaly and surface temperature anomaly over the ccean areas flanking the United States are described in Figure 3.4. In general, over the eastern North Pacific, the seasonal changes in circulation abcut the annual mean were not responsible for any radical seasonal shifts in the "preconditioned" surface temperature field. Some greater seasonal variability in SST anomaly was generated however over the western Atlantic.

During <u>winter</u> (December 1974-February 1975) the westerlies of the Western Hemisphere attained a greater anomalous intensity than during any other season of 1975. In January, Wagner 1975b:360) noted that along the axis of the upper westerlies ". . . speeds were around 5 m/s stronger than normal over the Pacific and averaged nearly 10 m/s above normal across the Atlantic . . ." In that month the mid-latitude zonal index for the Western Hemisphere equalled that of February 1974 (13.3 m/s) which itself was the second strongest monthly index of record. Around the latitude of maximum zonality mild maritime influences penetrated far into northern North America and Eurasia. At lower latitudes the northward expansion and intensification of the subtropical anticyclones led to a weakening of the subtropical westerlies aloft, resulting in the mean windspeed profile shown in Figure 3.5 (from Wagner 1975b). During February, the fast zonal flow began to break down, but nevertheless over the eastern Pacific the seasonal mean of 700 mb height still indicated a sizeable anomaly gradient of over 290 ft (88 m) between 30N and 60N at 170W (Fig. 3.4).

As already described, the underlying zonal distribution of SST anomaly is largely in keeping with this high-index circulation and a similar basic pattern will be encountered in all seasons of 1975. However certain differences of detail may be described which are peculiar to each season. In winter our attention is drawn to the tongue of warm water which extends northeastward from the main warm center towards the Gulf of Alaska and which appears to be out of keeping with the northwesterly anomaly wind in this area. In fact this situation is a partial reflection of events in the antecedent season (fall 1974) when an anticyclonic anomaly cell centered over the American west coast had generated warm surface conditions throughout the Gulf of Alaska (Namias and Dickson 1976). Thus while the northerlies of the succeeding winter did not entirely eradicate these warm conditions, they were responsible for a substantial weakening and southward retraction of this warm-water tongue.

In the western Atlantic the winter surface temperature distribution was dominated by the contrast between abnormally warm conditions (>+2F) off the southern U.S. seaboard and cold conditions (>-2F) off the Canadian Maritimes. Again this is readily explicable in terms of the prevailing circulation pattern; a localized upper-level ridge off the Atlantic seaboard brought enhanced southerlies and warm surface conditions to the former area, but coupled with a trough over southern Greenland, this cell was also responsible for directing a strong northwesterly flow from arctic Canada toward the Labrador Sea and northwestern Atlantic.

Although fast zonal flow continued over the Western Hemisphere during March, the <u>spring</u> season as a whole was characterized by a general weakening of the zonal flow and an amplification of the circulation into a more meridional pattern. In March and April, the Pacific subtropical anticyclone moved east while retaining its former anomalous amplitude, resulting in a more direct northerly anomaly airflow over the western seaboard. In response, the weak upper-level trough which had persisted over the Rockies throughout the winter became strongly developed as cyclonic centers crossing the Pacific were driven south into this area, resulting in depressed westerlies across the southern United States, and encouraging the buildup of a further upper trough off the Atlantic seaboard. By April, Wagner (1975c) noted that mean 700 mb winds were at twice their normal strength east of Cape Hatteras. Record or near-record cold prevailed over much of the United States.

In May as the amplification of the circulation continued, strong ridges built over the eastern Atlantic and northeastern Asia. In the Atlantic this resulted in a further disruption of the westerly airflow, but the advection of cool air around the eastern flank of the Siberian ridge generated a strong thermal gradient between that area and the long-standing anomalous warmth prevailing in the ocean's surface layer across the lower latitudes of the North Pacific. Dickson[3] (1975) regarded this development as being responsible for enhancing the supply of zonal available potential energy and hence for a late-season acceleration of the westerlies over the North Pacific (5 m/s above normal from 170E to 130W in May).

These successive events are indicated in the mean distribution of 700 mb height anomaly for spring 1975 (Fig. 3.4) and are reflected in the seasonal changes in surface temperature over the eastern Pacific and western Atlantic. In the eastern Pacific, enhanced heat exchange and coastal upwelling under the direct northerly anomaly wind completed the eradication of the warm-water tongue which had formerly extended to the Gulf of Alaska. Thus while the main area of warm surface temperature anomalies persisted to the southwest under the strong subtropical anticyclone, it suffered a marked truncation along its eastern margin. In the west Atlantic the depressed westerlies and offshore trough brought a retraction of the preexisting warm SST anomalies to the coast while cool surface conditions intensified and spread offshore [>-4F (>-2.2C) off Nova Scotia].

The <u>summer</u> was characterized by ridging at relatively high latitudes over both the Pacific and Atlantic Oceans. The persistent upper level anomaly ridge over the North Pacific showed some weakening compared with the preceding season [+70 ft (+21 m) compared with +140 ft (+42 m)], but moved northeastward to become centered at 40-45N, 150W. Generally strong westerlies continued to the north of the ridge throughout most of the summer. The underlying warm SST anomaly generated by this ridge also showed a corresponding northeastward shift, but along the western seaboard, northerly anomaly winds weakened drastically as the ridge itself weakened so that the strip of cool water at the coast narrowed markedly.

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[3] No relation to present author.

Farther east an upper-level mean ridge which had progressed slowly eastward across Arctic Canada through March, April, and May finally merged with the preexisting ridge over the eastern Atlantic to form a single zonal cell from Hudson Bay to eastern Europe. To the north of this cell intense westerlies were generated at high latitudes across the Davis Strait, Greenland, the Norwegian-Greenland Sea, and northern Norway, and were reflected in the extreme departures of +3 m/s in the mean zonal wind at high latitudes over the Western Hemisphere (Fig. 3.5).

Equally extreme developments took place along the southern flank of this cell. The merging of the two centers of positive height anomaly (over northeasternern Canada and the east Atlantic) caused a rapid realignment of these meridional cells into a zonal distribution. As this zonal realignment took place at middle to high latitudes, the Atlantic subtropical anticyclone to the south underwent a remarkable weakening which persisted throughout the summer season. At the center of greatest weakening (30N, 50W, approximately), the following standardized departures of 700 mb height were recorded for the summer season and for its component months:

Table 3.2. Standardized anomaly (departure from the long-term mean height divided by the standard deviation) of 700 mb height at 30N, 50W for the summer of 1975.

June	-2.2
July	-3.3
August	-3.0
Season	-3.4

Since the standard deviation of seasonal means is less than that for any component month, the seasonal standardized anomaly of 700 mb height appears greater than the monthly anomalies.

Coupled with the zonal ridge to the north, this troughing tendency at lower latitudes brought a northeasterly anomaly airflow to the western Atlantic, and thus continued the spread of abnormally cold surface water in this area (Fig. 3.4).

More generally, as Wagner (1976b) pointed out, the subtropical high pressure belts were sufficiently far north by the end of July to develop the subtropical easterlies south of 30N with the result that several tropical storms formed over the western Atlantic and eastern Pacific.

Certain general tendencies of the summer circulation continued into fall. In September (Taubensee 1975), well-developed ridges continued to dominate the mean flow at mid-latitudes so that an intense cyclonic vortex prevailed over much of the polar regions. As Taubensee pointed out, the polar westerlies index for the Western Hemisphere between 55N and 75N was at a record level for September (6.7 m/s vs. a normal of 4.0 m/s). However, although the mid-latitude high pressure belt remained present, adjustments in the position of individual high pressure centers within this belt took place, assisted by the normal progression of seasonal forcing.

Over the North Pacific the strong subtropical ridge remained centered at 45N but had intensified and moved westward compared with its summer position. In the west this movement implied unusual weakness in the Asiatic coastal trough; in the east, northerly anomaly winds began to flow strongly once again along the western American seaboard, reviving the tendency for cooling in the surface waters along the coast. With SST anomalies of >-2F widely distributed throughout the Gulf of Alaska and southward to southern California, this coastal water was at its coolest during this season of 1975. On the other hand the persistent warm pool lying offshore to the southwest was eroding rapidly since the westward shift of the mid-Pacific ridge was now generating a northerly airflow over this offshore region also. In response to these developments in the Pacific, a full-latitude upper level trough remained (on average) over the Rockies for the fourth successive season. (This feature was subsequently destroyed in the winter of 1976.)

In the area of eastern North America and the west Atlantic, seasonal forcing operated to bring winds and pressure belts southward from their summer positions. Progressively the broad Atlantic high pressure cell spread southward in the west Atlantic, weakening the preexisting block over northeastern Canada and reintensifying the Bermuda High (Fig. 3.4). Accompanying this change, "The record strong polar westerlies of September, . . . moved south during October as the middle latitude westerly index over the western half of the Northern Hemisphere increased from a below normal 7.0 m/s in September to an above normal 10.0 m/s in October." (Wagner 1976a).

With the strong reestablishment of the Bermuda High in October and November, unusually warm weather prevailed over the eastern United States. Offshore the previous cooling trend was reversed as warm SST anomalies redeveloped along the southern and western flanks of this cell. However, owing to the small latitudinal extent of this isolated high pressure center, the cooling persisted south of Newfoundland, where a northwesterly airflow from the continent was directed across the coast.

ACKNOWLEDGMENTS

Our thanks go to Madge Sullivan for computational assistance, to Fred Crowe for drafting, and Carolyn Heintskill for typing the manuscript. All are employed at Scripps Institution of Oceanography. Part of this research was sponsored by the National Science Foundation Office for the International Decade of Ocean Exploration under NSF Contract No. OCE74-24592, and the University of California, San Diego, Scripps Institution of Oceanography through NORPAX.

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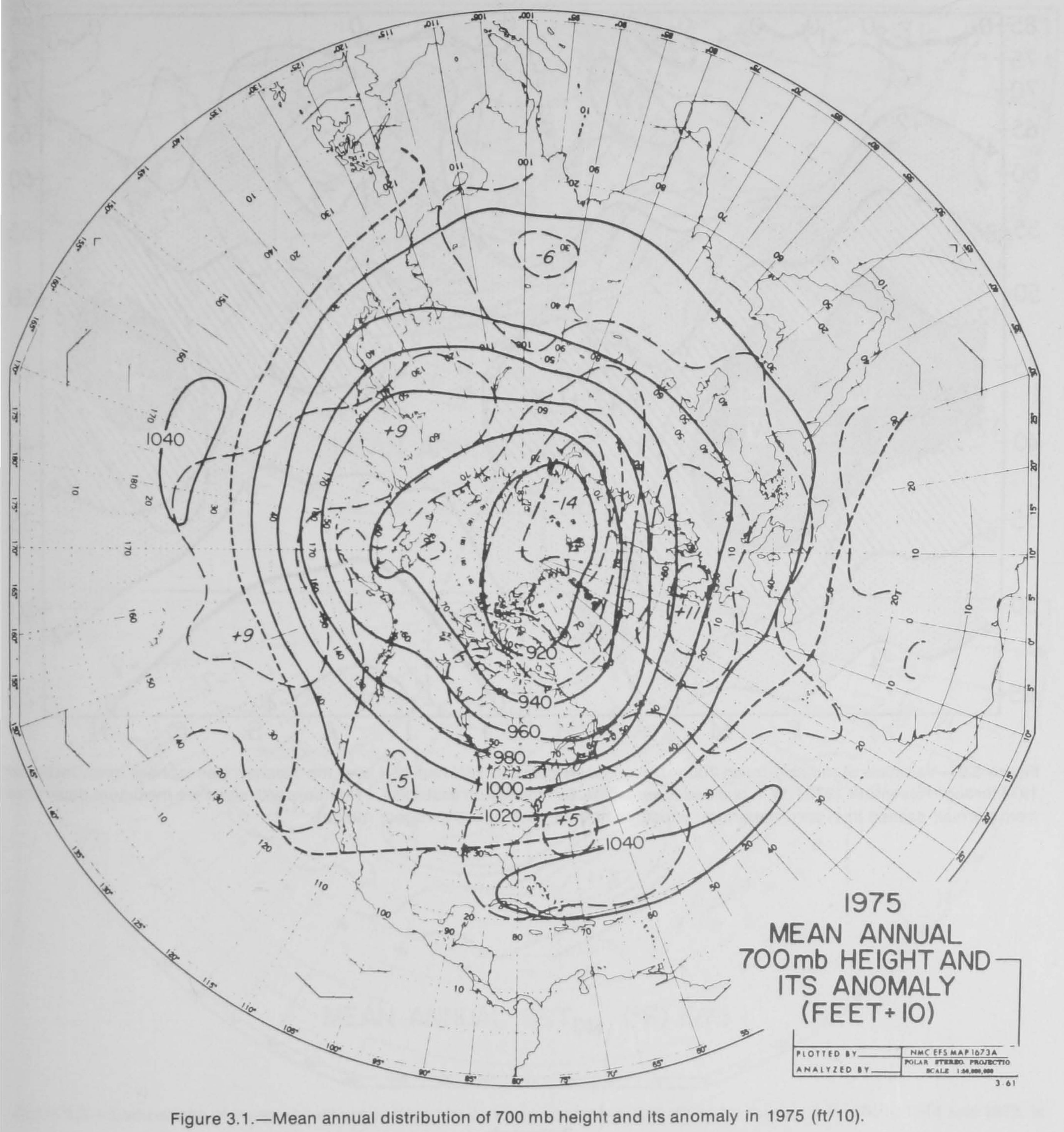

Figure 3.1.—Mean annual distribution of 700 mb height and its anomaly in 1975 (ft/10).

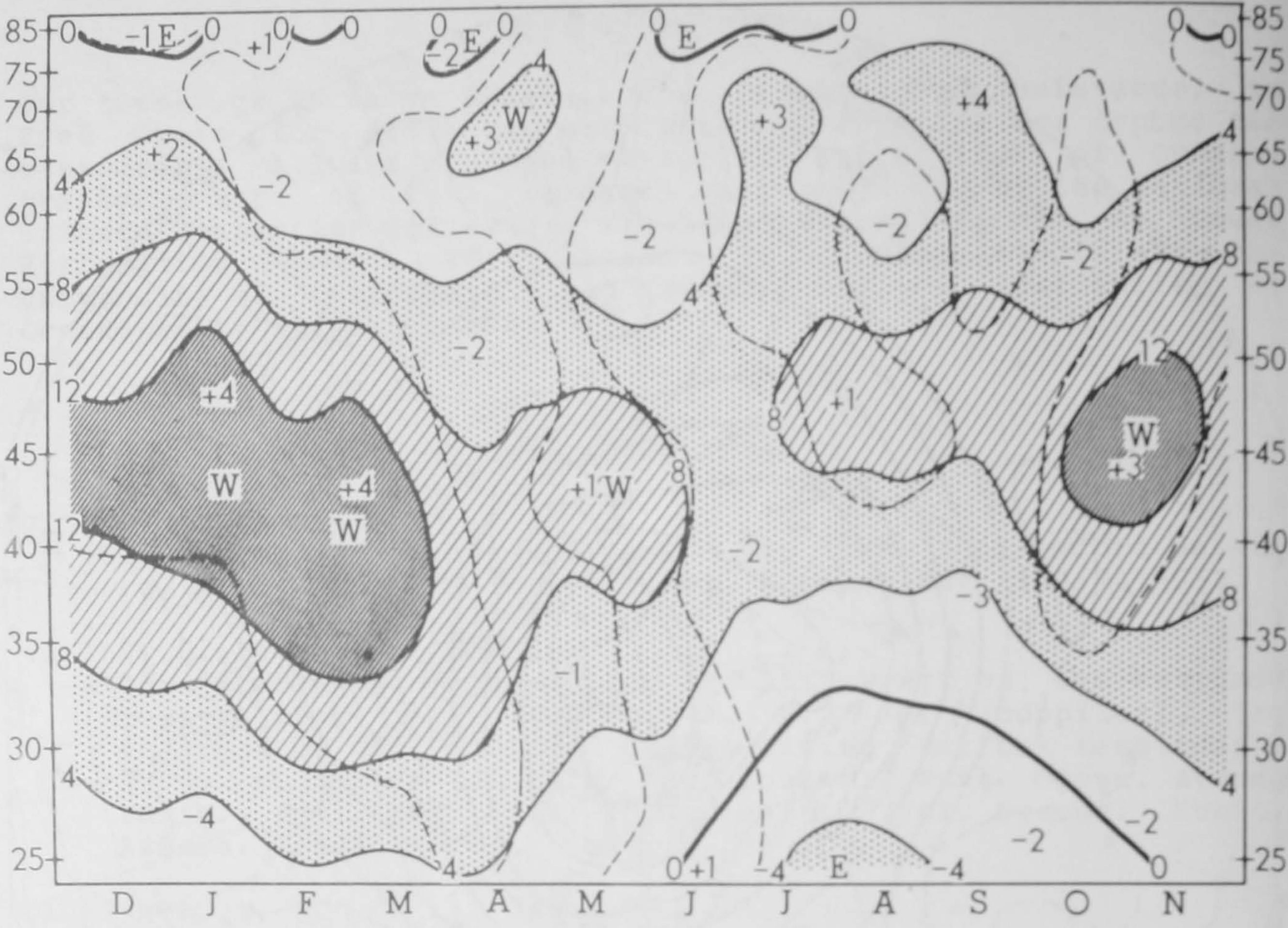

Figure 3.2.—Variation of monthly mean 700 mb wind (m/s) between 25N and 85N over the Western Hemisphere from December 1974 through November 1975. W = maximum westerlies, E = maximum easterlies. Numbers with signs are maximum departures from normal; dashed line, zero departure, indicates normal wind speed (Wagner 1976b).

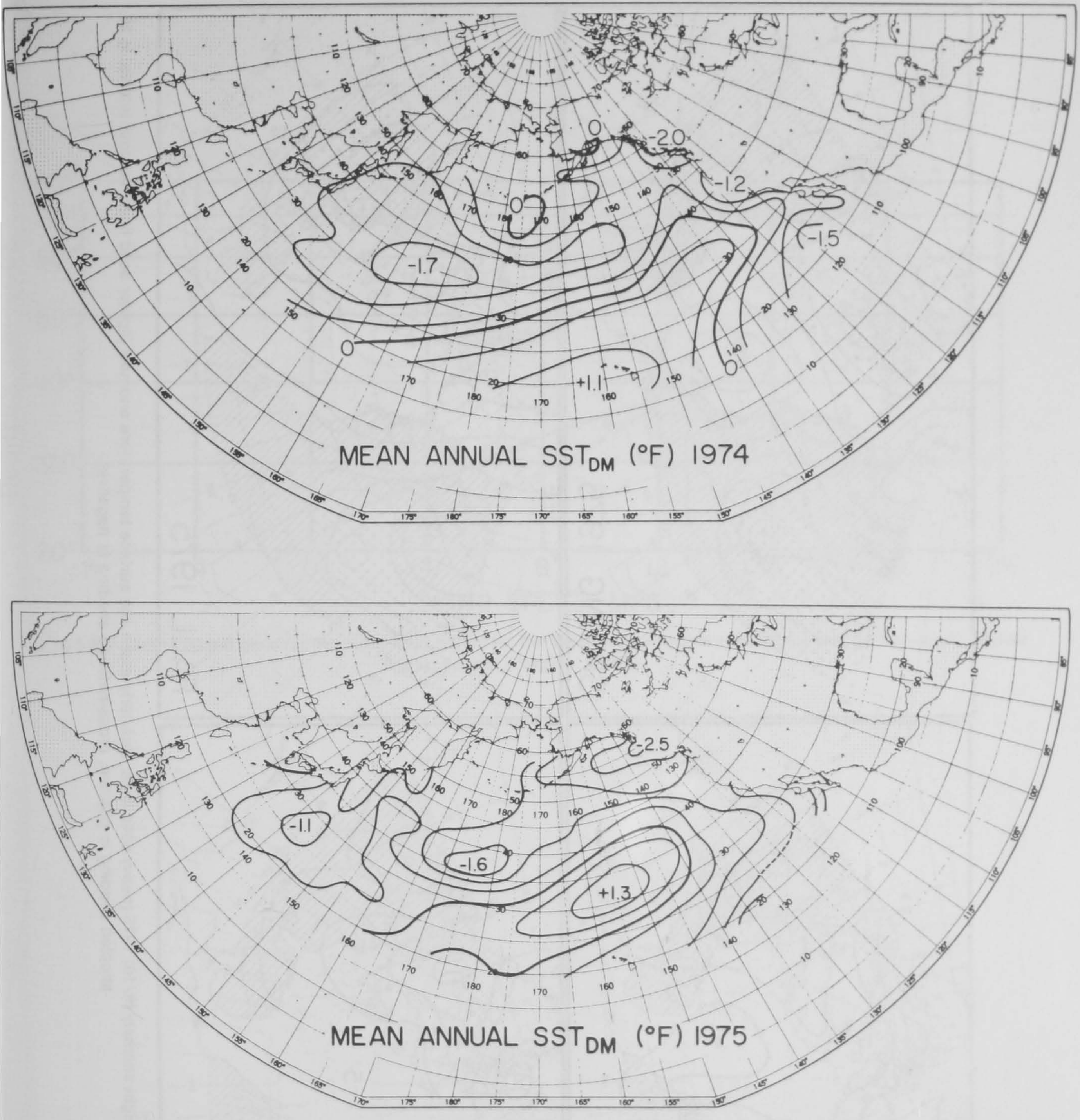

Figure 3.3.—Comparison of mean annual sea surface temperature anomaly distributions for the North Pacific in 1974 and 1975, in degrees F.

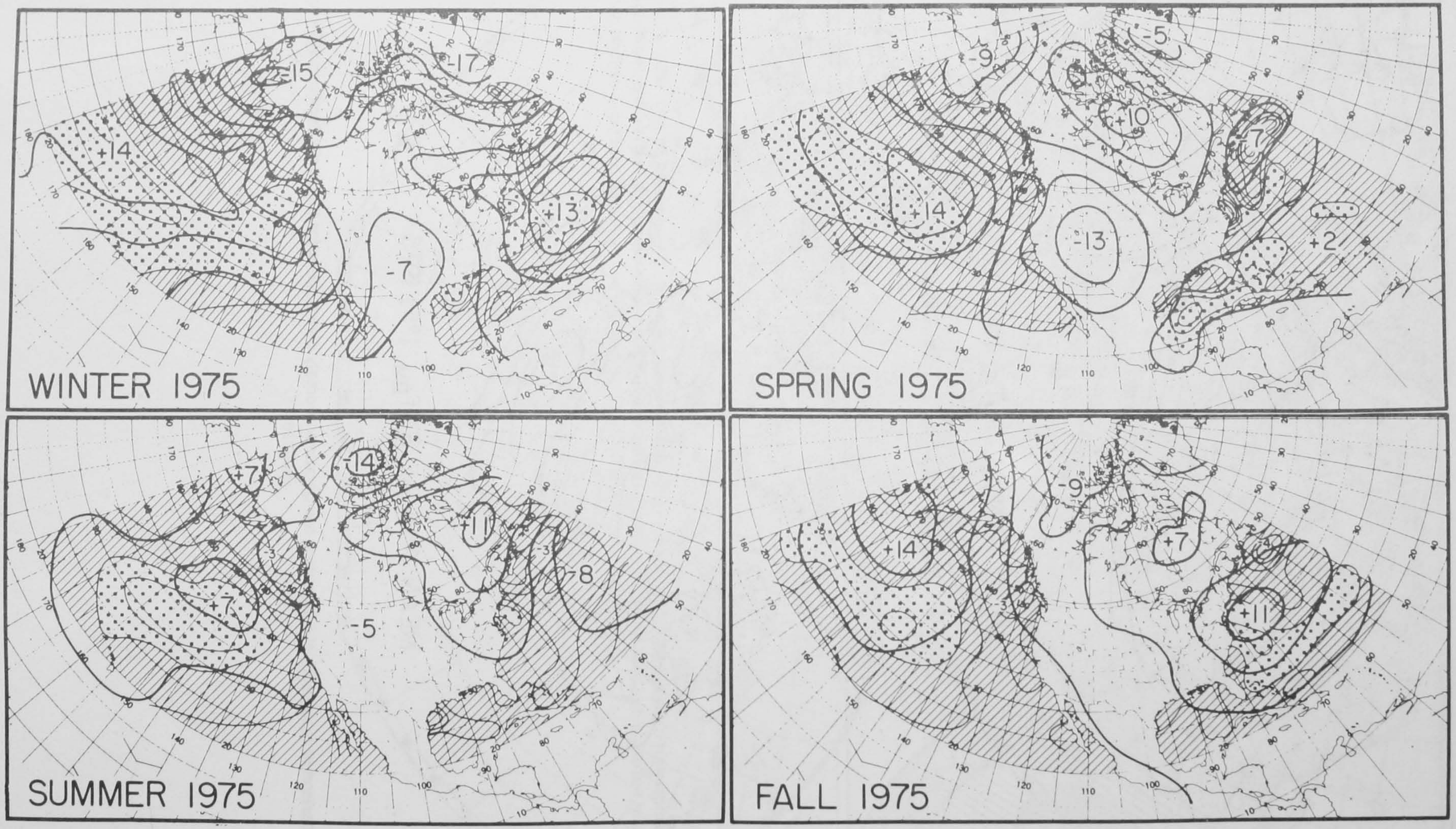

Figure 3.4.—Quarterly mean 700 mb height anomaly (ft/10) 1975 (heavy solid lines. Quarterly mean sea surface temperature anomaly (lighter solid lines; contour interval is 1F, stippled shading is positive, cross-hatched shading is negative).

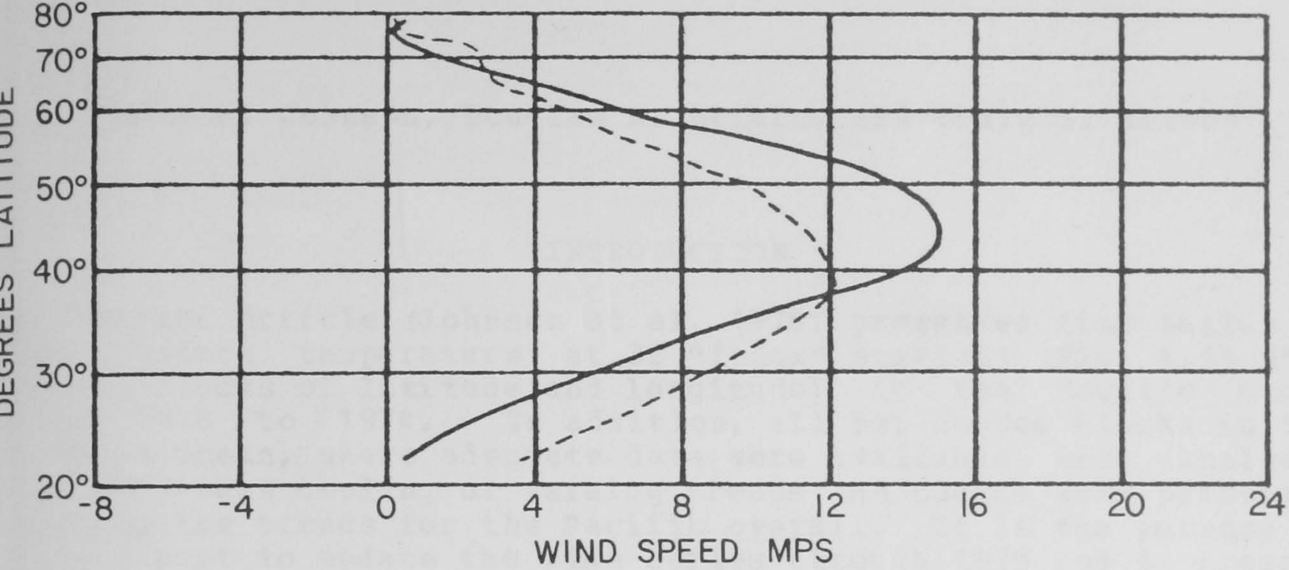

Figure 3.5.—Mean 700 mb geostrophic zonal wind profile for the Western Hemisphere for January. Solid line, 1975; dashed line, normal (Wagner 1975b).

CLIMATIC CHANGE IN THE PACIFIC OCEAN - AN UPDATE THROUGH 1975

James H. Johnson, Douglas R. McLain, and Craig S. Nelson[1]

INTRODUCTION

An earlier article (Johnson et al. 1976) presented time series of sea surface temperature at 33 "index" stations (Fig. 4.1) (5x5 degree blocks of latitude and longitude) in the Pacific Ocean from 1948 to 1974. In addition, all 5x5 degree blocks in the Pacific Ocean, where adequate data were available, were analyzed for long-term cooling or warming trends and charts were presented showing the trends for the Pacific overall. It is the purpose of this report to update the time series through 1975 and to present data showing the magnitude of anomalies in terms of normalized standard deviations (Z-statistic).

DATA SOURCE AND PROCESSING

Source of data and methods used in developing the time series and the charts of temperature trends over the Pacific were presented by Johnson et al. (1976). Data for this update were obtained from Fleet Numerical Weather Central.

Magnitudes of anomalies for the annual, winter, and summer time series were presented in terms of a standardized variable (Z-statistic). The change of variable was calculated by

$$Z = (x - X)/s$$

where X is the 20-yr (1948-67) mean, (x - X) is the anomaly from the mean, and s is the corresponding standard deviation.

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Time series sea surface temperature data and the Z-statistic are presented for the 33 index stations in Appendix 4.1.

DISCUSSION

Northeastern Pacific Ocean

At 21 index stations in the northeastern Pacific Ocean, 17 annual means remained colder in 1975 than the 20-yr (1948-67) average, 3 warmer, and 1 showed no deviation from the average (Table 4.1). This distribution was similar for the winter (January-March) and summer (July-September) means, though there appeared to be a slight tendency for cold anomalies to be more widespread in summer than in winter. Seventeen index stations in summer were colder than the 20-yr average in 1975, whereas 14 were colder in winter. Most significant deviations continued to be in the general area of the Aleutian Islands and Gulf of Alaska and in the coastal region off Mexico and southern California. In the former region, normalized standard deviations at index stations 195-3, 197-1, and 198-1 ranged from -2.2 to -2.6. This was a continuation of very cold conditions that have characterized this region since the start of 1971. The number of years with such high normalized standard deviation was unprecedented in the time series of the Pacific we have so far analyzed. This anomalous cold period in terms of normalized standard deviation and time it had prevailed was even more proncunced than the anomalously warm pericd of 1957-58 in the eastern Pacific Ocean. In Section 5 of this report, McLain presenteds data on sea surface coastal tide gage staticns which alsc shcw anomalous cooling in recent years. The consequences to fisheries of this climatic change were discussed in McLain and Favorite (1976).

The other region of the northeastern Pacific that showed a striking persistence in anomalcusly cold temperatures was the regicn frcm Southern California to Central America (index stations 46-1 and 83-2). Cold anomalies have persisted in general over the last decade. In fact, in 1975 the cold ancmalies appeared even more pronounced, the largest normalized standard deviation appearing in the summer at index station 46-1.

Northwestern Pacific Ocean

The northwestern Pacific Ocean did not show a pronounced trend to either cooler or warmer conditions. Cold and warm anomalies were about equally divided. An exception to this, however, was at index station 130-3 where cold temperatures have prevailed for several years. The normalized standard deviation reached -3.5 in 1975.

Southeastern Pacific Ocean

The "real-time" data available for the three index stations off South America were not sufficient to detect any major shifts in sea surface temperature trends. However, what were available supported the findings of the projections by Quinn (1976) that a weak El Nino would occur in early 1975. The data available at the coastal stations off South America, 308-1 and 343-2, indicated that warmer than normal temperatures prevailed early in the year. The weak El Nino was also verified by NORPAX surveys in the Eastern Tropical Pacific in early 1975 (Quinn, Section 9).

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Table 4.1.--Sea surface temperatures, sea surface temperature anomalies, and Z-statistics at 33 index stations in the Pacific Ocean, 1975.

Index Station	Annual Anomaly	Annual Z-stat	Jan, Feb, Mar Anomaly	Jan, Feb, Mar Z-stat	Jul, Aug, Sep Anomaly	Jul, Aug, Sep Z-Stat
Northeast Pacific						
9-1	+0.1	+0.2	0.0	+0.1	+0.6	+1.1
46-1	-0.6	-2.2	-0.3	-0.7	-1.0	-3.5
48-4	-1.0	-1.8	-1.9	-1.7	-1.2	-1.9
83-2	-1.1	-2.2	-1.1	-1.5	-1.2	-1.8
87-3	-0.2	-0.7	+0.3	+0.9	-0.5	-1.0
89-1	-0.4	-1.3	+0.2	+0.6	-0.6	-1.4
90-1	0.0	-0.1	+0.3	+0.7	-0.4	-1.2
120-2	-1.3	-1.9	-0.9	-1.1	-1.6	-1.8
121-3	-1.0	-1.5	-0.7	-1.1	-0.9	-1.1
122-1	-0.3	-0.7	+0.3	+0.6	-0.4	-0.7
123-3	-0.2	-0.4	-0.4	-0.8	0.0	0.0
124-1	+0.7	+1.8	+0.3	+0.5	+0.9	+1.5
125-2	+0.3	+0.6	+0.1	+0.1	+0.1	+0.2
157-4	-0.9	-1.8	-0.6	-0.8	-0.8	-1.4
159-3	-0.9	-1.8	-0.2	-0.4	-1.6	-1.9
160-2	-0.3	-0.4	-0.9	-0.8	-0.4	-0.3
160-3	-0.8	-1.8	-0.4	-0.7	-1.5	-1.6
162-1	-1.0	-1.4	-0.9	-1.2	-1.7	-1.3
195-3	-1.4	-2.2	-0.9	-1.0	-1.5	-1.3
197-1	-0.7	-2.6	-0.3	-0.9	-1.0	-2.0
198-1	-0.7	-2.3	-0.5	-1.3	-0.9	-2.3
Northwest Pacific						
58-2	+0.1	+0.1	+0.1	+0.2	-0.2	-0.4
60-4	+0.3	+0.1	+0.3	+0.6	+0.1	+0.3
91-3	+0.5	+1.4	+0.6	+1.1	0.0	-0.1
95-3	+0.3	+0.8	+0.4	+0.9	-0.1	-0.2
127-3	-0.7	-1.0	-0.4	-0.5	-1.4	-1.8
129-1	-0.7	0.0	0.0	-0.5	+0.5	+1.0
130-3	-2.8	-3.5	-3.9	-3.2	-1.3	-1.4
163-3	-0.2	-0.4	-0.2	-0.3	-0.4	-0.5
165-2	+0.1	+0.1	0.0	-0.1	+0.5	+0.4
Southeast Pacific						
308-1	-	-	+0.2	+0.3	+0.2	+0.2
309-1	-0.5	-0.7	-0.7	-1.4	-0.2	-0.2
343-2	-	-	+1.5	+1.4	-	-

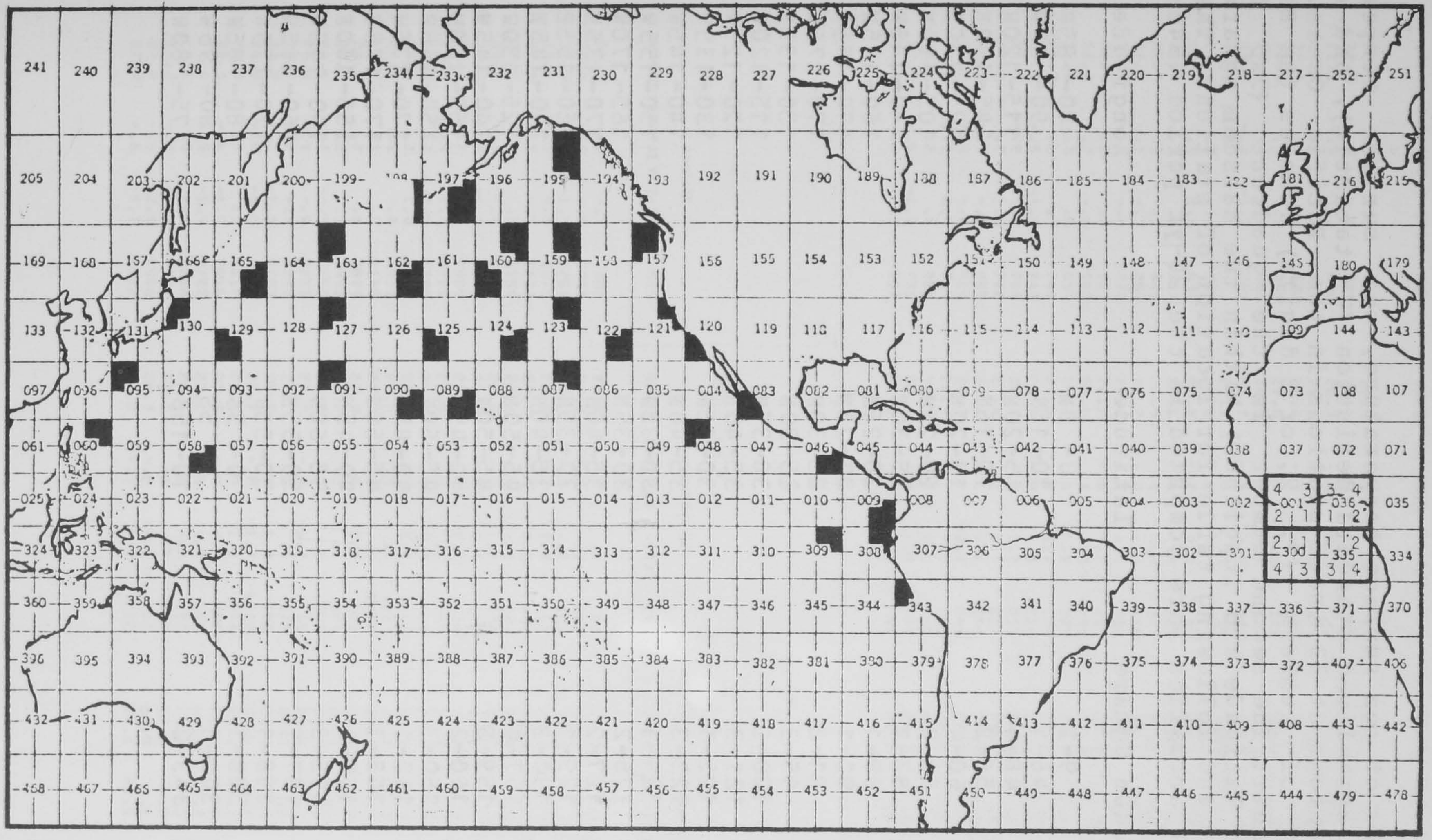

Figure 4.1.—Index stations, Pacific Ocean. Numbering of quadrants within Marsden squares for the four quarters of the globe is shown in the inset. Note that numbering sequences change at the intersection of the equator and the prime meridian.

APPENDIX 4.1

Time series of sea surface temperature, sea surface temperature anomaly, normalized standard deviation (Z-statistic), and number of observations at 33 index stations in the Pacific Ocean. The first set of numbers (1, 2, or 3 digits) denotes the Marsden square number. The second number is the quadrant (5x5 degree blocks of latitude and longitude) within the Marsden square. See Figure 4.1 and following table for location of stations. The mean upon which anomalies were computed is the 20-yr period 1948-67.

Marsden Square	Latitude	Longitude
9-1	0- 5N	80- 85W
46-1	10-15N	90- 95W
48-4	15-20N	115-120W
58-2	10-15N	145-150E
60-4	15-20N	125-130E
83-2	20-25N	105-110W
87-3	25-30N	140-145W
89-1	20-25N	160-165W
90-1	20-25N	170-175W
91-3	25-30N	170-175W
95-3	25-30N	130-135E
120-2	30-35N	115-120W
121-3	35-40N	120-125W
122-1	30-35N	130-135W
123-3	35-40N	140-145W
124-1	30-35N	150-155W
125-2	30-35N	165-170W
127-2	35-40N	170-175E
129-1	30-35N	150-155E
130-3	35-40N	140-145E
157-4	45-50N	125-130W
159-3	45-50N	140-145W
160-2	40-45N	155-160W
160-3	45-50N	150-155W
162-1	40-45N	170-175W
163-3	45-50N	170-175E
165-2	40-45N	155-160E
195-3	55-60N	140-145W
197-1	50-55N	160-165W
198-1	50-55N	170-175W
308-1	0- 5S	80- 85W
309-1	0- 5S	90- 95W
343-2	10-15S	75- 80W

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YEAR	ANNUAL				JANFEBMAR				JULAUGSEP			
	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS
1948	26.6	.1	.3	317	26.9	.2	.4	61	26.5	.3	.5	88
1949	26.3	-.2	-.4	389	26.4	-.3	-.7	95	26.1	-.1	-.2	111
1950	26.1	-.5	-1.0	454	26.0	-.8	-1.8	97	26.0	-.2	-.3	125
1951	27.0	.5	1.1	413	26.3	-.5	-1.1	90	27.2	1.0	1.9	108
1952	26.5	.0	.0	477	26.6	-.1	-.2	123	26.0	-.2	-.3	138
1953	27.0	.5	1.2	350	27.6	.8	1.9	111	26.4	.2	.4	72
1954	25.8	-.7	-1.6	402	26.5	-.3	-.6	102	25.1	-1.1	-2.1	69
1955	25.7	-.8	-1.7	391	26.3	-.4	-.9	103	25.5	-.8	-1.4	69
1956	INSUF DATA				27.1	.3	.8	56	INSUF DATA			
1957	27.2	.7	1.6	352	26.4	-.4	-.9	73	27.3	1.1	2.1	76
1958	27.3	.8	1.8	432	27.7	1.0	2.2	97	26.8	.6	1.1	102
1959	26.8	.3	.6	784	27.1	.4	.8	221	26.3	.1	.2	182
1960	26.6	.0	.1	880	26.9	.1	.3	203	26.2	-.0	-.1	221
1961	26.4	-.1	-.3	1267	26.7	-.0	-.1	315	25.8	-.4	-.7	295
1962	26.2	-.4	-.8	1225	26.4	-.4	-.9	331	25.9	-.3	-.6	280
1963	26.5	.0	.0	919	26.7	-.0	-.0	211	26.3	.1	.2	203
1964	26.3	-.3	-.6	963	26.9	.1	.3	281	25.8	-.4	-.8	226
1965	26.8	.3	.6	854	26.8	.0	.0	229	26.3	.0	.1	186
1966	26.7	.1	.3	748	27.2	.5	1.0	164	26.3	.1	.2	190
1967	26.1	-.5	-1.0	747	26.5	-.2	-.5	229	25.8	-.4	-.7	152
1968	26.3	-.2	-.5	765	26.2	-.6	-1.3	219	26.4	.2	.3	175
1969	27.2	.7	1.6	772	27.4	.6	1.4	217	26.7	.5	1.0	159
1970	26.2	-.3	-.7	899	26.7	-.0	-.1	266	25.5	-.7	-1.3	199
1971	26.2	-.4	-.8	528	26.3	-.5	-1.1	244	25.9	-.3	-.5	88
1972	27.6	1.1	2.4	243	26.9	.2	.5	65	28.2	2.0	3.7	67
1973	26.7	.2	.4	224	27.5	.8	1.8	59	26.5	.3	.5	47
1974	25.9	-.6	-1.4	230	26.5	-.2	-.5	77	26.7	.5	.9	34
1975	26.6	.1	.2	252	26.8	.0	.1	48	26.8	.6	1.1	71

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YEAR	ANNUAL				JANFEBMAR				JULAUGSEP			
	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS
1948	28.5	-.0	-.1	396	27.7	.2	.3	66	29.0	-.1	-.2	87
1949	28.4	-.1	-.5	1311	27.5	-.0	-.0	306	29.2	.1	.3	285
1950	28.0	-.5	-1.7	1760	27.2	-.3	-.7	401	28.8	-.3	-1.2	522
1951	28.4	-.1	-.5	1875	26.7	-.8	-1.7	442	29.2	.1	.5	470
1952	28.5	-.0	-.1	2421	27.9	.4	1.0	487	28.9	-.2	-.8	687
1953	28.6	.1	.3	2554	27.1	-.4	-.8	687	29.6	.5	1.8	656
1954	28.4	-.1	-.4	2462	27.6	.1	.2	539	29.0	-.1	-.2	649
1955	28.2	-.3	-1.1	2583	27.0	-.5	-1.1	588	28.6	-.5	-1.7	705
1956	28.3	-.2	-.8	2825	27.1	-.4	-1.0	624	28.8	-.3	-1.2	759
1957	29.0	.5	1.8	3255	27.8	.3	.6	769	29.6	.5	2.0	834
1958	29.2	.7	2.4	3285	28.3	.8	1.7	710	29.4	.3	1.1	865
1959	28.8	.3	1.0	3691	28.1	.5	1.2	846	29.4	.3	1.0	974
1960	28.6	.1	.4	4251	27.6	.1	.3	1015	29.1	.0	.1	1072
1961	28.6	.1	.5	4146	27.7	.2	.5	1027	29.1	.0	.1	1092
1962	28.7	.2	.8	3679	27.9	.4	1.0	960	29.3	.2	.7	910
1963	28.7	.2	.7	3493	27.8	.3	.6	885	29.3	.2	.7	810
1964	28.4	-.1	-.5	3750	27.7	.2	.5	807	28.9	-.2	-.8	1008
1965	28.4	-.1	-.4	3802	27.0	-.5	-1.2	799	28.9	-.1	-.5	1007
1966	28.3	-.2	-.7	3897	27.7	.2	.4	971	28.9	-.2	-.7	1046
1967	28.2	-.3	-1.1	4203	26.7	-.8	-1.8	880	28.8	-.2	-.9	1235
1968	28.0	-.5	-1.9	4073	26.7	-.8	-1.7	1013	28.5	-.6	-2.2	1013
1969	28.8	.3	.9	4118	28.0	.5	1.1	851	29.0	-.1	-.3	1129
1970	28.1	-.4	-1.5	3846	27.2	-.3	-.7	769	28.6	-.5	-1.9	1049
1971	28.0	-.5	-1.9	2762	27.1	-.4	-.9	870	28.4	-.7	-2.7	632
1972	28.8	.3	1.1	2066	27.4	-.1	-.1	455	29.3	.2	.7	554
1973	28.2	-.3	-1.2	1532	27.7	.1	.3	387	28.5	-.6	-2.1	385
1974	28.0	-.5	-2.0	1588	26.9	-.6	-1.4	427	28.5	-.6	-2.2	413
1975	27.9	-.6	-2.2	1201	27.2	-.3	-.7	232	28.1	-1.0	-3.5	328

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YEAR	ANNUAL VALUE	ANOMALY	Z-STAT	OBS	JANFEBMAR VALUE	ANOMALY	Z-STAT	OBS	JULAUGSEP VALUE	ANOMALY	Z-STAT	OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	INSUF DATA				24.1	-.2	-.4	58	26.2	-.8	-1.3	48
1950	25.1	-.4	-.7	201	24.4	.1	.2	37	25.9	-1.2	-1.8	41
1951	25.4	-.2	-.3	247	23.7	-.7	-1.2	59	27.0	-.0	-.0	69
1952	25.6	.1	.2	334	24.4	.1	.2	64	27.2	.1	.2	90
1953	25.4	-.1	-.3	384	24.0	-.3	-.6	122	27.4	.4	.6	103
1954	26.0	.5	.9	308	24.6	.2	.4	57	27.5	.4	.7	88
1955	24.8	-.7	-1.4	292	23.8	-.6	-1.0	59	26.7	-.3	-.5	77
1956	24.7	-.8	-1.6	339	23.2	-1.1	-1.9	45	26.5	-.5	-.8	119
1957	26.2	.6	1.2	523	25.3	1.0	1.7	107	27.8	.8	1.2	136
1958	26.3	.8	1.5	531	25.3	1.0	1.7	171	27.6	.6	.9	115
1959	26.8	1.3	2.5	537	25.5	1.1	2.0	111	28.4	1.4	2.2	204
1960	25.4	-.1	-.1	530	24.1	-.2	-.3	99	27.0	-.0	-.1	153
1961	25.3	-.3	-.5	566	24.1	-.3	-.5	130	26.7	-.4	-.6	122
1962	25.6	.1	.2	641	24.2	-.2	-.3	179	27.8	.7	1.1	133
1963	25.4	-.1	-.2	581	24.2	-.1	-.2	153	26.5	-.5	-.8	111
1964	25.3	-.2	-.4	535	24.7	.4	.6	130	26.9	-.1	-.2	106
1965	25.3	-.2	-.4	689	24.2	-.1	-.2	151	26.3	-.8	-1.2	166
1966	25.6	.1	.2	937	24.3	.0	.0	228	27.1	.1	.1	194
1967	25.6	.1	.2	1422	24.2	-.1	-.1	401	27.3	.2	.4	275
1968	25.6	.1	.2	1522	24.4	.1	.2	497	26.9	-.1	-.2	278
1969	25.2	-.3	-.6	1432	24.7	.3	.6	301	26.3	-.8	-1.2	396
1970	25.4	-.1	-.3	1139	23.9	-.4	-.8	356	27.2	.2	.3	281
1971	24.8	-.8	-1.5	769	23.7	-.6	-1.1	253	26.3	-.7	-1.2	175
1972	25.2	-.3	-.7	656	23.7	-.6	-1.1	239	26.5	-.5	-.8	137
1973	25.0	-.5	-1.0	609	24.3	-.0	-.0	189	26.3	-.7	-1.2	106
1974	25.0	-.5	-1.0	520	23.5	-.8	-1.4	212	26.8	-.2	-.3	103
1975	24.6	-1.0	-1.8	318	23.4	-.9	-1.7	109	25.8	-1.2	-1.9	60

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YEAR	ANNUAL VALUE	ANOMALY	Z-STAT	OBS	JANFEBMAR VALUE	ANOMALY	Z-STAT	OBS	JULAUGSEP VALUE	ANOMALY	Z-STAT	OBS
1948	28.2	-.2	-.6	169	27.5	-.1	-.1	42	28.9	-.3	-.7	40
1949	28.4	-.0	-.1	265	27.2	-.4	-.8	47	29.3	.1	.3	117
1950	INSUF DATA				INSUF DATA				28.7	-.5	-1.1	50
1951	28.7	.3	.8	208	27.7	.1	.3	53	29.5	.4	.8	60
1952	28.7	.2	.6	226	27.7	.2	.3	53	29.4	.3	.6	59
1953	28.7	.3	.8	330	27.7	.2	.4	59	29.6	.4	1.0	95
1954	28.3	-.1	-.2	298	27.4	-.1	-.3	93	29.3	.1	.2	53
1955	28.2	-.3	-.7	406	27.8	.3	.6	93	28.5	-.7	-1.7	99
1956	28.0	-.5	-1.2	524	27.2	-.3	-.7	141	28.8	-.4	-.9	132
1957	28.3	-.2	-.4	839	27.4	-.1	-.2	132	29.1	-.1	-.2	234
1958	28.0	-.5	-1.2	735	26.9	-.5	-1.3	202	28.8	-.3	-.8	164
1959	28.0	-.4	-1.0	1226	27.0	-.5	-1.1	272	28.8	-.3	-.8	316
1960	28.4	-.0	-.1	1445	27.3	-.2	-.4	288	29.1	-.1	-.2	372
1961	29.0	.6	1.6	859	28.0	.5	1.0	357	30.1	.9	2.1	77
1962	29.2	.8	2.1	360	28.6	1.0	2.2	81	29.8	.6	1.3	102
1963	28.9	.5	1.4	404	28.5	1.0	2.1	101	29.6	.4	.9	99
1964	28.3	-.1	-.3	1835	27.3	-.2	-.5	397	28.9	-.3	-.6	488
1965	27.9	-.5	-1.4	1722	27.2	-.3	-.6	484	28.5	-.7	-1.5	478
1966	28.4	-.0	-.1	1836	27.0	-.6	-1.2	478	29.4	.2	.5	394
1967	28.7	.3	.7	634	27.9	.4	.8	138	29.5	.3	.8	153
1968	28.6	.2	.5	803	27.5	.0	.0	223	29.2	.0	.1	195
1969	28.8	.4	1.0	678	27.8	.3	.6	203	29.6	.4	.9	168
1970	28.7	.3	.8	432	27.9	.3	.7	151	29.0	-.1	-.3	72
1971	28.8	.4	.9	638	28.2	.7	1.5	113	29.3	.1	.3	107
1972	28.1	-.3	-.9	1370	27.3	-.2	-.5	312	28.7	-.5	-1.1	338
1973	28.5	.0	.1	1437	27.4	-.1	-.2	362	29.3	.1	.3	362
1974	28.6	.1	.4	1346	28.0	.5	1.1	308	29.1	-.1	-.3	357
1975	28.5	.1	.1	1291	27.6	.1	.2	377	29.0	-.2	-.4	272

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				29.0	.1	.3	28
1949	27.8	.2	.7	257	25.6	-.2	-.4	59	29.7	.7	1.8	68
1950	27.6	-.0	-.1	175	26.3	.4	.7	50	29.1	.1	.4	29
1951	27.7	.0	.1	233	26.1	.2	.4	88	28.4	-.5	-1.3	44
1952	27.9	.2	.8	230	26.3	.5	.8	57	29.0	.1	.2	52
1953	27.8	.2	.5	731	26.7	.8	1.4	53	28.7	-.3	-.6	211
1954	27.7	.1	.2	939	25.9	.1	.1	242	29.3	.4	1.0	180
1955	27.1	-.5	-1.7	1362	25.0	-.8	-1.4	302	28.3	-.6	-1.5	269
1956	26.9	-.7	-2.3	2205	24.9	-.9	-1.5	412	28.1	-.8	-2.1	631
1957	27.3	-.4	-1.1	2872	25.4	-.5	-.8	723	28.6	-.3	-.7	713
1958	27.5	-.1	-.3	4123	26.0	.2	.3	757	28.7	-.2	-.5	1100
1959	27.5	-.1	-.3	5491	25.6	-.3	-.5	1353	29.0	.0	.1	1271
1960	27.7	.1	.3	6504	26.3	.5	.8	1782	28.8	-.1	-.4	1364
1961	27.8	.2	.7	2390	25.4	-.5	-.8	1214	29.4	.5	1.1	30
1962	28.1	.5	1.6	157	26.2	.3	.6	42	29.4	.4	1.1	41
1963	27.5	-.1	-.4	159	24.7	-1.2	-1.9	32	29.2	.3	.6	39
1964	27.7	.1	.3	6374	26.0	.2	.3	1677	28.9	-.1	-.1	1576
1965	27.5	-.2	-.5	5975	25.7	-.1	-.2	1396	28.6	-.3	-.7	1539
1966	27.8	.2	.5	6876	26.3	.5	.8	1734	29.0	.1	.3	1706
1967	28.2	.5	1.7	561	26.9	1.0	1.8	132	29.4	.5	1.1	105
1968	27.8	.2	.5	593	26.2	.3	.6	98	29.3	.4	.9	184
1969	28.2	.6	2.0	543	26.3	.4	.7	149	29.7	.8	1.9	143
1970	28.5	.9	2.8	308	26.6	.7	1.2	86	29.5	.6	1.4	105
1971	28.0	.4	1.1	545	26.0	.1	.2	45	29.5	.6	1.5	86
1972	27.9	.2	.6	1053	26.1	.2	.4	196	28.8	-.1	-.3	365
1973	28.2	.6	1.8	894	26.5	.6	1.1	258	29.3	.4	.9	223
1974	27.7	.1	.2	929	26.1	.2	.4	226	28.9	-.0	-.0	266
1975	27.9	.3	1.0	967	26.2	.3	.6	188	29.0	.1	.3	230

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	25.7	-.1	-.3	271	22.6	-.6	-.9	47	29.2	.5	.9	68
1949	25.5	-.4	-.7	937	23.0	-.1	-.2	221	28.4	-.3	-.4	220
1950	25.8	-.1	-.2	1304	22.7	-.5	-.7	297	28.1	-.6	-.9	375
1951	25.9	-.0	-.0	1372	23.2	-.0	-.0	323	28.5	-.2	-.3	324
1952	25.9	.1	.1	1802	24.0	.8	1.2	383	28.3	-.3	-.5	520
1953	26.0	.1	.2	1770	23.4	.2	.3	478	29.1	.5	.7	427
1954	25.9	.0	.0	1830	23.6	.4	.6	405	28.7	.0	.1	480
1955	24.7	-1.1	-2.2	1955	21.8	-1.3	-1.9	459	27.4	-1.2	-1.9	516
1956	26.1	.2	.5	2473	22.5	-.6	-.9	519	29.4	.8	1.2	691
1957	26.3	.5	.9	2585	23.7	.5	.8	585	29.6	1.0	1.5	693
1958	26.9	1.1	2.2	2853	24.8	1.6	2.4	589	29.3	.7	1.1	746
1959	26.7	.9	1.7	3336	24.2	1.0	1.5	800	29.4	.7	1.2	833
1960	25.6	-.3	-.5	3536	23.0	-.1	-.2	878	27.8	-.8	-1.3	853
1961	26.0	.1	.3	3254	23.4	.2	.3	847	29.0	.3	.5	862
1962	25.9	-.0	-.0	3363	22.9	-.3	-.4	887	28.8	.1	.2	796
1963	26.4	.5	1.1	2785	23.2	.1	.1	693	29.4	.8	1.2	636
1964	25.1	-.8	-1.5	3093	22.8	-.4	-.6	740	27.9	-.8	-1.2	750
1965	25.6	-.3	-.6	2837	22.3	-.9	-1.3	643	28.6	-.0	-.0	702
1966	25.8	-.1	-.2	2598	23.6	.4	.6	706	28.1	-.5	-.8	632
1967	25.6	-.3	-.6	2598	22.7	-.5	-.7	599	28.0	-.7	-1.0	705
1968	25.6	-.3	-.6	2750	23.4	.2	.3	698	27.9	-.7	-1.1	642
1969	25.5	-.4	-.8	2771	23.5	.3	.5	639	28.0	-.7	-1.1	766
1970	25.3	-.5	-1.0	2585	23.0	-.2	-.3	600	28.0	-.7	-1.1	682
1971	25.0	-.8	-1.7	1917	22.0	-1.1	-1.6	564	27.7	-1.0	-1.5	429
1972	26.1	.3	.5	1693	22.9	-.3	-.4	360	28.7	.0	.0	485
1973	25.1	-.8	-1.6	1542	24.0	.8	1.2	344	27.1	-1.6	-2.4	390
1974	25.2	-.7	-1.4	1657	21.7	-1.5	-2.2	427	27.9	-.8	-1.2	470
1975	24.8	-1.1	-2.2	1193	22.1	-1.1	-1.5	217	27.5	-1.2	-1.8	340

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				23.4	.3	.7	74
1949	21.1	-.5	-1.4	784	19.4	-.7	-1.8	208	22.7	-.4	-.9	143
1950	21.9	.3	.7	832	20.1	-.0	-.0	153	23.5	.4	.7	219
1951	21.6	-.0	-.1	1131	20.2	.1	.3	305	22.8	-.3	-.6	285
1952	20.8	-.8	-2.4	1132	19.8	-.3	-.8	294	21.8	-1.3	-2.6	294
1953	21.5	-.1	-.4	1526	19.5	-.6	-1.6	398	23.0	-.1	-.2	380
1954	21.6	.0	.0	1344	19.9	-.2	-.4	382	23.0	-.1	-.3	335
1955	21.0	-.6	-1.7	1403	19.7	-.4	-1.1	338	22.2	-.9	-1.8	319
1956	21.5	-.2	-.5	1558	20.0	-.1	-.2	394	22.8	-.2	-.5	395
1957	21.9	.3	.8	2033	20.0	-.1	-.3	469	23.5	.4	.8	509
1958	21.6	-.1	-.2	1899	20.0	-.1	-.2	508	23.1	-.0	-.0	475
1959	22.0	.4	1.2	1877	20.8	.7	1.9	443	23.4	.3	.5	492
1960	21.6	-.0	-.0	2183	20.2	.2	.4	538	23.0	-.1	-.3	570
1961	21.9	.2	.7	2231	20.2	.1	.4	607	23.5	.4	.9	562
1962	21.8	.2	.6	2136	20.1	.0	.1	517	23.3	.2	.4	514
1963	21.9	.3	.8	2037	20.5	.4	1.1	516	23.3	.2	.3	486
1964	21.6	-.1	-.1	2116	20.6	.5	1.4	537	23.2	.1	.2	511
1965	22.0	.4	1.1	2495	20.4	.4	1.0	630	23.7	.6	1.2	579
1966	21.4	-.2	-.6	2802	19.6	-.5	-1.3	777	22.9	-.2	-.4	638
1967	22.0	.4	1.2	2658	20.4	.3	.8	743	23.9	.9	1.7	673
1968	22.9	1.3	3.5	2878	20.7	.6	1.6	886	25.1	2.0	4.0	606
1969	21.9	.2	.7	3008	20.5	.4	1.1	771	23.1	.0	.1	772
1970	21.7	.1	.2	3147	20.0	-.1	-.2	963	23.5	.4	.7	725
1971	21.8	.2	.5	2286	20.0	-.1	-.1	628	23.9	.8	1.6	471
1972	21.4	-.2	-.7	1896	19.5	-.5	-1.4	526	23.2	.1	.2	433
1973	21.4	-.2	-.5	1507	19.6	-.5	-1.3	525	23.3	.2	.4	271
1974	21.9	.3	.9	1277	20.3	.2	.7	361	23.7	.6	1.2	286
1975	21.4	-.2	-.7	1024	20.4	.3	.9	296	22.6	-.5	-1.0	221

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				23.7	-.2	-.6	202	26.8	.2	.6	121
1949	24.8	-.5	-1.9	1089	23.3	-.6	-1.9	278	26.0	-.6	-1.6	380
1950	25.1	-.2	-.7	441	23.5	-.4	-1.2	100	26.2	-.4	-1.1	107
1951	25.6	.3	1.1	477	23.7	-.1	-.4	115	27.0	.4	1.0	98
1952	25.0	-.3	-1.1	667	23.9	-.0	-.1	170	26.3	-.3	-.8	174
1953	25.4	.1	.2	765	24.1	.2	.6	229	26.4	-.2	-.5	182
1954	25.3	-.1	-.2	859	23.8	-.0	-.1	246	26.6	-.0	-.1	184
1955	24.7	-.6	-2.1	901	23.5	-.3	-1.1	215	25.6	-1.0	-2.5	247
1956	25.3	-.0	-.1	1010	24.3	.4	1.4	240	26.6	-.0	-.0	269
1957	25.4	.1	.3	1214	23.9	-.0	-.1	304	26.8	.2	.4	329
1958	25.0	-.3	-1.0	1286	23.5	-.4	-1.3	312	26.3	-.3	-.7	335
1959	25.6	.3	.9	1409	23.7	-.1	-.5	295	27.1	.5	1.2	369
1960	25.4	.1	.5	1273	23.8	-.0	-.1	324	26.8	.2	.4	320
1961	25.6	.3	1.1	1599	24.5	.7	2.1	433	26.8	.2	.6	429
1962	25.4	.0	.2	1730	24.1	.2	.7	409	26.7	.1	.1	421
1963	25.3	.0	.0	1686	24.0	.1	.4	396	26.4	-.2	-.5	421
1964	25.3	-.0	-.0	1849	24.2	.4	1.1	484	26.6	.0	.1	438
1965	25.3	.0	.1	2137	23.8	-.1	-.4	575	26.9	.3	.7	455
1966	25.6	.2	.8	2404	24.0	.1	.4	684	27.0	.4	.9	578
1967	25.8	.5	1.8	2708	24.2	.3	1.1	764	27.3	.7	1.7	679
1968	26.1	.8	2.6	3085	24.1	.2	.7	908	27.6	1.0	2.4	662
1969	25.6	.3	.9	2501	24.2	.4	1.2	727	26.9	.3	.8	626
1970	25.3	.0	.1	2472	24.0	.1	.3	833	26.4	-.2	-.4	615
1971	25.4	.1	.2	1715	23.8	-.1	-.3	523	26.8	.2	.5	414
1972	25.2	-.1	-.3	1641	23.6	-.3	-.9	389	26.7	.1	.2	478
1973	25.0	-.3	-1.1	1182	23.4	-.4	-1.4	364	26.3	-.3	-.7	310
1974	25.7	.4	1.3	1065	24.4	.6	1.8	367	26.8	.2	.4	270
1975	24.9	-.4	-1.3	745	24.1	.2	.6	214	26.0	-.6	-1.4	165

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				23.3	-.6	-1.3	149	27.9	.5	1.4	66
1949	25.2	-.5	-1.5	613	23.6	-.4	-.8	172	26.8	-.6	-1.7	226
1950	25.6	-.1	-.2	299	23.6	-.4	-.9	89	27.4	.0	.0	53
1951	25.7	-.0	-.0	314	23.8	-.1	-.3	93	27.4	.0	.1	73
1952	25.8	.1	.4	449	24.2	.3	.6	125	27.4	.1	.2	100
1953	25.9	.3	.9	597	24.1	.1	.3	188	27.6	.2	.5	127
1954	25.5	-.2	-.6	591	23.7	-.2	-.5	175	27.3	-.1	-.4	133
1955	25.2	-.4	-1.5	559	23.8	-.1	-.3	136	26.9	-.5	-1.4	83
1956	25.5	-.2	-.8	656	24.0	.1	.2	155	27.1	-.3	-.9	163
1957	25.7	.1	.2	796	23.9	-.0	-.0	214	27.5	.1	.4	216
1958	25.2	-.5	-1.6	845	23.6	-.4	-.8	253	26.8	-.6	-1.8	183
1959	25.7	-.0	-.0	772	23.1	-.9	-1.9	194	27.7	.3	1.0	177
1960	26.0	.4	1.2	823	24.2	.3	.6	222	27.7	.3	.9	145
1961	26.0	.3	1.0	990	24.7	.7	1.6	323	27.6	.2	.5	190
1962	26.1	.4	1.3	857	24.7	.7	1.6	275	27.8	.4	1.2	152
1963	26.0	.3	1.1	994	24.4	.5	1.1	280	27.4	-.0	-.1	191
1964	25.8	.1	.3	1234	24.7	.8	1.7	363	27.0	-.4	-1.0	268
1965	25.3	-.4	-1.2	1492	23.6	-.4	-.9	400	27.1	-.3	-.8	344
1966	25.7	.0	.2	1830	23.7	-.3	-.6	537	27.5	.1	.4	376
1967	26.1	.4	1.4	1642	24.2	.3	.6	513	27.9	.5	1.5	344
1968	26.1	.4	1.3	2134	23.6	-.4	-.8	841	28.1	.7	2.0	348
1969	25.7	.1	.2	1507	23.8	-.1	-.2	499	27.6	.3	.7	295
1970	25.9	.2	.7	1434	24.3	.3	.8	549	27.1	-.3	-.8	287
1971	25.6	-.1	-.4	1001	23.8	-.2	-.3	300	27.5	.1	.2	275
1972	25.5	-.2	-.7	1130	23.7	-.3	-.6	297	27.2	-.2	-.7	275
1973	25.3	-.4	-1.2	920	23.4	-.6	-1.3	293	26.9	-.5	-1.5	166
1974	26.1	.4	1.4	914	24.2	.3	.6	350	27.6	.2	.6	156
1975	25.6	-.0	-.1	594	24.3	.3	.7	213	27.0	-.4	-1.2	109

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	24.6	.5	1.4	359	21.6	.6	1.1	89	26.9	-.5	-1.2	86
1950	24.1	-.0	-.1	303	21.4	.4	.7	124	26.4	-1.0	-2.4	54
1951	24.3	.2	.6	433	21.2	.2	.4	128	27.9	.5	1.2	56
1952	24.9	.7	2.0	440	21.0	-.0	-.0	156	28.2	.8	1.8	68
1953	24.5	.4	1.1	800	21.5	.5	1.0	294	27.6	.2	.4	121
1954	24.4	.2	.7	666	21.6	.6	1.2	154	27.5	.1	.2	168
1955	24.5	.3	.9	524	21.7	.7	1.4	171	27.6	.2	.4	73
1956	23.8	-.3	-.9	537	20.4	-.5	-1.0	157	27.4	.0	.0	91
1957	23.8	-.3	-.9	635	19.9	-1.1	-2.1	145	27.7	.2	.5	154
1958	24.3	.1	.4	832	20.8	-.1	-.3	266	27.4	-.0	-.1	172
1959	24.1	-.0	-.1	753	21.2	.2	.4	244	27.7	.3	.6	131
1960	24.1	-.1	-.2	752	21.1	.1	.2	275	27.6	.1	.3	123
1961	24.2	.0	.1	843	21.2	.3	.5	336	27.6	.2	.4	116
1962	23.9	-.3	-.8	761	20.3	-.7	-1.3	269	27.4	-.1	-.2	129
1963	23.9	-.2	-.7	826	20.7	-.3	-.5	239	27.6	.1	.3	146
1964	24.2	.0	.1	1322	21.2	.2	.4	437	27.7	.2	.6	260
1965	23.3	-.8	-2.4	1550	19.9	-1.1	-2.0	432	26.8	-.6	-1.5	278
1966	24.0	-.2	-.5	2281	20.9	-.1	-.2	765	27.7	.3	.7	375
1967	24.1	-.1	-.2	2233	21.2	.2	.4	790	26.9	-.5	-1.3	384
1968	24.2	.1	.2	2059	20.8	-.2	-.4	572	28.1	.7	1.6	424
1969	24.6	.5	1.3	1819	21.4	.4	.8	501	27.7	.3	.6	301
1970	24.2	.1	.3	1381	21.2	.2	.4	602	27.2	-.2	-.4	193
1971	24.6	.4	1.2	1096	21.3	.3	.5	333	27.8	.4	.9	192
1972	23.5	-.6	-1.8	1010	20.4	-.5	-1.1	348	27.3	-.1	-.2	183
1973	24.7	.6	1.7	991	21.3	.3	.5	391	27.6	.2	.4	141
1974	24.2	.1	.2	1000	21.3	.3	.6	434	27.3	-.1	-.3	134
1975	24.6	.5	1.4	731	21.6	.6	1.1	319	27.4	-.0	-.1	101

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				28.0	-.3	-.6	57
1949	24.0	-.2	-.5	648	21.0	.5	1.0	114	27.8	-.5	-1.1	183
1950	24.0	-.1	-.4	781	21.1	.6	1.2	217	27.4	-.9	-1.9	183
1951	24.0	-.1	-.4	745	20.4	-.0	-.1	175	27.9	-.4	-1.0	188
1952	24.6	.4	1.3	988	20.9	.4	.8	252	28.8	.6	1.2	228
1953	24.3	.1	.3	1610	20.8	.4	.8	313	28.6	.3	.6	389
1954	24.3	.1	.3	2089	21.0	.5	1.0	544	28.2	-.1	-.3	596
1955	24.1	-.1	-.3	3091	20.5	-.0	-.1	668	28.0	-.3	-.7	630
1956	24.2	-.0	-.1	4402	19.7	-.8	-1.6	875	28.3	.1	.1	1356
1957	23.5	-.7	-2.0	5479	19.6	-.9	-1.9	1287	28.0	-.3	-.7	1462
1958	23.8	-.4	-1.1	5900	20.3	-.2	-.5	1111	27.8	-.5	-1.1	1708
1959	24.1	-.0	-.1	7753	20.7	.2	.5	1822	28.3	.0	.0	2124
1960	23.9	-.3	-.9	8907	20.5	.0	.1	2216	28.1	-.2	-.5	2348
1961	24.5	.3	.8	3973	19.7	-.8	-1.6	1651	28.9	.7	1.5	375
1962	24.8	.6	1.6	1294	20.6	.1	.2	336	29.1	.8	1.8	370
1963	24.7	.5	1.5	1267	20.3	-.2	-.3	294	28.8	.5	1.2	412
1964	24.4	.2	.7	6807	20.8	.4	.7	1687	28.3	.0	.1	2053
1965	23.8	-.4	-1.1	7279	19.8	-.6	-1.3	1419	28.4	.1	.2	2084
1966	24.1	-.1	-.2	7959	20.9	.4	.9	1722	28.1	-.2	-.4	2318
1967	24.7	.5	1.5	2273	20.8	.3	.7	590	28.9	.6	1.3	681
1968	24.3	.1	.4	1949	20.6	.1	.2	420	28.2	-.1	-.1	549
1969	24.8	.6	1.7	1532	21.7	1.2	2.5	333	28.9	.6	1.4	518
1970	24.6	.4	1.1	1338	20.7	.2	.4	271	28.5	.3	.6	440
1971	24.5	.3	1.0	1292	20.6	.1	.2	170	28.7	.4	.9	240
1972	24.1	-.1	-.2	2865	20.8	.3	.7	474	27.8	-.5	-1.1	1019
1973	24.3	.1	.3	2457	21.4	.9	1.9	466	27.9	-.4	-.9	819
1974	24.3	.1	.2	2669	20.4	-.1	-.2	426	28.0	-.3	-.6	985
1975	24.5	.3	.8	2696	20.9	.4	.9	517	28.2	-.1	-.2	887

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	16.1	-.9	-1.3	3619	14.1	-.9	-1.0	296	17.5	-1.6	-1.9	1401
1949	16.6	-.3	-.5	4715	13.7	-1.2	-1.4	989	19.2	.0	.0	1756
1950	16.3	-.7	-1.0	4069	13.6	-1.4	-1.6	1668	18.5	-.6	-.7	783
1951	16.7	-.3	-.4	2814	15.0	.0	.1	978	18.4	-.8	-.9	201
1952	16.6	-.4	-.6	2939	15.1	.2	.2	582	18.1	-1.0	-1.2	997
1953	16.9	-.1	-.1	3685	15.0	.1	.1	923	18.9	-.2	-.3	777
1954	17.0	.0	.0	4528	14.6	-.4	-.4	942	19.7	.5	.6	1508
1955	16.5	-.4	-.6	5307	14.4	-.5	-.6	1663	19.1	-.1	-.1	1168
1956	16.3	-.7	-1.0	4678	13.8	-1.2	-1.4	1338	19.2	.0	.0	920
1957	17.7	.8	1.1	4557	15.5	.5	.6	1468	20.3	1.2	1.4	958
1958	18.5	1.5	2.2	3985	16.7	1.7	2.0	871	20.3	1.2	1.4	996
1959	18.5	1.5	2.2	4955	16.3	1.4	1.6	1279	20.9	1.7	2.0	1037
1960	17.3	.4	.6	5871	15.3	.4	.4	1548	20.0	.9	1.0	1300
1961	17.0	.0	.0	5610	15.9	.9	1.1	1439	19.5	.4	.4	1428
1962	16.1	-.8	-1.2	5229	14.4	-.6	-.7	1760	18.2	-.9	-1.1	1222
1963	17.5	.6	.8	5470	14.9	-.1	-.1	1381	19.6	.5	.5	1262
1964	16.5	-.5	-.7	5254	15.8	.9	1.0	1324	18.3	-.8	-.9	1340
1965	16.9	-.1	-.1	7657	14.6	-.4	-.5	1882	18.6	-.5	-.6	2178
1966	17.1	.1	.2	7264	14.8	-.1	-.2	1444	19.1	-.0	-.0	1775
1967	17.3	.3	.4	7002	15.6	.7	.8	1515	19.5	.3	.4	1699
1968	16.9	-.0	-.0	6714	15.6	.6	.7	1797	19.0	-.2	-.2	1380
1969	17.0	.0	.0	5813	15.0	.0	.1	1816	19.2	.0	.0	1728
1970	17.0	.1	.1	4925	15.3	.3	.4	1180	19.1	-.0	-.0	1919
1971	16.3	-.6	-.9	4705	13.8	-1.2	-1.4	1325	20.2	1.1	1.2	1277
1972	16.9	-.1	-.1	4118	13.3	-1.7	-2.0	1079	19.8	.7	.8	807
1973	16.2	-.7	-1.1	2361	15.4	.5	.6	642	17.9	-1.3	-1.5	695
1974	16.2	-.8	-1.1	2665	13.7	-1.2	-1.5	721	18.6	-.5	-.6	783
1975	15.7	-1.3	-1.9	984	14.0	-.9	-1.1	274	17.6	-1.6	-1.8	178

EP

-STAT	OBS
.9	125
1.6	56
2.4	98
1.2	99
1.2	190
.6	142
.6	98
.8	112
.2	124
.4	154
.5	125
.2	191
.1	204
.5	199
.0	193
.5	156
.0	222
.1	444
.1	551
.4	632
.5	431
.0	402
.8	264
.7	180
.3	184
.4	193
.2	120

P

TAT	OBS
0	121
7	388
4	155
6	97
2	138
7	172
1	176
9	199
5	250
5	221
6	216
5	193
6	212
[illegible]	197
[illegible]	248
[illegible]	191
[illegible]	390
[illegible]	472
[illegible]	533
[illegible]	382
[illegible]	388
[illegible]	388
[illegible]	323
[illegible]	195
[illegible]	345
[illegible]	322
[illegible]	300
[illegible]	272

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	18.0	.2	.4	478	15.6	.5	1.0	128	20.7	-.5	-.6	121
1950	18.5	.7	1.5	384	15.3	.2	.3	93	22.3	1.0	1.2	91
1951	18.2	.4	.9	496	14.8	-.3	-.6	124	22.6	1.4	1.7	111
1952	17.3	-.5	-1.1	564	15.1	-.0	-.1	130	20.2	-1.1	-1.3	126
1953	17.1	-.6	-1.4	581	14.5	-.6	-1.2	181	20.6	-.6	-.7	114
1954	17.0	-.7	-1.6	572	15.1	.0	.0	159	19.7	-1.5	-1.8	140
1955	17.8	.0	.0	506	14.6	-.5	-1.0	112	21.3	.0	.1	139
1956	17.8	.0	.1	696	14.4	-.7	-1.2	124	21.3	.0	.0	163
1957	18.4	.6	1.4	810	16.2	1.1	2.0	203	21.5	.3	.4	184
1958	17.8	-.0	-.0	690	14.6	-.5	-.9	166	22.1	.9	1.0	147
1959	18.2	.4	.9	785	15.0	-.1	-.1	187	21.1	-.1	-.1	177
1960	17.9	.1	.2	962	15.2	.1	.3	267	21.4	.2	.2	182
1961	17.0	-.8	-1.6	1073	14.7	-.4	-.8	292	20.0	-1.3	-1.5	222
1962	18.1	.4	.8	1016	15.5	.4	.7	238	21.8	.5	.6	217
1963	17.6	-.2	-.4	921	15.6	.5	.9	216	21.2	-.0	-.1	184
1964	17.5	-.2	-.5	985	15.1	-.0	-.0	224	20.9	-.3	-.4	241
1965	18.3	.5	1.1	1237	16.0	.9	1.7	229	21.7	.5	.6	321
1966	17.3	-.4	-1.0	1453	14.2	-.9	-1.7	314	20.6	-.6	-.7	402
1967	18.1	.3	.8	1580	15.1	.0	.0	368	22.7	1.5	1.8	418
1968	18.3	.5	1.1	1563	15.2	.1	.3	272	22.4	1.2	1.4	447
1969	17.1	-.7	-1.5	1403	14.6	-.5	-.9	294	20.9	-.3	-.4	373
1970	17.6	-.1	-.3	1346	14.0	-1.1	-2.1	230	22.0	.8	.9	423
1971	17.7	-.1	-.2	1243	15.0	-.1	-.2	210	21.3	.1	.1	285
1972	17.6	-.2	-.5	1400	15.2	.1	.3	171	20.6	-.7	-.8	491
1973	17.1	-.7	-1.5	1286	14.4	-.7	-1.3	253	20.7	-.5	-.6	331
1974	17.2	-.6	-1.2	1324	14.0	-1.1	-2.1	259	20.7	-.5	-.6	417
1975	17.6	-.2	-.4	1146	14.7	-.4	-.8	266	21.2	-.0	-.0	285

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				23.1	-.7	-1.2	20
1949	20.7	.3	.7	457	18.6	1.0	1.6	143	23.2	-.6	-1.0	86
1950	21.0	.6	1.6	420	18.2	.6	.9	159	24.7	1.0	1.7	55
1951	20.6	.2	.6	768	17.2	-.4	-.6	274	23.8	.1	.1	87
1952	20.0	-.4	-1.0	806	18.3	.7	1.1	309	22.6	-1.2	-2.0	95
1953	20.5	.1	.1	1204	17.7	.1	.1	394	24.0	.2	.4	194
1954	20.0	-.4	-1.1	838	17.5	-.1	-.2	274	23.1	-.6	-1.1	134
1955	20.9	.5	1.3	813	17.5	-.1	-.2	287	24.1	.3	.5	73
1956	20.6	.2	.4	979	17.7	.1	.1	343	24.0	.2	.4	143
1957	20.4	-.0	-.0	1067	18.2	.6	.9	414	23.5	-.2	-.4	135
1958	19.8	-.7	-1.6	933	16.4	-1.1	-1.7	299	24.1	.3	.5	144
1959	20.4	-.0	-.0	1096	17.0	-.6	-.9	378	24.1	.4	.7	116
1960	20.0	-.4	-1.0	1223	17.1	-.5	-.8	473	23.7	-.1	-.1	133
1961	19.7	-.7	-1.7	1298	16.5	-1.1	-1.6	526	23.0	-.7	-1.3	157
1962	20.9	.5	1.2	1284	18.2	.6	.9	467	24.5	.8	1.3	179
1963	20.0	-.4	-.9	1000	16.8	-.8	-1.2	323	23.3	-.5	-.9	125
1964	20.7	.3	.7	1069	18.4	.8	1.2	326	24.0	.3	.5	138
1965	20.7	.3	.7	1382	18.2	.6	.9	340	24.3	.5	.9	180
1966	20.3	-.1	-.3	2220	17.1	-.5	-.7	626	23.6	-.2	-.3	386
1967	20.8	.4	1.0	2304	17.9	.3	.4	666	24.6	.8	1.4	425
1968	21.0	.6	1.5	2291	18.2	.6	.9	574	24.7	.9	1.5	554
1969	19.8	-.7	-1.6	2187	16.9	-.7	-1.0	493	23.2	-.5	-.9	404
1970	20.4	-.0	-.1	1708	16.4	-1.2	-1.8	508	24.5	.7	1.2	358
1971	20.8	.4	1.0	1567	17.8	.2	.3	494	24.3	.6	1.0	221
1972	20.7	.3	.8	1168	18.4	.8	1.3	324	23.5	-.2	-.4	193
1973	20.1	-.3	-.8	1168	17.4	-.2	-.3	365	23.1	-.6	-1.1	188
1974	20.4	.0	.0	1190	17.8	.2	.3	350	23.9	.2	.3	253
1975	21.1	.7	1.8	943	17.9	.3	.5	292	24.6	.9	1.5	162

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YEAR	ANNUAL				JANFEBMAR				JULAUGSEP			
	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	21.4	.9	1.7	552	18.8	1.8	2.0	151	24.4	-.4	-.9	125
1950	21.4	.9	1.8	390	18.1	1.1	1.2	134	25.4	.6	1.6	56
1951	20.3	-.2	-.4	782	17.4	.4	.4	284	23.8	-1.0	-2.4	98
1952	20.8	.3	.5	831	18.2	1.2	1.3	320	24.3	-.5	-1.2	99
1953	20.8	.3	.6	1282	17.1	.1	.1	422	25.3	.5	1.2	190
1954	20.1	-.4	-.8	845	16.7	-.3	-.3	280	24.5	-.3	-.6	142
1955	20.9	.4	.7	954	17.1	.1	.1	333	25.0	.2	.6	98
1956	20.9	.5	.9	1013	17.9	.8	1.0	358	25.1	.3	.8	112
1957	20.1	-.4	-.8	1194	17.2	.1	.1	474	24.7	-.1	-.2	124
1958	19.8	-.7	-1.3	1030	15.8	-1.2	-1.4	356	24.6	-.2	-.4	154
1959	19.9	-.6	-1.1	1305	16.5	-.5	-.6	496	25.0	.2	.5	125
1960	19.6	-.9	-1.7	1296	15.7	-1.3	-1.5	456	24.7	-.1	-.2	191
1961	20.0	-.5	-1.0	1521	15.6	-1.5	-1.7	597	24.8	-.0	-.1	204
1962	20.4	-.1	-.1	1427	17.1	.1	.1	482	25.4	.6	1.5	199
1963	20.6	.1	.3	1231	16.1	-1.0	-1.1	346	24.8	.0	.0	193
1964	21.0	.5	1.1	1265	17.5	.5	.6	419	25.4	.6	1.5	156
1965	20.2	-.2	-.5	1510	17.1	.0	.1	365	24.8	-.0	-.0	222
1966	20.4	-.1	-.1	2432	17.3	.2	.3	669	24.7	-.0	-.1	444
1967	20.9	.4	.9	2611	17.4	.4	.5	717	24.8	.1	.1	551
1968	20.5	-.0	-.1	2506	17.0	-.1	-.1	488	25.4	.6	1.4	632
1969	20.2	-.3	-.5	2377	16.6	-.4	-.5	596	24.6	-.2	-.5	431
1970	20.6	.1	.2	1826	16.1	-1.0	-1.1	505	25.2	.4	1.0	402
1971	21.0	.5	.9	1663	17.4	.4	.4	486	25.1	.3	.8	264
1972	20.3	-.2	-.3	1061	17.5	.5	.6	289	24.5	-.3	-.7	180
1973	20.7	.2	.3	1070	16.6	-.4	-.5	310	24.9	.1	.3	184
1974	20.3	-.2	-.4	1001	17.4	.4	.4	306	24.2	-.6	-1.4	193
1975	20.8	.3	.6	950	17.2	.1	.1	320	24.9	.1	.2	120

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YEAR	ANNUAL				JANFEBMAR				JULAUGSEP			
	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS	VALUE	ANOMALY	Z-STAT	OBS
1948	INSUF DATA				INSUF DATA				22.5	-.0	-.0	121
1949	18.0	.1	.2	1122	14.3	-.0	-.0	300	23.1	.6	.7	388
1950	19.2	1.4	2.0	417	15.3	1.0	1.4	87	23.6	1.1	1.4	155
1951	18.5	.7	1.0	486	15.7	1.4	1.8	120	23.0	.5	.6	97
1952	18.5	.6	.9	530	14.9	.7	.9	120	22.7	.2	.2	138
1953	17.7	-.1	-.2	622	15.0	.7	.9	111	22.0	-.6	-.7	172
1954	17.8	-.0	-.0	690	13.9	-.4	-.5	154	22.6	.1	.1	176
1955	18.6	.7	1.0	633	14.8	.5	.7	129	23.3	.7	.9	199
1956	18.8	.9	1.4	871	15.4	1.1	1.4	149	23.8	1.2	1.5	250
1957	16.6	-1.3	-1.9	916	14.1	-.2	-.3	178	20.6	-2.0	-2.5	221
1958	17.2	-.6	-.9	965	13.4	-.9	-1.2	262	22.1	-.5	-.6	216
1959	17.4	-.5	-.7	1007	14.2	-.1	-.1	238	22.9	.4	.5	193
1960	17.6	-.2	-.3	1067	14.2	-.0	-.1	258	22.1	-.5	-.6	212
1961	18.1	.2	.3	1057	13.6	-.7	-.9	288	23.2	.6	.8	197
1962	18.4	.5	.7	788	14.6	.3	.4	183	22.8	.3	.4	248
1963	17.5	-.3	-.5	801	13.9	-.4	-.5	167	22.0	-.5	-.7	191
1964	17.2	-.7	-1.0	1640	13.2	-1.1	-1.5	471	22.1	-.4	-.6	390
1965	16.9	-1.0	-1.5	1833	12.9	-1.4	-1.8	440	21.3	-1.3	-1.6	472
1966	17.7	-.2	-.3	2184	14.1	-.2	-.2	495	22.2	-.3	-.4	533
1967	18.2	.3	.5	1070	14.4	.1	.1	138	23.2	.6	.8	382
1968	17.7	-.2	-.2	1134	14.2	-.1	-.2	148	22.4	-.1	-.1	388
1969	17.9	.0	.1	960	15.1	.9	1.1	145	22.6	.1	.1	388
1970	17.9	.0	.1	911	13.4	-.8	-1.1	108	23.6	1.0	1.3	323
1971	17.9	-.0	-.0	872	14.7	.5	.6	144	22.6	.1	.1	195
1972	17.3	-.6	-.8	1161	13.8	-.4	-.6	183	21.9	-.6	-.8	345
1973	18.1	.2	.3	1203	14.4	.1	.1	256	23.2	.6	.8	322
1974	17.2	-.6	-.9	1329	14.6	.3	.4	273	21.2	-1.4	-1.8	300
1975	17.1	-.7	-1.0	1338	13.9	-.4	-.5	346	21.1	-1.4	-1.8	272

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YEAR	ANNUAL VALUE	ANOMALY	Z-STAT	OBS	JANFEBMAR VALUE	ANOMALY	Z-STAT	OBS	JULAUGSEP VALUE	ANOMALY	Z-STAT	OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	21.4	-.1	-.3	550	18.3	.7	1.4	187	25.5	-.8	-1.6	100
1950	22.3	.8	1.9	618	17.8	.2	.5	153	27.1	.8	1.6	109
1951	22.0	.6	1.3	1138	18.8	1.3	2.4	467	26.6	.3	.7	119
1952	21.7	.2	.4	1043	17.4	-.2	-.4	328	26.5	.3	.6	164
1953	21.1	-.4	-.8	1410	17.3	-.2	-.4	498	26.1	-.2	-.4	254
1954	21.2	-.3	-.7	1155	17.8	.2	.4	398	25.8	-.4	-.9	209
1955	21.8	.3	.8	1344	17.5	-.0	-.1	467	26.7	.5	1.0	196
1956	21.6	.1	.2	1564	17.9	.3	.6	531	26.1	-.2	-.4	262
1957	20.7	-.7	-1.8	2006	16.8	-.7	-1.4	751	26.1	-.2	-.4	289
1958	21.2	-.3	-.6	1937	17.0	-.6	-1.0	658	25.9	-.4	-.8	344
1959	20.9	-.6	-1.3	2258	17.2	-.4	-.7	838	25.2	-1.1	-2.2	303
1960	21.0	-.4	-1.0	2537	17.3	-.3	-.5	900	25.9	-.4	-.8	349
1961	21.7	.3	.6	2185	17.2	-.3	-.6	1021	27.0	.8	1.6	268
1962	21.7	.2	.5	1387	17.9	.4	.7	397	26.3	.0	.1	285
1963	21.4	-.1	-.3	1269	17.1	-.5	-.9	336	26.3	.0	.0	254
1964	21.3	-.2	-.5	2949	17.3	-.3	-.5	1096	26.4	.1	.2	449
1965	21.2	-.3	-.7	3173	17.3	-.3	-.6	890	26.3	.0	.0	785
1966	21.7	.2	.4	4301	17.3	-.2	-.4	1178	26.8	.6	1.2	1014
1967	22.2	.7	1.6	2561	18.5	.9	1.8	581	26.5	.2	.5	712
1968	21.6	.1	.3	2071	18.2	.7	1.3	477	25.8	-.5	-.9	486
1969	21.9	.4	.9	2036	18.1	.6	1.1	483	26.7	.4	.9	567
1970	21.4	-.1	-.2	1582	17.7	.1	.3	380	26.2	-.1	-.2	386
1971	21.4	-.1	-.2	1544	17.5	-.1	-.2	327	26.5	.2	.4	260
1972	21.7	.2	.6	2236	17.7	.1	.3	636	26.4	.2	.3	383
1973	21.5	-.0	-.0	2132	18.0	.5	.9	802	25.9	-.4	-.8	332
1974	21.2	-.3	-.7	2100	17.2	-.4	-.7	711	26.0	-.3	-.5	392
1975	21.5	.0	.0	2283	17.6	-.0	-.0	956	26.7	.5	1.0	326

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YEAR	ANNUAL VALUE	ANOMALY	Z-STAT	OBS	JANFEBMAR VALUE	ANOMALY	Z-STAT	OBS	JULAUGSEP VALUE	ANOMALY	Z-STAT	OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	20.7	.9	1.2	542	16.6	1.6	1.3	95	24.7	-.3	-.3	184
1950	20.4	.7	.9	1159	15.5	.4	.3	131	26.7	1.7	1.9	214
1951	20.1	.4	.5	3206	16.7	1.6	1.3	1225	25.0	.1	.1	286
1952	19.7	-.1	-.1	1275	15.3	.2	.2	271	25.4	.4	.4	353
1953	19.7	-.0	-.1	1046	14.9	-.1	-.1	172	24.5	-.5	-.5	340
1954	19.3	-.5	-.6	1102	16.3	1.2	1.0	163	23.5	-1.4	-1.6	426
1955	19.5	-.2	-.3	1377	12.8	-2.3	-1.9	338	25.9	.9	1.0	376
1956	20.4	.7	.9	1458	15.8	.7	.6	240	25.2	.2	.2	427
1957	19.9	.1	.2	1957	15.5	.4	.3	302	25.0	.0	.0	740
1958	19.3	-.5	-.6	2007	15.3	.2	.2	433	24.1	-.8	-.9	562
1959	19.5	-.3	-.3	1904	14.3	-.8	-.6	436	24.3	-.6	-.7	570
1960	19.9	.2	.3	2135	15.2	.1	.1	455	24.8	-.2	-.2	640
1961	20.7	.9	1.2	1384	15.2	.1	.1	329	26.5	1.6	1.7	274
1962	20.7	.9	1.2	928	16.2	1.2	.9	170	25.5	.6	.6	282
1963	19.1	-.6	-.8	980	13.5	-1.6	-1.3	240	24.6	-.3	-.4	288
1964	19.1	-.6	-.8	2268	13.8	-1.3	-1.0	522	24.9	-.1	-.1	625
1965	17.6	-2.2	-2.7	1993	12.3	-2.8	-2.2	442	23.4	-1.6	-1.7	583
1966	19.2	-.6	-.7	2235	15.0	-.0	-.0	499	24.6	-.4	-.4	698
1967	20.8	1.1	1.4	760	16.0	.9	.8	104	26.5	1.5	1.6	261
1968	20.3	.5	.7	783	15.7	.6	.5	147	25.2	.3	.3	227
1969	20.8	1.0	1.3	672	17.3	2.2	1.8	95	24.9	-.1	-.1	265
1970	20.2	.4	.6	620	15.5	.5	.4	99	25.0	.0	.0	222
1971	19.7	-.1	-.1	900	16.5	1.4	1.1	103	24.6	-.4	-.4	124
1972	18.0	-1.7	-2.2	3218	13.5	-1.6	-1.3	653	23.9	-1.0	-1.1	613
1973	17.8	-2.0	-2.5	5336	12.0	-3.1	-2.5	2424	24.4	-.5	-.6	502
1974	17.4	-2.3	-2.9	6700	12.9	-2.2	-1.8	2881	23.7	-1.3	-1.4	744
1975	17.0	-2.8	-3.5	7726	11.2	-3.9	-3.2	2997	23.7	-1.3	-1.4	632

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	11.5	-.2	-.4	514	8.4	-.3	-.4	41	15.3	.1	.2	79
1949	11.3	-.4	-.7	699	7.5	-1.2	-1.6	118	15.2	-.0	-.1	257
1950	10.9	-.8	-1.5	539	7.3	-1.4	-1.8	193	15.0	-.2	-.4	111
1951	11.3	-.4	-.8	944	8.3	-.4	-.6	216	14.6	-.6	-1.0	208
1952	11.2	-.5	-1.0	677	7.8	-.9	-1.2	199	14.2	-1.0	-1.7	133
1953	11.7	.0	.1	671	8.9	.2	.3	159	15.1	-.1	-.2	166
1954	11.7	-.0	-.0	699	8.9	.1	.2	152	14.9	-.3	-.5	178
1955	10.9	-.8	-1.5	1175	8.8	.0	.1	164	14.8	-.4	-.7	421
1956	11.5	-.2	-.4	1176	7.9	-.8	-1.1	220	15.3	.1	.2	402
1957	12.0	.3	.5	1341	7.9	-.8	-1.1	267	15.8	.5	.9	393
1958	12.7	1.0	1.9	1260	9.8	1.1	1.4	332	16.1	.8	1.4	319
1959	12.3	.6	1.3	1141	9.5	.8	1.0	334	15.5	.3	.5	256
1960	12.3	.6	1.2	2122	9.7	1.0	1.3	348	15.4	.1	.2	518
1961	12.2	.5	1.0	1146	9.8	1.1	1.4	338	16.2	1.0	1.7	297
1962	11.8	.1	.1	1018	9.0	.3	.4	265	15.2	-.0	-.0	260
1963	INSUF DATA				9.6	.9	1.2	259	INSUF DATA			
1964	INSUF DATA				8.8	.1	.1	58	14.1	-1.2	-2.0	25
1965	INSUF DATA				INSUF DATA				INSUF DATA			
1966	11.3	-.4	-.8	1410	8.8	.1	.1	207	14.5	-.7	-1.2	660
1967	11.9	.2	.4	2858	8.8	.0	.1	537	15.9	.6	1.1	843
1968	11.4	-.3	-.6	3850	8.3	-.4	-.5	587	14.8	-.4	-.7	1906
1969	11.6	-.1	-.2	1731	7.8	-.9	-1.1	371	15.5	.2	.4	513
1970	11.6	-.1	-.2	1613	9.5	.8	1.0	389	14.5	-.8	-1.3	486
1971	10.8	-.8	-1.7	1557	8.1	-.7	-.9	367	15.0	-.3	-.4	322
1972	10.5	-1.2	-2.4	2700	7.5	-1.2	-1.6	223	13.8	-1.4	-2.3	1142
1973	11.1	-.6	-1.1	1376	8.4	-.3	-.4	390	14.6	-.7	-1.1	338
1974	11.2	-.5	-1.0	1813	7.8	-.9	-1.1	274	14.5	-.7	-1.2	836
1975	10.8	-.9	-1.8	1426	8.1	-.6	-.8	303	14.4	-.8	-1.4	418

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	10.1	.2	.4	456	6.8	-.2	-.3	107	14.0	-.0	-.0	112
1950	9.0	-1.0	-2.0	409	7.0	-.0	-.0	102	12.2	-1.8	-2.2	84
1951	10.2	.3	.7	423	5.8	-1.2	-2.0	82	15.9	1.8	2.2	130
1952	9.8	-.1	-.2	476	6.1	-.9	-1.5	110	14.1	-.0	-.0	142
1953	9.9	-.0	-.1	513	7.0	.1	.1	89	14.5	.4	.5	139
1954	9.8	-.1	-.2	610	6.9	-.1	-.2	128	14.0	-.1	-.1	170
1955	9.5	-.4	-.8	592	7.1	.2	.3	118	13.1	-1.0	-1.2	184
1956	9.5	-.4	-.9	757	6.2	-.7	-1.2	147	14.3	.2	.3	204
1957	11.0	1.1	2.2	879	7.5	.6	.9	143	14.3	.2	.3	296
1958	10.6	.7	1.5	855	7.9	1.0	1.6	165	14.7	.6	.7	229
1959	10.2	.3	.6	785	7.4	.4	.6	175	13.2	-.8	-1.0	211
1960	9.6	-.3	-.6	871	7.0	.0	.0	180	13.7	-.4	-.5	257
1961	10.1	.2	.3	819	6.6	-.3	-.6	185	14.8	.7	.9	210
1962	10.3	.4	.8	932	8.0	1.0	1.7	209	14.6	.5	.6	248
1963	10.4	.5	.9	1006	8.0	1.0	1.7	252	15.1	1.0	1.2	213
1964	9.3	-.6	-1.3	1024	6.6	-.4	-.6	269	13.0	-1.1	-1.3	244
1965	10.0	.1	.3	1134	7.1	.1	.2	255	14.3	.2	.3	285
1966	9.7	-.2	-.4	1350	6.7	-.2	-.4	357	13.7	-.3	-.4	297
1967	9.6	-.3	-.6	1557	6.7	-.3	-.5	296	14.0	-.1	-.1	402
1968	9.5	-.4	-.9	1874	6.5	-.4	-.7	434	13.5	-.6	-.7	497
1969	9.1	-.8	-1.7	1311	6.1	-.9	-1.4	327	13.0	-1.0	-1.2	370
1970	9.5	-.5	-1.0	1256	7.1	.1	.2	239	12.4	-1.7	-2.0	354
1971	9.2	-.8	-1.6	1209	7.1	.1	.1	284	12.2	-1.9	-2.3	222
1972	10.5	.6	1.2	794	7.1	.1	.2	161	14.9	.8	1.0	174
1973	9.4	-.5	-1.0	1040	7.4	.5	.8	226	13.0	-1.1	-1.3	239
1974	9.3	-.6	-1.2	977	6.6	-.4	-.6	222	13.2	-.8	-1.0	256
1975	9.0	-.9	-1.8	1117	6.7	-.2	-.4	295	12.5	-1.6	-1.9	287

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	14.1	1.3	1.9	337	12.4	2.5	2.4	60	18.6	1.1	.9	84
1950	12.6	-.2	-.3	225	10.1	.2	.2	43	17.6	.0	.0	87
1951	12.7	-.1	-.1	417	9.8	-.1	-.1	70	16.9	-.7	-.6	153
1952	13.5	.7	1.0	403	10.9	.9	.9	91	19.0	1.4	1.2	103
1953	12.2	-.6	-.9	364	8.6	-1.3	-1.2	54	17.4	-.2	-.2	122
1954	12.4	-.4	-.6	387	9.3	-.7	-.6	85	17.3	-.3	-.2	128
1955	12.7	-.1	-.1	351	9.8	-.1	-.1	67	17.4	-.2	-.2	99
1956	12.1	-.6	-.9	538	9.7	-.2	-.2	114	15.5	-2.0	-1.7	139
1957	13.4	.6	.9	659	11.6	1.6	1.6	149	17.9	.3	.3	158
1958	11.6	-1.2	-1.7	742	9.3	-.6	-.6	139	15.1	-2.5	-2.2	228
1959	12.2	-.6	-.8	810	8.8	-1.1	-1.0	250	17.2	-.4	-.4	204
1960	11.7	-1.1	-1.7	878	8.6	-1.3	-1.3	206	17.0	-.6	-.5	228
1961	12.4	-.4	-.6	951	8.3	-1.6	-1.6	183	17.2	-.4	-.3	315
1962	13.4	.6	.8	960	10.6	.7	.7	226	18.8	1.2	1.0	279
1963	13.6	.8	1.2	1119	10.3	.4	.4	267	19.5	1.9	1.7	310
1964	13.5	.7	1.0	963	9.5	-.4	-.4	187	19.6	2.0	1.7	349
1965	13.3	.5	.7	1018	10.9	1.0	1.0	187	17.7	.1	.1	321
1966	12.7	-.1	-.1	1139	10.0	.1	.1	231	17.0	-.5	-.5	339
1967	12.9	.2	.2	1312	9.9	-.0	-.0	260	17.3	-.3	-.2	456
1968	12.7	-.0	-.1	1319	10.6	.7	.7	204	16.5	-1.1	-.9	492
1969	12.1	-.7	-1.0	1337	9.6	-.3	-.3	247	17.4	-.2	-.2	484
1970	12.1	-.7	-1.0	1181	8.4	-1.5	-1.4	153	16.9	-.6	-.5	385
1971	13.1	.3	.4	965	10.2	.3	.3	200	17.7	.1	.1	234
1972	13.3	.5	.8	695	11.0	1.0	1.0	119	17.5	-.1	-.0	220
1973	12.0	-.8	-1.2	660	9.1	-.8	-.8	120	16.6	-1.0	-.9	184
1974	12.2	-.6	-.9	732	9.6	-.3	-.3	136	16.1	-1.5	-1.3	217
1975	12.5	-.3	-.4	651	9.0	-.9	-.8	111	17.2	-.4	-.3	224

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	10.1	1.0	2.1	302	7.1	.7	1.2	32	15.0	1.6	1.8	104
1950	8.8	-.4	-.8	265	7.0	.6	1.0	53	12.1	-1.2	-1.3	73
1951	9.1	-.0	-.1	540	5.0	-1.4	-2.3	72	14.3	1.0	1.1	218
1952	9.6	.4	.9	510	6.6	.2	.4	103	14.3	1.0	1.1	167
1953	8.9	-.3	-.6	607	5.9	-.4	-.7	98	13.9	.6	.6	210
1954	9.1	-.0	-.0	556	6.1	-.3	-.4	89	13.6	.2	.2	175
1955	9.0	-.2	-.4	683	6.5	.1	.1	119	12.9	-.5	-.5	230
1956	8.8	-.4	-.9	879	6.2	-.2	-.4	130	12.4	-.9	-1.0	292
1957	10.1	.9	1.9	986	7.5	1.1	1.8	174	13.6	.3	.3	315
1958	8.7	-.4	-.9	1168	6.5	.1	.2	188	11.9	-1.4	-1.5	331
1959	8.8	-.3	-.8	1164	5.9	-.5	-.8	210	12.4	-1.0	-1.1	354
1960	8.7	-.5	-1.1	1311	5.9	-.5	-.8	258	12.9	-.5	-.5	462
1961	9.1	-.0	-.1	1058	5.8	-.6	-1.0	200	13.5	.2	.2	358
1962	9.5	.3	.7	1219	7.1	.7	1.2	243	14.2	.9	1.0	367
1963	9.7	.5	1.2	1325	7.1	.8	1.2	301	14.9	1.5	1.7	309
1964	8.7	-.4	-1.0	1123	6.0	-.4	-.7	251	12.8	-.6	-.6	285
1965	9.6	.4	.9	1257	6.7	.3	.5	234	13.5	.1	.2	399
1966	8.8	-.4	-.8	1268	6.4	-.0	-.0	308	12.5	-.9	-1.0	326
1967	9.0	-.1	-.3	1492	6.1	-.3	-.5	278	13.0	-.3	-.4	384
1968	8.6	-.6	-1.2	1714	6.2	-.2	-.3	435	11.9	-1.4	-1.5	433
1969	8.1	-1.1	-2.3	1229	5.4	-.9	-1.6	285	12.3	-1.0	-1.1	363
1970	8.3	-.9	-2.0	1119	5.7	-.7	-1.1	217	11.4	-1.9	-2.1	311
1971	8.4	-.8	-1.7	1083	6.4	-.0	-.0	287	11.8	-1.6	-1.7	159
1972	9.3	.2	.4	641	6.6	.2	.3	123	13.2	-.1	-.2	167
1973	8.1	-1.0	-2.3	834	6.3	-.1	-.1	159	11.2	-2.1	-2.3	194
1974	8.6	-.5	-1.2	748	5.8	-.6	-.9	184	12.7	-.7	-.8	172
1975	8.3	-.8	-1.8	833	5.9	-.4	-.7	212	11.9	-1.5	-1.6	216

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	12.6	.0	.0	268	10.2	.4	.6	38	17.8	.6	.4	82
1950	13.1	.5	.7	207	9.7	-.1	-.1	43	18.8	1.6	1.2	91
1951	12.6	.0	.1	336	10.6	.7	.9	43	16.6	-.7	-.5	125
1952	12.6	.0	.1	365	10.6	.8	1.0	82	16.6	-.7	-.5	90
1953	12.0	-.5	-.7	344	8.9	-.9	-1.2	51	16.6	-.7	-.5	115
1954	11.8	-.8	-1.1	345	9.5	-.3	-.4	78	16.9	-.3	-.3	118
1955	12.8	.2	.3	373	9.6	-.3	-.3	57	17.7	.4	.3	110
1956	13.1	.5	.6	576	10.7	.9	1.2	124	17.1	-.2	-.1	156
1957	12.4	-.2	-.2	662	10.6	.8	1.0	129	16.4	-.8	-.6	165
1958	11.5	-1.1	-1.5	690	9.6	-.2	-.3	160	14.8	-2.4	-1.9	181
1959	12.2	-.4	-.5	1842	10.5	.7	.9	486	16.8	-.4	-.3	458
1960	11.7	-.9	-1.2	2041	7.8	-2.0	-2.6	565	16.8	-.5	-.4	506
1961	12.5	-.1	-.1	1589	8.6	-1.2	-1.5	326	17.6	.4	.3	448
1962	11.9	-.7	-.9	1915	9.3	-.5	-.6	366	16.9	-.3	-.3	489
1963	14.2	1.6	2.2	1459	9.8	-.0	-.0	382	19.6	2.4	1.8	426
1964	13.9	1.3	1.7	2197	9.6	-.3	-.3	517	19.5	2.3	1.8	528
1965	12.2	-.4	-.5	1419	10.0	.2	.3	446	16.3	-.9	-.7	384
1966	12.2	-.4	-.5	1160	9.9	.1	.1	204	15.5	-1.7	-1.3	347
1967	13.7	1.1	1.5	482	10.7	.9	1.2	66	19.1	1.9	1.5	204
1968	12.9	.3	.4	518	10.5	.7	.8	88	16.3	-1.0	-.7	151
1969	13.1	.5	.6	408	10.7	.8	1.1	63	18.2	1.0	.8	155
1970	12.9	.3	.4	441	9.0	-.8	-1.0	46	17.8	.6	.5	174
1971	13.0	.4	.6	339	10.7	.8	1.1	48	18.2	1.0	.8	64
1972	12.3	-.3	-.4	632	9.8	-.0	-.0	87	16.3	-.9	-.7	205
1973	11.8	-.8	-1.1	659	9.0	-.8	-1.0	109	15.7	-1.5	-1.2	178
1974	11.8	-.8	-1.0	714	9.4	-.4	-.5	126	16.3	-.9	-.7	202
1975	11.5	-1.0	-1.4	749	8.9	-.9	-1.2	167	15.5	-1.7	-1.3	210

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	6.3	-.4	-.8	404	3.4	-.4	-.7	57	10.3	-.5	-.7	150
1950	6.8	.1	.2	429	3.6	-.2	-.4	71	11.5	.7	.9	97
1951	6.5	-.2	-.4	797	3.6	-.1	-.3	100	10.9	.1	.1	289
1952	6.4	-.3	-.7	775	3.4	-.4	-.7	136	10.5	-.3	-.4	244
1953	6.1	-.6	-1.3	871	3.3	-.5	-.9	94	9.7	-1.2	-1.4	315
1954	6.1	-.6	-1.3	912	3.5	-.2	-.4	123	9.6	-1.2	-1.4	305
1955	6.7	-.0	-.0	1471	3.4	-.3	-.6	210	11.1	.3	.4	415
1956	7.6	.9	2.0	1760	4.9	1.1	2.1	247	12.0	1.2	1.5	638
1957	6.8	.1	.2	2033	4.6	.9	1.6	297	10.2	-.6	-.7	736
1958	6.4	-.3	-.6	2631	3.6	-.2	-.4	261	10.6	-.2	-.2	833
1959	7.0	.3	.6	2913	3.8	.0	.1	426	11.7	.9	1.1	973
1960	6.2	-.5	-1.0	2747	3.2	-.6	-1.1	434	10.9	.1	.1	999
1961	6.7	-.0	-.0	1481	3.1	-.7	-1.3	390	10.7	-.1	-.2	221
1962	7.4	.7	1.4	617	4.4	.6	1.2	102	11.8	1.0	1.3	198
1963	7.3	.6	1.3	578	4.4	.7	1.3	136	10.8	-.0	-.0	165
1964	6.3	-.4	-.9	3614	3.9	.1	.2	622	9.4	-1.4	-1.7	1163
1965	6.4	-.3	-.6	3228	3.7	-.1	-.1	650	10.0	-.8	-.9	967
1966	7.4	.7	1.4	805	4.5	.7	1.3	201	11.4	.6	.7	210
1967	7.0	.3	.7	378	3.6	-.2	-.3	48	12.1	1.2	1.5	142
1968	7.1	.4	.8	508	3.9	.1	.3	89	10.9	.1	.1	123
1969	7.2	.5	1.0	318	4.2	.5	.9	40	11.7	.9	1.2	144
1970	7.1	.4	.9	226	3.4	-.4	-.7	34	11.0	.2	.3	82
1971	7.4	.7	1.5	526	5.4	1.6	3.1	29	10.8	-.0	-.0	42
1972	6.6	-.0	-.1	1267	4.0	.2	.4	211	10.3	-.5	-.6	356
1973	6.5	-.2	-.4	1622	3.7	-.1	-.2	320	9.8	-1.0	-1.3	397
1974	6.5	-.1	-.3	1399	4.1	.3	.6	293	10.1	-.7	-.9	407
1975	6.5	-.2	-.4	1582	3.6	-.2	-.3	284	10.4	-.4	-.5	447

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	11.3	.3	.5	480	6.2	-.2	-.4	67	17.5	.8	.7	163
1950	11.7	.7	1.1	482	6.1	-.4	-.6	109	20.0	3.4	2.6	116
1951	11.1	.1	.2	823	6.0	-.4	-.7	117	17.3	.7	.5	305
1952	11.2	.2	.3	820	6.7	.2	.4	175	16.9	.3	.2	251
1953	10.7	-.2	-.3	962	6.5	.1	.1	149	16.0	-.7	-.5	375
1954	11.0	.0	.1	920	7.2	.8	1.3	159	17.0	.3	.2	338
1955	11.4	.5	.7	1406	6.7	.2	.4	242	17.3	.6	.5	492
1956	11.8	.8	1.2	2030	7.8	1.4	2.3	292	16.4	-.2	-.2	708
1957	10.7	-.2	-.4	2755	7.2	.7	1.2	442	16.1	-.6	-.4	926
1958	10.8	-.2	-.3	3638	6.7	.2	.4	438	16.2	-.4	-.3	1208
1959	10.4	-.6	-1.0	3543	6.1	-.3	-.5	630	16.2	-.4	-.3	1254
1960	10.6	-.4	-.6	4084	6.2	-.3	-.5	728	16.6	-.0	-.0	1392
1961	11.5	.5	.8	2145	5.9	-.5	-.9	634	17.7	1.0	.8	288
1962	11.5	.6	.9	832	7.1	.7	1.2	159	16.1	-.5	-.4	290
1963	11.2	.2	.4	838	6.9	.4	.7	188	16.2	-.5	-.4	254
1964	9.8	-1.2	-1.8	5254	5.6	-.9	-1.5	942	14.4	-2.3	-1.8	1466
1965	9.6	-1.3	-2.1	5363	5.7	-.7	-1.2	1046	14.4	-2.2	-1.7	1672
1966	10.3	-.6	-1.0	4974	5.8	-.6	-1.0	1030	15.8	-.8	-.7	1380
1967	11.9	.9	1.5	471	6.1	-.4	-.6	57	18.3	1.6	1.3	188
1968	12.4	1.4	2.3	637	7.5	1.0	1.7	106	17.8	1.2	.9	182
1969	11.4	.4	.7	434	6.8	.3	.5	38	16.7	.1	.1	200
1970	11.3	.4	.6	363	5.3	-1.1	-1.9	59	18.0	1.3	1.0	133
1971	11.4	.5	.7	730	8.5	2.0	3.4	28	15.9	-.8	-.6	54
1972	10.5	-.5	-.8	1959	5.9	-.6	-.9	371	16.7	.1	.1	621
1973	11.1	.1	.2	2291	6.5	.1	.1	423	16.6	-.0	-.0	591
1974	10.3	-.7	-1.1	2215	5.9	-.5	-.9	409	16.5	-.2	-.2	659
1975	11.0	.1	.1	2341	6.4	-.0	-.1	435	17.2	.5	.4	731

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	INSUF DATA				2.8	-2.7	-2.8	32	11.7	-1.5	-1.4	29
1950	INSUF DATA				INSUF DATA				INSUF DATA			
1951	INSUF DATA				INSUF DATA				INSUF DATA			
1952	INSUF DATA				INSUF DATA				13.0	-.2	-.2	20
1953	INSUF DATA				INSUF DATA				13.1	-.1	-.1	42
1954	9.2	.4	.7	167	5.7	.2	.2	28	14.2	1.0	.9	47
1955	8.2	-.5	-.8	195	6.3	.8	.8	37	11.7	-1.5	-1.4	48
1956	8.8	.0	.0	274	5.8	.3	.3	41	13.3	.1	.1	111
1957	9.7	1.0	1.6	264	5.0	-.5	-.5	65	15.9	2.7	2.5	73
1958	9.9	1.2	1.8	360	6.5	1.0	1.1	83	14.7	1.5	1.4	76
1959	9.3	.6	.9	267	6.0	.5	.5	67	13.3	.1	.1	57
1960	8.7	-.0	-.1	347	5.7	.2	.2	79	13.0	-.2	-.2	97
1961	9.1	.4	.6	490	5.9	.4	.5	89	13.4	.2	.2	135
1962	9.2	.5	.7	709	5.6	.1	.1	144	14.0	.7	.7	213
1963	9.5	.7	1.2	761	6.5	1.0	1.1	175	13.7	.4	.4	230
1964	8.7	-.0	-.0	728	6.3	.9	.9	129	12.5	-.7	-.7	186
1965	7.7	-1.0	-1.6	821	4.6	-.9	-.9	176	11.7	-1.5	-1.4	223
1966	8.0	-.8	-1.2	933	4.9	-.6	-.6	187	12.4	-.8	-.7	245
1967	8.5	-.2	-.3	1266	5.1	-.4	-.4	253	13.1	-.1	-.1	300
1968	8.5	-.3	-.4	1100	5.3	-.2	-.2	216	13.7	.5	.4	270
1969	7.8	-1.0	-1.5	773	3.9	-1.6	-1.7	167	12.1	-1.1	-1.0	224
1970	8.1	-.6	-.9	992	5.5	.1	.1	194	11.6	-1.6	-1.5	295
1971	7.0	-1.7	-2.6	866	4.7	-.8	-.8	230	11.1	-2.1	-1.9	148
1972	7.1	-1.7	-2.6	767	3.4	-2.0	-2.1	164	12.2	-1.0	-.9	241
1973	7.2	-1.5	-2.3	508	4.4	-1.1	-1.2	142	11.1	-2.1	-2.0	130
1974	7.9	-.8	-1.3	632	4.3	-1.2	-1.3	116	12.8	-.4	-.4	179
1975	7.3	-1.4	-2.2	2018	4.5	-.9	-1.0	666	11.8	-1.5	-1.3	543

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	6.7	-.0	-.1	272	3.3	-.6	-2.0	35	10.8	.2	.3	119
1950	6.6	-.1	-.3	261	4.3	.4	1.2	44	10.7	.1	.2	68
1951	6.9	.1	.4	414	3.6	-.3	-1.0	67	11.1	.5	1.0	135
1952	6.4	-.3	-1.2	358	3.9	-.1	-.2	61	10.0	-.6	-1.2	106
1953	6.9	.1	.4	425	3.7	-.3	-.8	73	11.1	.5	1.0	173
1954	6.9	.2	.7	504	3.6	-.3	-1.0	73	11.1	.5	.9	203
1955	6.4	-.3	-1.1	566	4.1	.1	.4	83	10.2	-.4	-.7	242
1956	6.4	-.3	-1.2	712	3.6	-.3	-1.0	117	10.1	-.6	-1.1	256
1957	7.5	.7	2.5	789	4.5	.5	1.8	89	11.0	.4	.8	327
1958	6.7	-.1	-.2	1162	4.1	.2	.7	113	9.9	-.7	-1.3	328
1959	6.9	.1	.4	879	4.1	.2	.6	275	10.7	.1	.2	280
1960	6.6	-.1	-.4	929	3.6	-.3	-1.0	168	10.9	.3	.5	336
1961	6.9	.2	.6	830	3.8	-.1	-.4	169	10.8	.2	.3	326
1962	6.7	-.1	-.2	1077	3.9	-.0	-.1	206	11.0	.4	.7	329
1963	7.1	.3	1.1	1317	4.4	.5	1.6	261	11.0	.4	.7	420
1964	6.6	-.1	-.4	1527	4.2	.3	.9	269	10.1	-.5	-1.0	450
1965	6.6	-.1	-.4	1545	4.1	.2	.5	313	10.6	.0	.0	483
1966	6.2	-.5	-1.8	2218	3.9	-.0	-.0	479	9.3	-1.3	-2.5	672
1967	7.0	.3	1.0	3100	3.9	-.1	-.2	584	11.2	.6	1.1	884
1968	6.5	-.3	-1.0	3020	3.9	-.0	-.1	502	10.1	-.5	-.9	686
1969	6.7	-.1	-.2	1647	3.5	-.4	-1.5	330	11.1	.4	.8	530
1970	6.7	-.0	-.1	1916	4.2	.3	.9	395	9.7	-.9	-1.6	592
1971	5.7	-1.1	-3.8	1369	3.8	-.2	-.6	293	8.8	-1.8	-3.4	364
1972	5.8	-1.0	-3.4	1103	3.4	-.5	-1.8	163	9.5	-1.1	-2.1	303
1973	5.9	-.8	-3.0	1464	3.7	-.3	-.9	290	9.2	-1.4	-2.7	392
1974	6.5	-.2	-.8	1543	3.4	-.5	-1.7	249	10.8	.2	.3	428
1975	6.0	-.7	-2.6	1633	3.7	-.3	-.9	350	9.6	-1.0	-2.0	480

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	5.9	-.3	-1.0	201	3.6	-.4	-1.1	43	9.0	-.4	-1.0	66
1950	6.1	-.1	-.5	188	4.4	.4	1.2	30	9.4	.0	.1	49
1951	6.3	.0	.1	367	3.6	-.4	-1.1	62	9.9	.5	1.3	118
1952	5.9	-.3	-1.1	272	3.7	-.3	-.8	41	9.1	-.3	-.7	75
1953	6.3	.0	.0	319	3.8	-.1	-.4	42	9.6	.2	.4	124
1954	6.2	.0	.0	370	3.4	-.5	-1.5	51	9.5	.1	.3	160
1955	6.2	-.1	-.2	371	4.1	.2	.4	66	9.3	-.1	-.3	132
1956	6.3	.0	.1	636	4.1	.1	.4	92	9.2	-.2	-.6	251
1957	6.8	.5	1.8	778	4.3	.3	1.0	87	9.7	.3	.7	270
1958	6.4	.2	.5	762	4.3	.3	.9	83	9.4	.0	.0	274
1959	6.3	.1	.3	878	3.7	-.3	-.8	102	9.9	.5	1.2	338
1960	5.9	-.3	-1.2	920	3.6	-.3	-.9	171	9.3	-.0	-.1	302
1961	6.3	.1	.2	451	3.8	-.2	-.4	123	9.2	-.2	-.4	93
1962	6.2	-.1	-.3	413	4.1	.1	.4	71	9.4	.1	.1	130
1963	6.3	.1	.2	422	4.0	.0	.0	129	9.5	.1	.2	140
1964	5.9	-.4	-1.2	1737	4.2	.3	.7	270	8.3	-1.1	-2.7	611
1965	6.1	-.2	-.6	1790	3.9	-.1	-.3	299	9.2	-.2	-.5	580
1966	6.2	-.0	-.0	334	3.9	-.1	-.2	101	9.4	-.0	-.1	105
1967	7.1	.8	2.9	368	4.9	.9	2.6	63	10.2	.8	2.1	117
1968	6.4	.1	.5	373	4.5	.5	1.4	81	9.2	-.2	-.6	107
1969	6.7	.4	1.5	317	4.3	.3	.9	51	9.8	.4	.9	122
1970	6.8	.6	2.1	374	4.6	.6	1.7	81	9.4	.0	.0	120
1971	5.8	-.4	-1.4	546	5.2	1.2	3.4	57	7.9	-1.5	-3.8	68
1972	5.5	-.8	-2.7	938	3.6	-.4	-1.0	175	8.5	-.9	-2.3	223
1973	5.4	-.9	-2.9	1280	3.3	-.7	-2.0	238	8.0	-1.4	-3.4	352
1974	6.1	-.2	-.6	1257	3.8	-.1	-.3	217	9.3	-.1	-.2	413
1975	5.6	-.7	-2.3	1369	3.5	-.5	-1.3	272	8.5	-.9	-2.3	453

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	23.4	-.1	-.1	173	25.8	.7	.9	60	21.6	-.7	-.8	47
1950	23.3	-.2	-.2	168	25.1	-.0	-.0	41	23.0	.7	.7	40
1951	24.4	1.0	1.2	265	25.5	.4	.6	63	23.9	1.6	1.8	90
1952	23.1	-.4	-.5	305	24.7	-.4	-.5	78	22.3	-.0	-.0	75
1953	24.6	1.2	1.5	152	26.6	1.5	2.0	49	23.6	1.3	1.5	31
1954	22.3	-1.2	-1.5	267	23.5	-1.6	-2.1	57	21.6	-.7	-.7	47
1955	21.9	-1.6	-2.0	233	23.9	-1.2	-1.6	38	20.4	-1.9	-2.1	39
1956	23.4	-.1	-.1	312	24.8	-.3	-.4	63	22.7	.4	.4	62
1957	24.8	1.4	1.7	370	25.3	.2	.3	61	23.8	1.5	1.6	67
1958	24.2	.7	.9	578	25.9	.8	1.1	114	22.4	.1	.1	135
1959	23.9	.4	.6	718	25.5	.4	.5	207	22.6	.3	.4	191
1960	23.4	-.1	-.1	755	24.9	-.1	-.2	177	22.0	-.3	-.4	231
1961	23.1	-.3	-.4	1002	25.2	.1	.2	211	21.3	-1.0	-1.1	269
1962	22.9	-.6	-.7	1069	24.0	-1.1	-1.4	275	21.8	-.5	-.5	322
1963	23.2	-.2	-.3	719	24.8	-.3	-.4	154	22.1	-.2	-.2	156
1964	22.7	-.7	-.9	630	24.4	-.7	-.9	198	21.5	-.8	-.9	119
1965	24.5	1.1	1.3	815	25.7	.6	.8	171	23.0	.7	.8	137
1966	23.4	.0	.0	902	25.4	.3	.5	203	22.4	.1	.1	293
1967	22.9	-.5	-.6	646	25.1	.1	.1	132	21.7	-.6	-.7	159
1968	22.6	-.9	-1.1	578	23.3	-1.8	-2.4	180	21.8	-.5	-.5	136
1969	24.0	.5	.6	573	24.5	-.6	-.8	166	22.4	.1	.1	122
1970	22.8	-.7	-.8	525	24.1	-.9	-1.2	163	21.4	-.9	-1.0	110
1971	23.3	-.2	-.2	557	24.4	-.7	-.9	144	22.4	.1	.1	108
1972	25.1	1.7	2.1	522	26.6	1.5	2.0	103	24.7	2.4	2.6	171
1973	INSUF DATA				INSUF DATA				21.0	-1.2	-1.4	22
1974	INSUF DATA				25.0	-.1	-.1	23	22.5	.2	.2	23
1975	INSUF DATA				25.3	.2	.3	18	INSUF DATA			

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YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	23.3	-.2	-.3	270	25.6	-.2	-.4	60	20.7	-.6	-.6	64
1949	23.0	-.5	-.7	288	25.4	-.4	-.8	68	20.3	-1.1	-1.0	67
1950	22.7	-.8	-1.1	447	24.6	-1.2	-2.3	96	20.9	-.5	-.5	105
1951	24.9	1.4	1.9	262	26.2	.4	.8	52	23.7	2.3	2.0	90
1952	23.6	.1	.1	337	26.5	.7	1.4	80	20.9	-.5	-.4	86
1953	24.5	1.0	1.4	351	26.5	.7	1.4	115	22.4	1.0	.9	92
1954	22.4	-1.1	-1.5	378	25.6	-.2	-.4	72	19.9	-1.5	-1.4	83
1955	INSUF DATA				25.6	-.2	-.4	87	20.6	-.8	-.7	64
1956	INSUF DATA				25.2	-.5	-1.1	16	INSUF DATA			
1957	INSUF DATA				25.9	.1	.2	17	23.6	2.2	1.9	30
1958	INSUF DATA				27.0	1.2	2.3	17	INSUF DATA			
1959	23.6	.1	.1	470	25.5	-.2	-.4	134	21.3	-.1	-.1	76
1960	23.2	-.3	-.4	363	25.5	-.2	-.4	103	21.3	-.1	-.0	79
1961	23.3	-.2	-.2	493	26.1	.4	.7	142	20.6	-.8	-.7	97
1962	23.0	-.5	-.6	445	25.8	.0	.0	111	21.0	-.4	-.4	89
1963	23.9	.4	.5	446	25.5	-.2	-.4	108	22.4	1.1	.9	115
1964	22.6	-.9	-1.2	671	25.6	-.1	-.2	300	20.4	-.9	-.8	114
1965	24.6	1.1	1.5	505	25.9	.1	.3	132	22.8	1.4	1.2	130
1966	23.1	-.4	-.6	519	26.0	.2	.4	135	20.8	-.6	-.5	115
1967	23.0	-.5	-.7	445	25.4	-.4	-.7	153	20.7	-.7	-.6	87
1968	23.3	-.2	-.2	515	24.4	-1.4	-2.7	158	22.2	.8	.7	95
1969	24.7	1.2	1.6	530	25.8	.0	.1	162	22.9	1.5	1.3	102
1970	23.0	-.5	-.7	556	26.1	.3	.6	145	20.3	-1.1	-1.0	118
1971	23.2	-.3	-.5	391	25.1	-.7	-1.3	147	21.2	-.2	-.2	88
1972	25.1	1.6	2.2	142	26.1	.4	.7	39	24.0	2.6	2.3	36
1973	INSUF DATA				27.2	1.5	2.8	43	20.4	-.9	-.8	26
1974	23.2	-.3	-.4	170	25.4	-.4	-.7	42	21.1	-.3	-.3	43
1975	23.0	-.5	-.7	170	25.0	-.7	-1.4	36	21.2	-.2	-.2	44

YEAR	ANNUAL VALUE	ANNUAL ANOMALY	ANNUAL Z-STAT	ANNUAL OBS	JANFEBMAR VALUE	JANFEBMAR ANOMALY	JANFEBMAR Z-STAT	JANFEBMAR OBS	JULAUGSEP VALUE	JULAUGSEP ANOMALY	JULAUGSEP Z-STAT	JULAUGSEP OBS
1948	INSUF DATA				INSUF DATA				INSUF DATA			
1949	INSUF DATA				22.0	.7	.7	39	INSUF DATA			
1950	17.7	-1.1	-1.1	127	20.9	-.5	-.5	19	16.3	-.5	-.4	39
1951	19.8	1.0	1.0	252	20.5	-.8	-.8	58	18.9	2.2	1.8	88
1952	18.8	-.1	-.1	145	21.9	.6	.6	50	16.2	-.6	-.5	25
1953	19.8	1.0	1.0	132	21.6	.3	.3	37	18.0	1.2	1.0	34
1954	17.0	-1.9	-1.9	188	20.5	-.8	-.8	56	14.4	-2.4	-2.0	42
1955	INSUF DATA				19.1	-2.3	-2.2	36	15.7	-1.1	-.9	43
1956	18.5	-.4	-.4	146	19.5	-1.8	-1.8	23	16.9	.1	.1	41
1957	20.8	2.0	1.9	284	22.1	.8	.7	74	19.3	2.5	2.1	43
1958	20.0	1.2	1.1	545	23.5	2.2	2.1	179	17.4	.6	.5	129
1959	19.1	.2	.2	453	22.0	.6	.6	166	16.4	-.4	-.3	103
1960	19.3	.4	.4	528	22.0	.7	.7	145	17.0	.3	.2	146
1961	19.0	.2	.2	680	22.0	.7	.6	166	16.7	-.0	-.0	165
1962	18.6	-.2	-.2	717	20.9	-.5	-.5	207	16.7	-.1	-.1	192
1963	19.3	.4	.4	515	21.4	.0	.0	146	17.5	.7	.6	111
1964	18.4	-.5	-.5	428	21.1	-.2	-.2	144	15.8	-.9	-.8	93
1965	20.3	1.4	1.4	466	21.9	.6	.6	107	18.2	1.4	1.1	114
1966	19.0	.2	.2	414	22.0	.7	.7	96	16.4	-.4	-.3	124
1967	17.6	-1.3	-1.3	249	20.4	-.9	-.9	70	15.5	-1.3	-1.0	64
1968	18.3	-.6	-.6	279	21.5	.2	.2	64	16.4	-.4	-.3	60
1969	19.4	.6	.5	294	21.8	.5	.5	62	17.0	.2	.2	72
1970	17.8	-1.1	-1.1	371	20.7	-.6	-.6	83	15.4	-1.4	-1.1	78
1971	INSUF DATA				19.9	-1.5	-1.4	103	16.7	-.1	-.1	28
1972	INSUF DATA				INSUF DATA				INSUF DATA			
1973	INSUF DATA				INSUF DATA				INSUF DATA			
1974	INSUF DATA				20.7	-.7	-.6	25	16.8	.0	.0	21
1975	INSUF DATA				22.8	1.5	1.4	18	INSUF DATA			

Section 5

ANOMALIES OF COASTAL SEA SURFACE TEMPERATURES ALONG THE WEST COAST OF NORTH AMERICA

Douglas R. McLain[1]

In their 1976 report, McLain and Favorite presented data on below normal temperatures in the southeastern Bering Sea from 1971 to May 1975 and effects on sockeye salmon and halibut resources. This article will update that report through December 1975 and provide updated time series of coastal sea surface temperature (SST) anomalies from the Aleutian Islands to California.

DATA SOURCES AND PROCESSING

Two sources of SST data and one source of air temperature data were used for this report. The first source of data is the monthly means of SST observations in 5 degree blocks of longitude by latitude ("index stations") in the North Pacific described by Johnson et al. (1976). The index stations chosen were those along the coast from California (120-2) to the Pacific Northwest (157-3), the Gulf of Alaska (195-39), and the Aleutian Chain (197-1 and 198-1). As stated by Johnson et al. (1976), these are means of edited SST observations from merchant and naval ships. Each mean was based on at least 12 temperature observations.

The second source of data is the monthly means of daily surface temperature observations at coastal tide gage stations operated by the U.S. National Ocean Survey (NOS) and at light stations operated by the Canadian Ministry of Transport. The stations presented were chosen for their proximity to the open coast. The U.S. historical data were keypunched from NOS forms whereas 1975 data were punched from special monthly summary cards provided by NOS. Data from British Columbia stations were taken from

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[1]Pacific Environmental Group, National Marine Fisheries Service, NOAA, Monterey, CA 93940.

Hollister and Sandnes (1972) with more recent data provided by Giovando.[2]

The third source of data is the monthly means of air temperature observations at National Weather Service (NWS) stations in the Gulf of Alaska and Bering Sea region. These data were obtained from the National Climatic Center, Asheville, NC 28801, and are used to supplement the SST data in the Bering Sea where long historical records of SST's are not available. Again the stations were chosen for their relatively exposed locations.

Long-term monthly means of available data during the 20-yr period 1948-67 were computed for all three sets of data (Table 5.1). This period was chosen as a standard reference period for use with a variety of time series data at NMFS Pacific Environmental Group as it is a recent 20-yr period in which numerous data are available in the various data files. It is also used as a standard period in the monthly _Fishing Information_ published by the Southwest Fisheries Center, NMFS, La Jolla, CA 92038.

Many time series of historical environmental data suffer from gaps of greater or lesser extent. Such gaps in coverage were particularly serious at index station 195-3 and at the NOS coastal station at Unalaska, AK. The number of years of record used for the various 20-yr means are shown in Table 5.2.

Anomalies of temperature were computed as the difference between the observed monthly mean and the 1948-67 monthly mean. All anomalies were plotted in time series form on an electrostatic plotter in a manner similar to that used by Robinson (1960) and Stearns (1964).

INDEX STATION SEA SURFACE TEMPERATURES

The data from the five "index stations" (Fig. 5.1) show that sea temperatures during 1975 along the entire coast from California to the Aleutians were colder than the 1948-67 mean and continued a period of below normal temperatures that has existed since 1973 off California and since 1971 or earlier at the northern stations.

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[2]Personal communication from L. F. Giovando, Environment Canada, Vancouver, B.C.

The cold anomalies appear most intense in the Gulf of Alaska at station 195-3. This, however, may be a result of the varying distribution of data in time. The reference period used, 1948-67, was characterized by generally warm temperatures, dominated by the very warm temperatures from 1957-59. Therefore the temperatures since 1967--particularly since 1971--appear as strong, persistent negative anomalies. If the reference period had been of longer duration the recent years might not appear as anomalously cold as in Figure 5.1.

The recent period of negative anomalies appears to have started in summer 1964 in the Gulf of Alaska (station 195-3) but not until mid-1971 at the other stations. This again may be a result of the sparse sampling from 1948 to 1955 and intense positive anomalies in 1957-59.

COASTAL SEA SURFACE TEMPERATURES

The SST data available from U.S. coastal tide gage stations (Figs. 5.2-5.4) are monthly means of 12 or more daily temperature observations at docks in protected harbors. The values thus are not as typical of open ocean conditions as are the "index station" data because of processes occurring in the harbors such as local river runoff and local heating and cooling in shallow waters. The time coverage of the data is generally good although significant gaps occur in the records.

The SST data from the British Columbia stations were taken at light stations on exposed points and thus are not as subject to local heating and cooling processes as are the U.S. tide gage observations. Each mean is the mean of at least 13 daily observations.

The coastal temperature data from the Alaskan stations show a period of negative SST anomalies from early 1971 to mid-1973 with the winters of 1973-74 and 1974-75 above normal. Temperatures during 1975 were near normal at Gulf of Alaska stations (Yakutat and Seward) while temperatures in the Aleutians were slightly below normal.

Off southeastern Alaska and British Columbia (Fig. 5.3), there have been persistent, negative anomalies since mid-1970, particularly at Sitka, AK. Data from the British Columbia stations for 1975 were, however, not available in time for this report. Exceptions to the trend of negative anomalies occurred at the British Columbia stations in fall 1974 and to a lesser extent in summers of 1971-73.

There have been persistent, negative temperature anomalies since early 1970 at Neah Bay, WA, but not at stations farther south (Fig. 5.4). Strong, positive anomalies occurred at Crescent City, San Francisco, and Avila Beach, CA, during 1972 and 1973.

There is significant station-to-station coherence of the temperature data in cases where there are no data gaps. Note, for example, the negative anomalies during late 1955, 1956, and early 1957 at coastal stations from Unalaska, AK, to Avila Beach, CA. Other examples are: 1) positive anomalies during 1957 and 1958 from Unalaska to Crescent City, and extending into 1959 and 1960 at Avila Beach and La Jolla, CA; 2) positive anomalies during 1940 and 1941 at all stations having data from these years; and 3) positive anomalies during 1963 from Kodiak, AK, to La Jolla, CA. Robinson (1960) described such coherence using data from 24 coastal stations from Yakutat to La Jolla.

The coherence of negative temperature anomalies during 1971 and 1972 at stations from Adak, AK, to Crescent City or San Francisco is striking. The anomaly appears most intense at Yakutat but unfortunately data are missing from that station during the last half of 1972 and most of 1973.

NATIONAL WEATHER SERVICE AIR TEMPERATURES

Air temperature data from the Bering Sea region are included here because of the lack of available SST records from the region. Air temperatures are closely related to sea surface temperatures in open ocean areas but near land may be only remotely related to sea temperatures. Lacking suitable SST records, air temperature records provide continuous monitoring data for coastal areas. Air temperature data are also included here partially to update through 1975 the data provided by McLain and Favorite (1976). Air temperature observations normally have a greater variability than SST observations and thus anomalies of air temperature were plotted at one-half the scale of sea temperature anomaly data. Air temperatures were most variable at King Salmon, AK, and least variable at Shemya, AK, reflecting the more continental climate at King Salmon and maritime climate at Shemya.

The air temperature records show relatively persistent, negative anomalies at all five Alaskan stations since early 1971, particularly at St. Paul Island, Cold Bay, and Kodiak. Exceptions are the winters of 1972-73 and 1973-74. Air temperatures at all five stations were colder than normal during most months of 1975 and were similar to the cold years of 1971 and 1972.

RELATION OF DATA SETS

The marked persistence of the cold anomalies since 1971 observed at the oceanic "index stations" in the Gulf of Alaska and eastern Aleutian Island areas was not well reflected in the coastal sea and air temperature records. Whereas the index station data showed extreme persistence of negative anomalies, the coastal station data were more variable. Thus it appears that the index station data are indicative of a large scale, oceanic fluctuation while the coastal sea and air temperature records reflect the oceanic fluctuation but contain significant distortions due to land or to smaller scale processes.

The air temperature anomaly data (Fig. 5.5) provide some verification of this hypothesis. To quantify the persistence of anomalies, the ratio of the number of months with positive anomalies to the number of months with negative anomalies was computed for the five air temperature stations for the years 1971-75. Months with missing data were ignored. The ratio would be 0.0 for completely persistent negative anomalies and 1.0 for random anomalies. The computed ratios for the Alaska stations are as follows:

Shemya	0.60
St. Paul Island	0.28
Cold Bay	0.46
King Salmon	0.82
Kodiak	0.18

Thus the negative anomalies of air temperature in southeastern Alaska were most persistent at St. Paul Island and Kodiak. Both are island stations and have typical maritime climates. In contrast King Salmon, at the head of Bristol Bay, has a more continental climate and the least persistent negative anomalies. Cold Bay, on the Alaska Peninsula, has a climate intermediate between maritime and continental and had anomalies of intermediate persistence. Shemya also had anomalies of intermediate persistence.

The well-known period of warm temperatures along the west coast during 1957-59 can be seen at all five index stations but it is interesting that in Alaskan areas the negative anomalies since 1971 are of greater magnitude and duration than the positive anomalies of 1957-59. The positive anomalies appear first in late 1956 at station 198-1 and later in early or middle 1957 in the Gulf of Alaska (195-3). The positive anomalies persist later in 1959, 1960, and even 1961 at the southern stations than at the northern stations. This was noted by Robinson (1961) from four coastal stations (Ketchikan, AK, Departure Bay, B.C., and Pacific Grove and La Jolla, CA). This is in agreement with the suggestion of Favorite and McLain (1973) that SST anomalies may drift with ocean currents, but it is not well verified by data from the 15 coastal stations presented herein.

EFFECTS ON FISHERIES

Air temperatures in the southeastern Bering Sea region (at St. Paul Island and King Salmon) during 1975 were anomalously low and similar to the years 1971 and 1972. It has been hypothesized that in 1971 and 1972 growth and survival of sockeye salmon and halibut in the region were below normal (catch statistics have not been analyzed by the authors) and one might hypothesize again that growth would be below normal in 1975 because of cold temperatures.

Water temperatures in lakes in the Bristol Bay region were lower in 1975 than in the warmer year 1974. For example, scientists of the NMFS Fisheries Laboratory at Auke Bay, AK, found that the heat content in Lake Nunavangaluk, near Dillingham, a tributary to Bristol Bay, was significantly less than in 1974.[3] The scientists speculated that biological productivity and growth of juvenile sockeye salmon would be affected by the low temperatures.

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[3]Northwest Fisheries Center Monthly Report, December 1975, National Marine Fisheries Service, Seattle, WA 98112.

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Table 5.1.--Mean temperature for 1948-67 (degrees C) at various stations in the northeast Pacific.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Index stations (5 degree blocks of latitude and longitude) (Fig. 5.1).												
198-1	4.3	3.9	3.7	4.1	5.0	6.3	8.3	10.1	9.8	8.0	6.4	5.
197-1	4.3	3.8	3.8	4.1	5.3	7.2	9.6	11.2	10.9	8.8	6.7	5.
195-3	5.8	5.7	5.3	5.9	7.4	10.5	12.6	14.3	13.0	10.5	8.3	6.
157-3	9.0	8.6	8.4	9.1	10.7	12.8	14.4	15.8	15.6	14.0	11.8	10.
120-2	15.1	14.9	14.9	15.4	16.0	16.8	18.3	19.6	19.5	19.0	17.6	16.
NOS Coastal Sea Surface Temperature Stations (Figs. 5.2-5.4).												
Adak, AK	2.9	2.6	3.2	3.6	4.8	6.3	7.4	7.7	7.5	5.9	4.5	3.
Unalaska, AK	2.4	2.1	2.6	3.9	5.5	7.6	9.4	9.8	8.6	6.0	4.5	2.
Kodiak, AK	0.4	0.7	1.2	3.7	6.6	9.1	11.7	12.2	10.1	6.7	3.6	1.
Seward, AK	3.3	3.0	3.1	4.2	7.2	10.2	12.0	12.1	10.4	8.2	6.1	4.
Yakutat, AK	3.5	3.2	3.6	5.2	7.8	10.7	12.8	12.8	11.4	8.7	6.5	4.
Sitka, AK	4.7	4.3	4.5	6.0	8.8	11.4	13.6	14.2	12.3	9.3	7.2	5.
Langara Is., B.C.	6.1	6.0	6.0	6.8	8.2	9.5	10.8	11.5	11.6	10.4	8.5	7.
Cape St. James, B.C.	7.3	7.0	6.8	7.3	8.5	10.1	11.8	12.6	11.8	9.9	8.6	7.
Kains Is., B.C.	7.6	7.5	7.6	8.5	10.0	11.3	12.4	13.2	13.0	11.4	9.6	8.
Amphitrite Pt., B.C.	7.5	7.7	8.0	9.0	10.3	11.4	12.4	13.1	12.8	11.5	10.1	8.
Neah Bay, WA	7.2	7.4	7.7	9.1	10.6	11.7	11.9	11.9	11.6	10.9	9.5	8.
Crescent City, CA	9.6	10.1	10.2	11.0	11.7	12.6	13.5	14.4	14.0	12.6	11.3	10.
San Francisco, CA	10.2	10.7	11.2	12.2	12.7	13.5	14.2	15.1	15.4	14.7	12.7	10.
Avila Beach, CA	12.2	12.3	12.1	12.6	13.0	13.9	15.2	15.8	15.6	14.9	13.9	12.
La Jolla, CA	13.9	13.9	14.2	15.4	16.7	18.0	19.7	20.8	19.3	17.9	16.3	14.
NWS Air Temperature Stations (Fig. 5.5).												
Shemya, AK	0.1	-0.4	0.3	1.8	3.9	5.6	8.0	9.6	8.6	5.5	2.1	0.
St. Paul Is., AK	-3.2	-5.2	-4.1	-2.0	1.6	4.9	7.6	8.6	6.8	2.9	0.6	-2.
Cold Bay, AK	-1.9	-2.2	-1.5	0.6	4.1	7.3	9.9	10.5	8.4	4.0	1.2	-1.
King Salmon, AK	-10.4	-10.2	-7.0	-0.7	5.6	10.2	12.4	12.1	8.6	0.6	-5.4	-11.
Kodiak, AK	-0.6	-0.7	-0.2	2.6	6.1	9.8	12.3	12.7	10.1	4.7	1.8	-1.

Table 5.2.--Number of years represented in 1948-67 means shown in Table 5.1.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Index Stations												
198-1	16	16	18	19	18	19	19	19	19	19	17	18
197-1	18	18	19	19	19	19	19	20	19	19	18	19
195-3	13	12	16	15	16	14	16	14	13	13	14	12
157-3	19	19	19	19	18	19	18	17	19	17	17	19
120-2	20	20	20	20	20	20	20	20	20	20	20	20
NOS Coastal Sea Surface Temperature Stations												
Adak, AK	13	12	15	16	17	19	19	18	17	18	17	17
Unalaska, AK	10	10	9	9	12	12	12	12	12	12	11	11
Kodiak, AK	15	14	14	14	15	16	16	15	15	15	16	16
Seward, AK	17	15	16	15	17	19	18	18	19	19	18	17
Yakutat, AK	20	20	20	20	19	20	20	20	20	20	20	20
Sitka, AK	20	20	20	20	20	20	20	20	20	20	20	20
Langara Is., B.C.	20	20	20	20	20	18	20	20	19	19	19	20
Cape St. James, B.C.	18	19	19	18	19	19	19	19	19	19	18	18
Kains Is., B.C.	20	20	20	20	20	19	20	20	20	20	20	19
Amphitrite Pt., B.C.	18	19	19	20	20	20	19	20	20	20	20	20
Neah Bay, WA	20	19	19	19	19	17	19	19	19	20	20	19
Crescent City, CA	17	17	17	16	16	17	16	17	18	17	17	18
San Francisco, CA	17	18	18	19	20	20	20	20	20	19	19	19
Avila Beach, CA	20	19	18	16	16	16	18	19	18	18	19	17
La Jolla, CA	20	20	20	20	20	20	20	20	20	20	20	20
NWS Air Temperature Stations												
Shemya, AK	19	19	19	19	19	19	19	19	19	19	19	19
St. Paul Is., AK	20	20	20	20	20	20	20	20	20	20	20	20
Cold Bay, AK	20	20	20	20	20	19	20	20	20	20	19	19
King Salmon, AK	20	20	20	20	20	20	20	20	20	20	20	20
Kodiak, AK	19	19	19	19	19	19	19	19	19	19	19	19

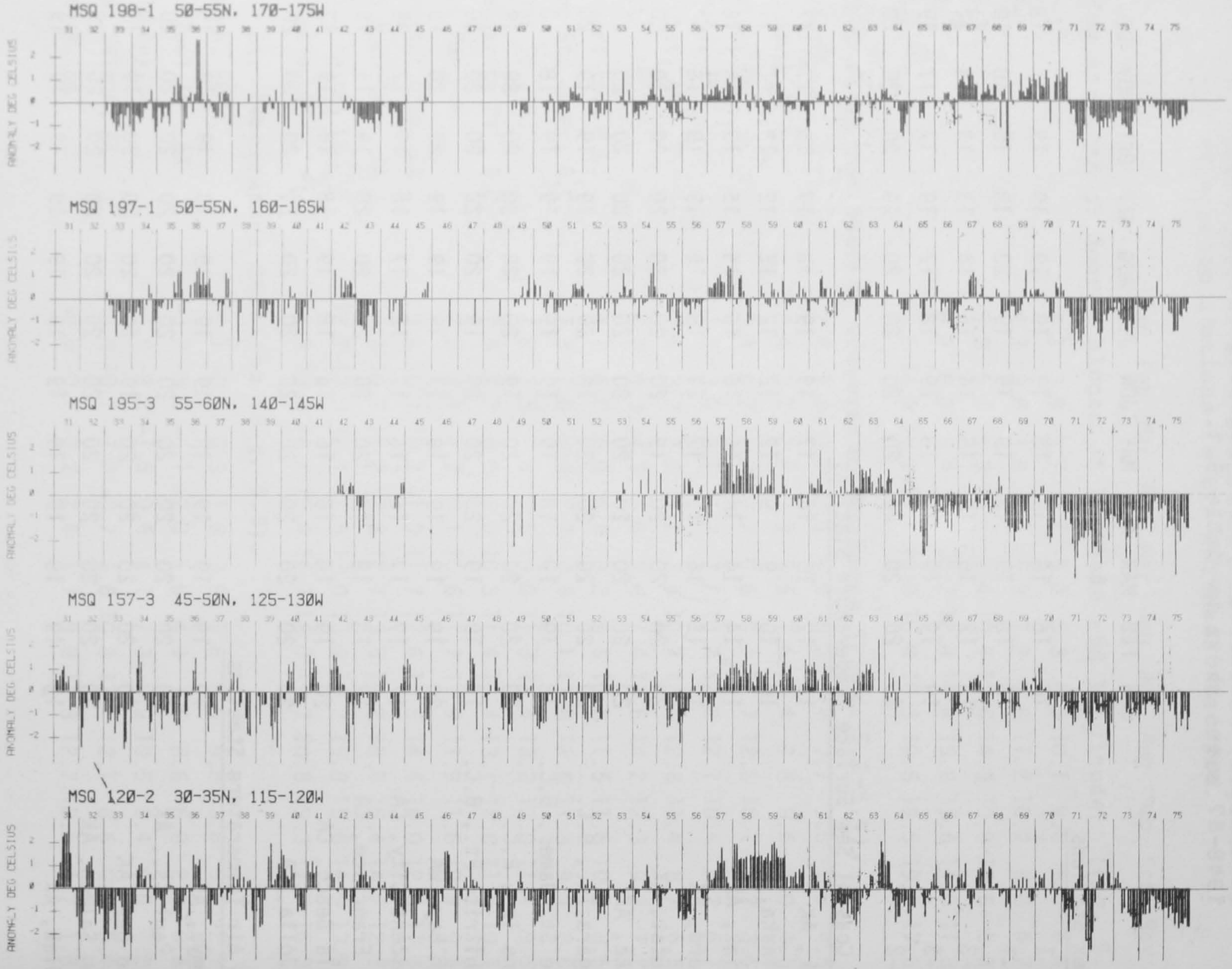

Figure 5.1.—Anomalies of sea surface temperature (degrees C) at "index stations" along the coast from central Aleutians to southern California. Index station numbers refer to Marsden square and quadrant.

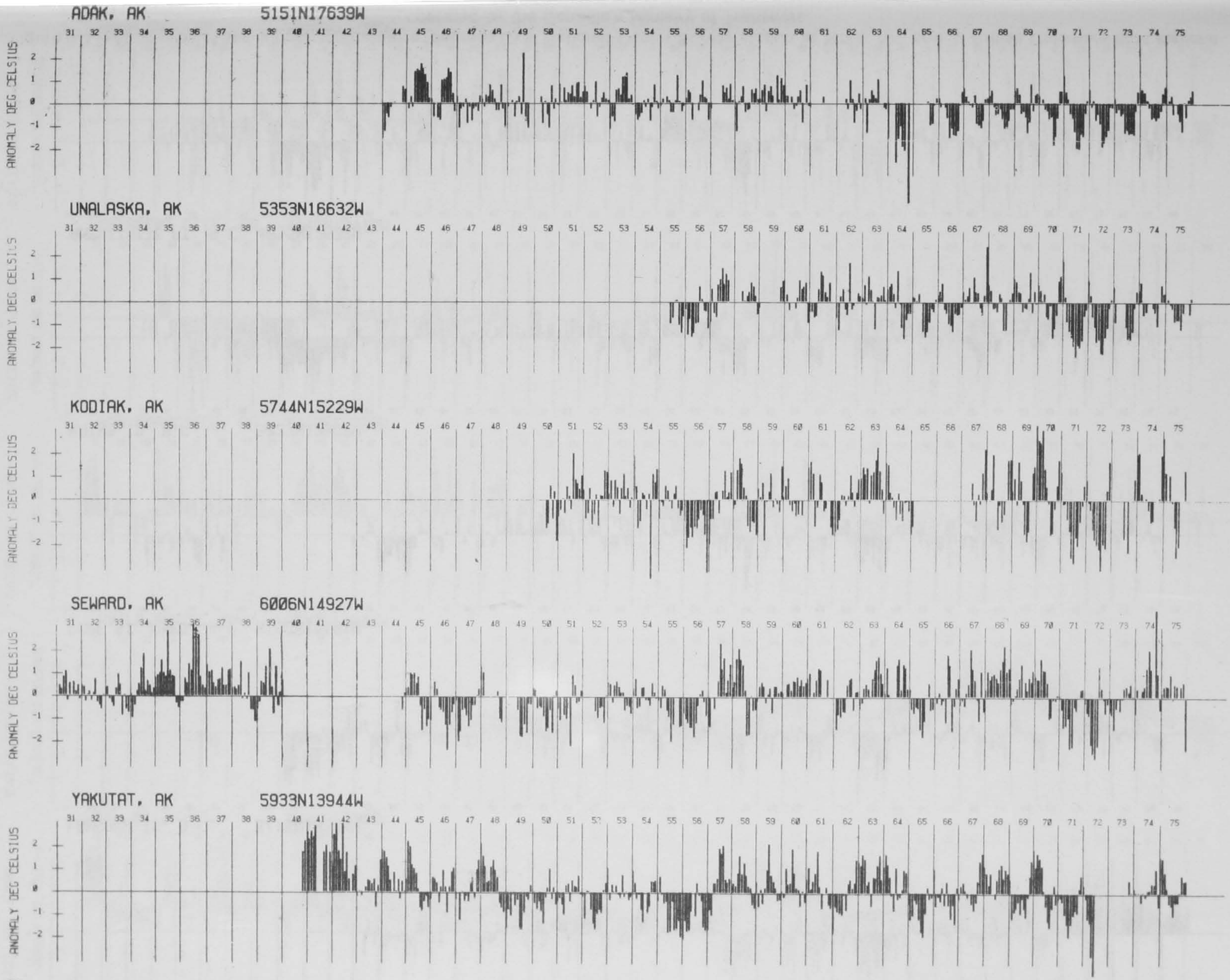

Figure 5.2.—Anomalies of sea surface temperature (degrees C) at selected National Ocean Survey coastal tide gage stations in southwestern and south central Alaska.

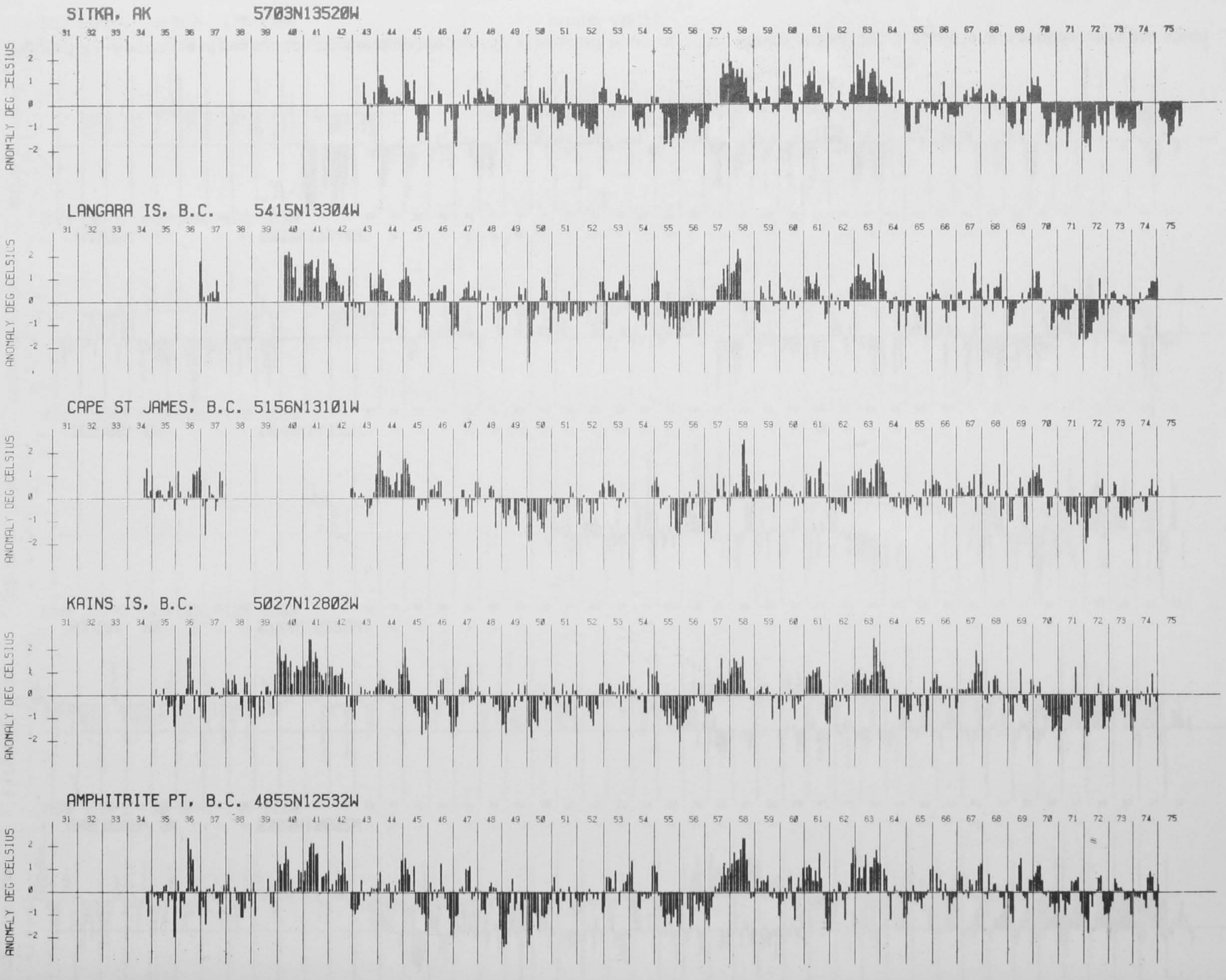

Figure 5.3.—Anomalies of sea surface temperature (degrees C) at National Ocean Survey station at Sitka, AK, and at British Columbia light stations operated by the Canadian Ministry of Transport.

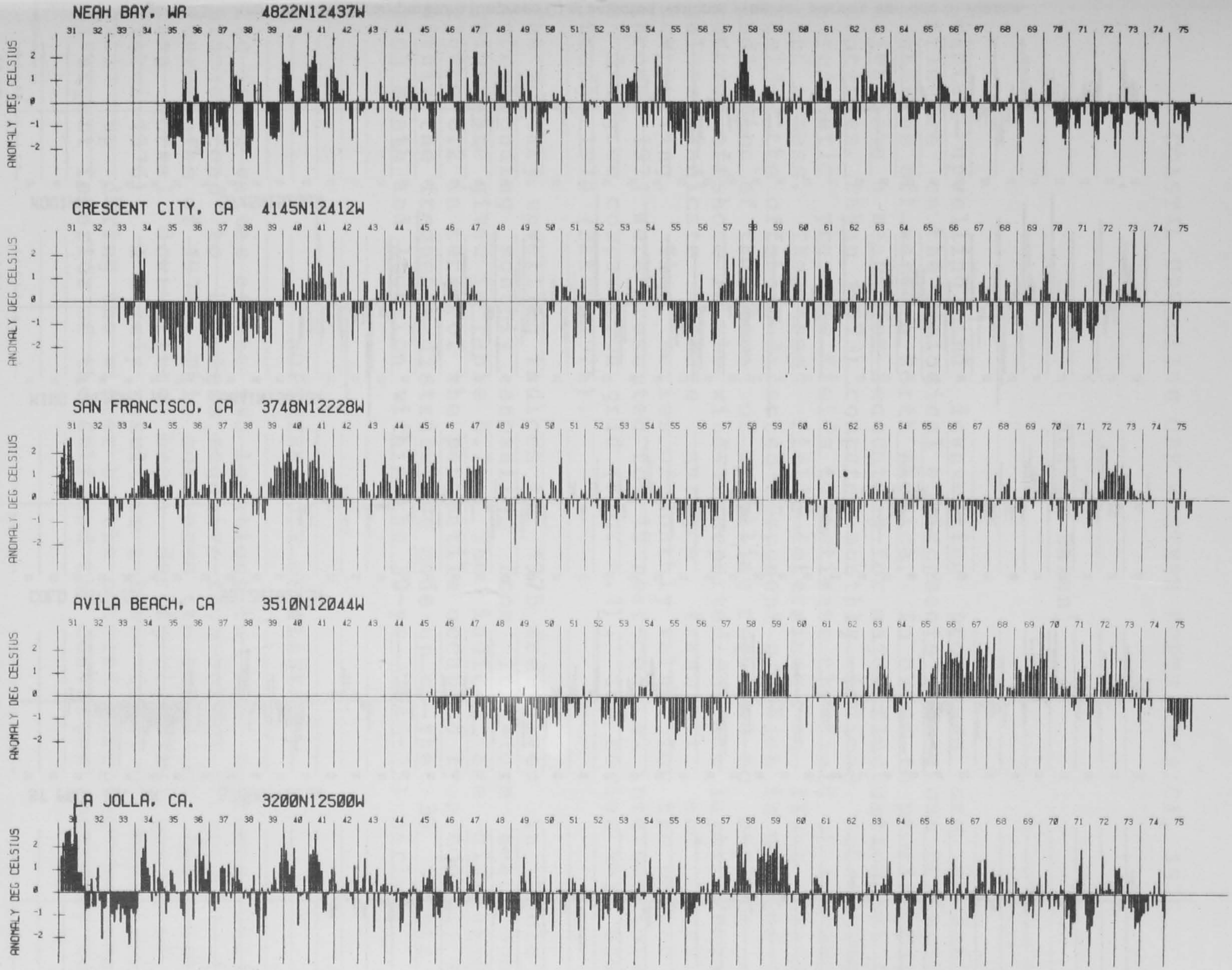

Figure 5.4.—Anomalies of sea surface temperature (degrees C) at selected National Ocean Survey coastal tide gage stations in Washington and California.

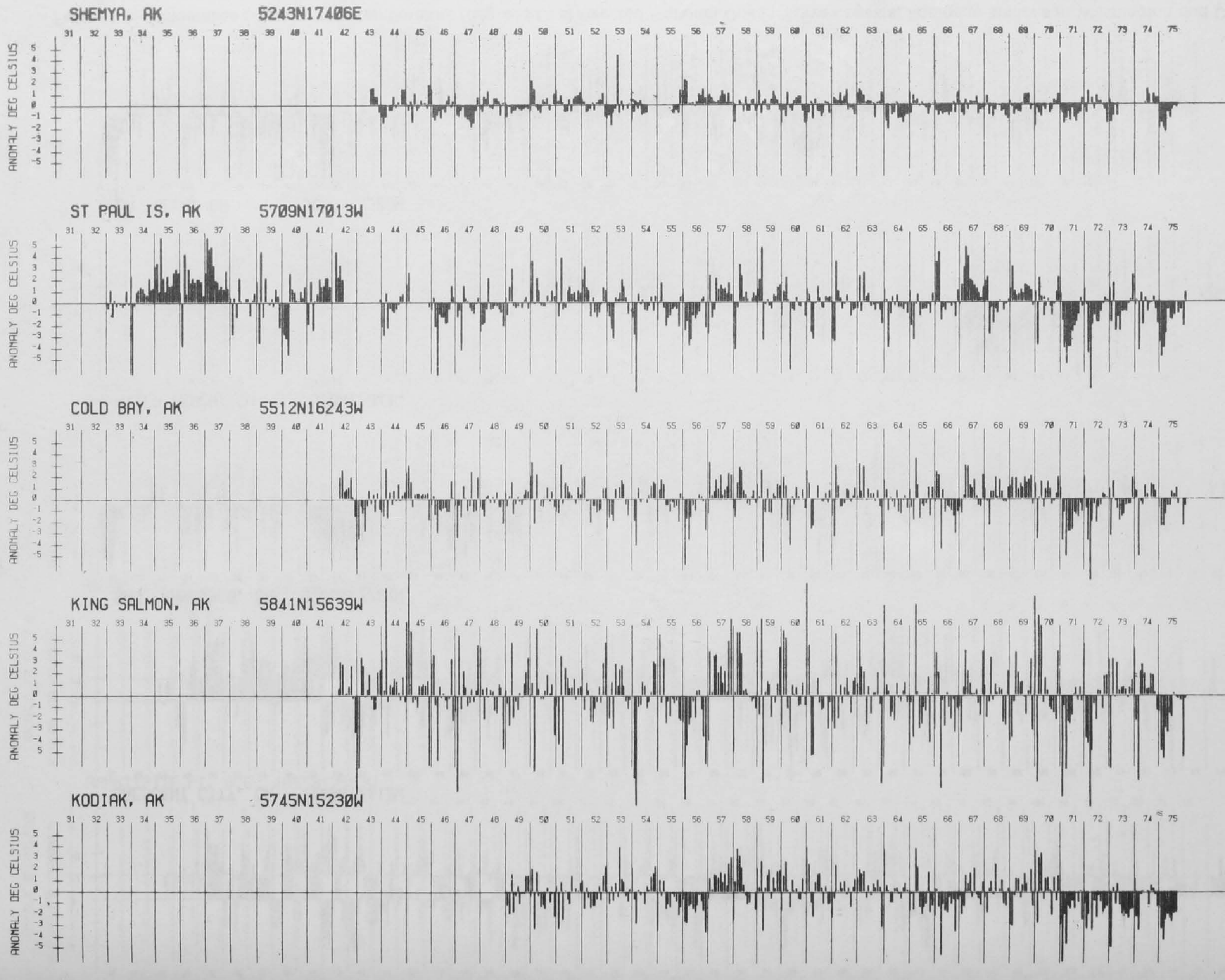

Figure 5.5.—Anomalies of air temperature (degrees C) at selected National Weather Service stations in Alaska.

Section 6

COASTAL UPWELLING OFF WESTERN NORTH AMERICA, 1975

Andrew Bakun[1]

Coastal upwelling and downwelling processes are a dominant influence on the biological environments in regions of important fisheries off western North America. In order to provide fishery scientists a means for accounting for major fluctuations in these processes, Bakun (1973) computed monthly indices using surface atmospheric pressure fields to estimate the field of sea surface wind stress. The stress field determines an Ekman transport field, the offshore-directed component of which is considered an indication of the amount of upwelling required to replace water carried offshore in the wind-transported surface layer. Negative values indicate onshore surface transport and resulting downwelling. Time series of monthly values for the period 1946 through 1971 were presented for 15 near-coastal intersections of a 3-degree computation grid (Fig. 6.1). The series were updated through 1974 (Bakun 1976).

The monthly upwelling indices for 1975 are given in Table 6.1; corresponding monthly anomalies from long-term mean monthly values are given in Table 6.2. The indices are displayed in Figure 6.2 in terms of the percentile occupied by a monthly value within the frequency distribution made up of the 30 values for each month and location within the 30-yr (1946-75) series.

NORTHERN GULF OF ALASKA

The index values at the two locations in the northern Gulf of Alaska tend to be less negative than normal through the first four months of 1975. This continues the trend of less intense than normal downwelling begun during the final months of 1974 (Bakun 1976). A likely result is a lower level of baroclinicity built up during the winter by the coupled "pumping" between the divergent interior of the Gulf and the convergent boundary region

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[1]Pacific Environmental Group, National Marine Fisheries Service, NOAA, Monterey, CA 93940.

(Bakun 1975a). It might be hypothesized that the counter-clockwise flow around the boundary of the Gulf may have experienced less than normal acceleration during this particular winter season.

The months of May through September were very relaxed (index values near zero) as is usual for this region. The only significant summer coastal upwelling, in terms of a monthly average, appears to have occurred in June. The indications of large percentile variations among the indices for these months (Fig. 6.2) are quite inconsequential because of the very small quantities of upwelling or downwelling

During October and November the indices are more negative During October and November the indices are more negative than normal, indicating more intense than normal downwelling at the coast, particularly during November. The December values correspond to a nearly normal situation of vigorous winter downwelling. Thus the early portion of winter 1975-76 contrasts with the markedly less intense corresponding portion of the previous winter, 1974-75.

EASTERN GULF OF ALASKA

Less intense than normal downwelling is indicated during January 1975 at the eastern Gulf locations (57N, 54N, and 51N). However, in February the downwelling at the coast appears to have been much more intense than normal. The indices for February are the most strongly negative of the entire 1974-75 season in contrast to the long-term mean seasonal progression where February is less intense than either December or January. During March and April the indices are anomalously positive (less negative) indicating a rapid relaxation of winter conditions; at 51N the indices are slightly positive, implying commencement of upwelling. In May the situation reverses; negative anomalies occur at all three locations. Slightly positive anomalies appear in June, whereas in July and August they tend to be slightly negative. The indices for the final months of 1975 indicate a fairly normal progression to conditions of energetic winter coastal downwelling, most intense in the northern part of the region and less intense toward the south.

VANCOUVER ISLAND TO CENTRAL OREGON

The patterns of positive anomalies (less vigorous than normal winter downwelling) during January, and negative anomalies (very vigorous downwelling) during February noted in the previous section continue to be apparent in the region from Vancouver Island to the central Oregon coast (i.e., series at 48N and 45N). Positive anomalies during March and April likewise reflect an early transition to summer upwelling conditions. Upwelling during May appears to have been slightly less vigorous than normal. However, strong positive anomalies appear in June, indicating an early peaking of the upwelling season in this region, where normally maximum values of the indices occur during July. The June value at 48N, in fact, reaches the 95th percentile (Fig. 6.2), i.e., the second largest June value at that location in the 30-yr series. Index values indicating generally normal upwelling intensities characterize the period July through September. During October an early shift to downwelling conditions again reflects the situation in the area to the north. During November anomalously intense downwelling continues to be indicated. However, a switch to strong positive anomalies, i.e., an abrupt relaxation of the level of coastal convergence and resultant downwelling, appears during December 1975.

CAPE BLANCO TO POINT CONCEPTION

The stretch of coastline from Cape Blanco to Point Conception encompasses the core of the California Current coastal upwelling region (Bakun et al. 1974). The winter season is generally characterized by nearly slack conditions, a result of a nearly equal mix of strong positive and negative events, while the summer season appears as a steady succession of energetic bursts of upwelling-producing activity (Bakun 1975b). These short scale features are of course averaged out in the monthly indices presented here.

The early part of 1975 is marked by the positive anomalies in January and negative anomalies in February noted in the regions to the north. March values are near normal at 42N and below normal at 39N and 36N. However, the month of April begins a remarkable series of strong positive upwelling index anomalies lasting through the month of September at all three locations. This series includes the highest June index values at 42N and 39N in the 30-yr record at each location. The tendency for positive anomalies continues, although less markedly, through the remainder of the year; significant upwelling appears to have occurred in the southern portion of the region even in December. Thus, 1975 appears to have been, in total, a year of unusually strong and sustained upwelling in this primary upwelling region of the California Current.

The two previous years, 1973 and 1974, were also years of notably strong upwelling in this region (Bakun 1976); thus we appear to have had a string of three consecutive years of unusually strong upwelling. In the absence of offsetting factors, this situation would seem to be strongly favorable to fishery stocks which depend on upwelling-based primary production. For example, Peterson (1973) and Botsford and Wickham (1975) have indicated a relationship between positive upwelling index anomalies and subsequent increased Dungeness crab catches.

BAJA CALIFORNIA

The area off Baja California is a secondary zone of coastal upwelling within the California Current region. Here the upwelling appears to be less energetic, but much steadier than in the area to the north. The indication in Table 6.1 of nearly equivalent absolute values of the indices in the two regions may be attributed to the spatial distortion discussed by Bakun (1973) whereby the numerical values near 33N are artificially amplified relative to other locations.

Major features during 1975 include positive upwelling index anomalies during March and April, negative anomalies in May, and strongly positive anomalies during the fall months. The values at 30N, 119W, near the normal position of strongest upwelling in the region (Bakun and Nelson 1977) surpass the 90th percentile in each of the months of September, October, and November. In general, the northern portion of the Baja California region appears to have participated in the summer and fall portion of the anomalously strong upwelling noted for the California coast to the north.

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Table 6.1.--Monthly coastal upwelling indices (cu m/s-100 m) for 1975. Negative values indicate onshore transport of surface waters and resultant downwelling.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
60N 149W	-85	-66	-20	-3	-6	8	2	0	3	-36	-119	-97
60N 146W	-109	-117	-26	-3	-4	10	3	0	-2	-40	-128	-131
57N 137W	-104	-239	-38	-17	-18	1	-5	-3	-34	-62	-105	-158
54N 134W	-69	-122	-13	-7	-17	3	-7	-4	-16	-49	-58	-87
51N 131W	-9	-72	2	17	-1	38	6	7	7	-24	-35	-30
48N 125W	-24	-90	-4	17	15	59	45	14	10	-60	-104	-48
45N 125W	-33	-77	-1	35	26	98	68	40	38	-48	-79	-44
42N 125W	-11	-65	6	89	101	220	133	123	72	-11	-17	-12
39N 125W	20	-20	21	150	254	355	230	247	165	24	19	5
36N 122W	27	10	55	156	271	287	266	201	152	71	57	23
33N 119W	10	45	123	197	282	362	322	251	166	100	55	16
30N 119W	50	62	127	174	187	197	192	194	180	146	134	58
27N 116W	43	84	127	183	165	161	99	115	117	133	99	40
24N 113W	45	85	133	185	130	93	37	46	50	96	56	35
21N 107W	19	47	41	75	100	28	2	-1	-6	6	28	26

Table 6.2.--Monthly coastal upwelling index anomalies (cu m/s-100 m) for 1975 relative to the 20-yr (1948-67) mean value for each month and location.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
60N 149W	53	20	26	8	-7	1	-3	-6	6	-10	-46	12
60N 146W	71	- 15	22	9	-2	4	-2	-3	7	-6	-34	-2
57N 137W	108	-121	14	6	-8	2	-6	2	-5	25	36	5
54N 134W	28	-55	15	13	-8	2	-10	-3	7	33	41	5
51N 131W	55	-36	14	22	-4	23	-9	-6	10	16	23	27
48N 125W	66	-43	16	17	-2	34	11	-9	6	-21	-17	52
45N 125W	61	-29	14	26	-8	49	-6	-10	21	-28	-6	49
42N 125W	56	-37	3	55	22	117	2	32	37	-11	26	46
39N 125W	33	-29	-15	81	130	188	49	109	102	4	26	17
36N 122W	17	-25	-25	36	68	49	67	18	58	21	45	16
33N 119W	-9	-4	3	19	-0	50	91	38	29	24	33	7
30N 119W	-6	-15	11	33	-12	-1	49	52	51	43	69	4
27N 116W	-28	-9	8	35	-37	-33	-15	10	7	27	25	-23
24N 113W	-5	10	41	69	-13	-36	-11	2	1	27	3	-4
21N 107W	2	7	-56	-25	13	-11	-1	-6	8	20	20	18

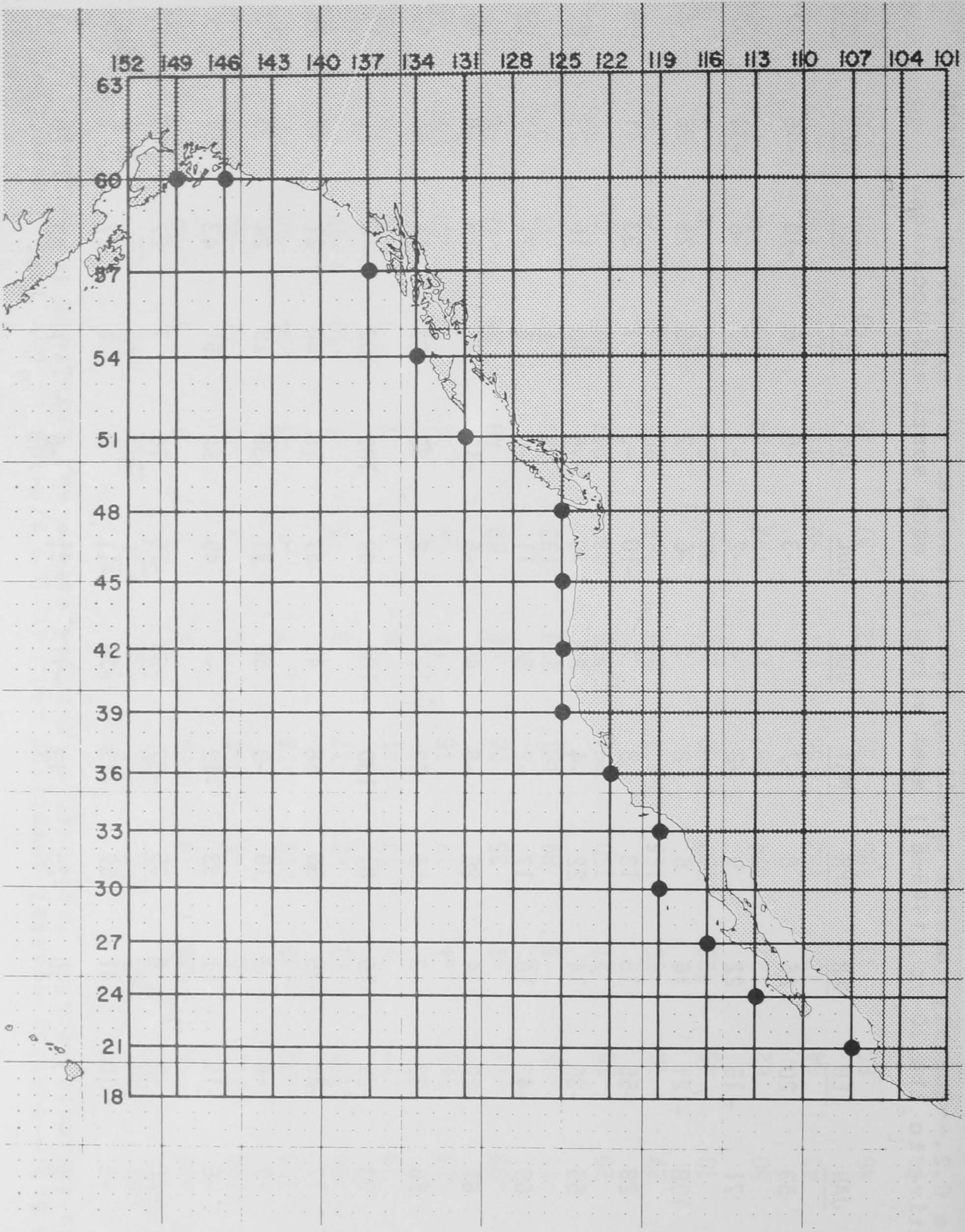

Figure 6.1.—Computation grid. Intersections at which upwelling indices are computed are marked with large dots.

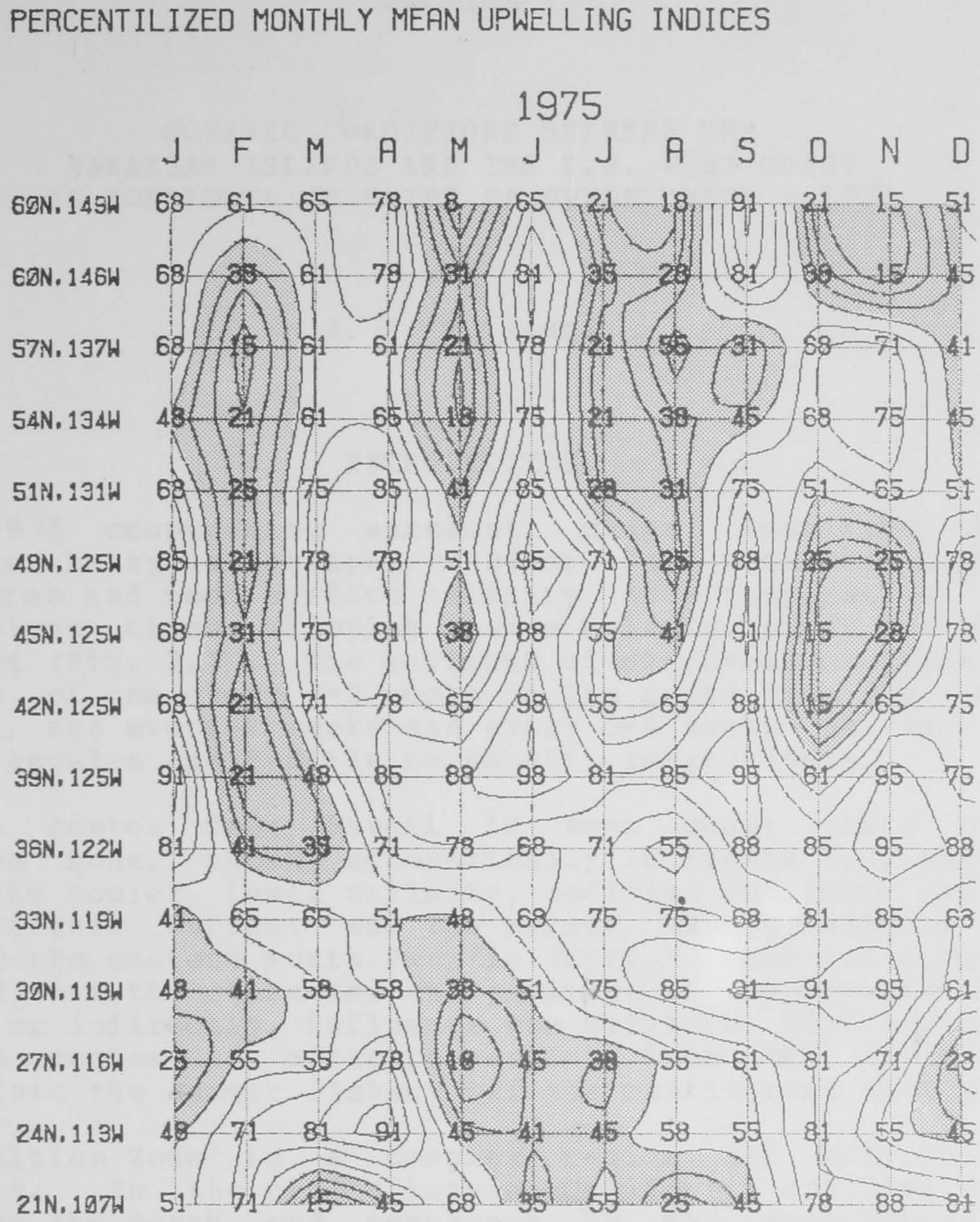

Figure 6.2.—Percentilized upwelling index values for 1975. Numbers indicate the percentile occupied by each monthly value within the frequency distribution of the 30 values for each respective month and location in the 30-yr series, 1946-75. The contour interval is 10 percentile units. Values below the median (50th percentile) are shaded.

Section 7

OCEANIC CONDITIONS BETWEEN THE HAWAIIAN ISLANDS AND THE U.S. WEST COAST AS MONITORED BY SHIPS OF OPPORTUNITY - 1975

J. F. T. Saur[1]

INTRODUCTION

During 1975 cooperating merchant ships regularly dropped expendable bathythermographs (XBT's) for obtaining subsurface temperatures and took surface salinity and temperature observations along three shipping routes between Hawaii and the U.S. west coast (Fig. 7.1). The sections of observations represent a frequency of one every 1-2 weeks on the route from San Francisco to Hawaii, and every 2 weeks and every 3-4 weeks on the routes from Los Angeles and Seattle to Hawaii, respectively.

The three routes from Hawaii to west coast ports cross a Transition Zone, shown schematically in Figure 7.1, which lies between the cooler, lower salinity, modified subarctic waters of the California Current and the warmer, higher salinity central waters of the eastern North Pacific (ENP). Laurs and Lynn have indicated that the character and position of the Transition Zone, directly or indirectly, influence the offshore distribution and migration routes of albacore moving from the central North Pacific into the summer fishery off the continental west coast.

The Transition Zone is a complex region and not yet fully understood. In the region between California and Hawaii, it is bounded on the south and southwest by the subtropical front (Roden 1971, 1975). On the north and northeast, respectively, it is bounded by the subarctic front and some type of southeastward extension of this feature, which LaFond and LaFond (1971) named the California front. These boundaries are not static. The sharpness and location of the associated oceanic fronts change with time; large waves and eddies occur in them; and within the Transition Zone surface fronts separated from subsurface

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boundaries are found in detailed observations[2,3,4] by research vessels (Roden 1975).

Observations from merchant vessels can provide a quasi-continuous monitoring of oceanic features frequently throughout the year as compared to less frequent but more detailed surveys by research vessels. Monitoring of oceanic features on the San Francisco route about every 18-21 days was started in June 1966 using a single vessel. Observations began on the Los Angeles route in October 1973 and on the Seattle route in April 1974. Therefore, only for the San Francisco route is the record of observations long enough to establish significant means and describe events of a given year in terms of departures from a long-term mean.

This report is divided into two parts. Part I describes the general oceanic features on each route at the end of the cooling and warming seasons in 1975. In Part II the mean seasonal distributions of surface salinity, surface temperature, and heat storage in the upper 100-m layer on the San Francisco route are given. The anomalies of these variables for the period 1972 through 1975 are discussed to show the characteristics of 1975.

OBSERVATIONS

Ships' mates routinely take XBT observations. Original records are digitized ashore by the Pacific Environmental Group (PEG) of NMFS, Monterey, CA, using facilities and procedures of the Fleet Numerical Weather Facility. The "surface" temperatures are subjective extrapolations of the near-surface gradient, so are probably representative of temperatures around 3-5 m.

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[2]Laurs, R. M., R. J. Lynn and R. N. Nishimoto. 1975. Rep. of joint NMFS-Am. Fishermen's Res. Found. albacore studies conducted during 1975. SWFC Admin. Rep. LJ-75-84, 49 p.

[3]Lynn, R. J., and R. M. Laurs. 1972. Study of the offshore distribution and availability of albacore and the migration routes followed by albacore tuna into North American Waters. In Rep. of joint NMFS-Am. Fishermen's Res. Found. albacore studies conducted during 1972. (Unpub. rep.)

[4]Lynn, R. J. 1973. Further examination of the offshore distribution and availability of albacore and migration routes followed by albacore into North American waters. In Rep. of joint NMFS-Am. Fishermen's Res. Found. albacore studies conducted during 1973. (Unpub. rep.)

To obtain surface salinites, water samples are drawn from the seawater intake system by ships' engineers, and salinity later determined ashore by laboratory salinometer. Seawater intakes of the various ships range in depth between 3 and 7 m below the surface.

Observations are scheduled every four hours. Depending upon the speed of the ship, distance between observations varies from 120 km (65 nm) to 165 km (90 nm). The distances used in the figures are great circle distances to the observation from a reference point, 21N21', 157W42', which lies in the ocean channel directly south of Makapuu Point, Oahu. This is the approximate departure point for the great circle track of the vessels going from Honolulu to the west coast ports.

PART I. SUBSURFACE TEMPERATURE STRUCTURE

Vertical sections of the distribution of temperature along the three routes in 1975 near the end of the cooling season, herein termed late winter, and near the end of the warming season, termed late summer, are shown in Figures 7.2-7.4. The figures also contain horizontal profiles of surface salinity and temperature along each route. The figures[5] show some typical features of the distribution of temperature in the northeast Pacific Ocean.

The surface mixed layers and thermoclines reach their maximum depths in late winter. Depths of the mixed layers are generally at least 100 m. They are deepest, attaining depths of greater than 150 m, in the central parts of the San Francisco and Los Angeles sections in the Transition Zone.

The warming which occurs during spring and summer is generally confined to the upper 75-100 m. The temperatures below 100 m in late summer remain essentially the same as in late winter. In late summer the sharpest and shallowest thermoclines are found in the subarctic waters of the California Current where salinities of the upper layers are low and downward mixing of heat is inhibited by the stability associated with the increase in salinity with depth. This effect is particularly noticeable on

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[5]Selected sections have been published monthly in Fishing Information, NMFS's environmental data publication distributed monthly by the Southwest fisheries Center, La Jolla, CA 92038, since March 1972. Interpretations of features in the sections were included through March 1975 (Saur 1972-75).

the Seattle section where about one half of the route lies in subarctic waters (surface salinities below 33.5 o/oo).

Slopes of the isotherms in and below the permanent thermocline reflect the geographic orientation of the individual routes. The Seattle sections, having the greatest change in latitude, show a consistent downward trend of the deeper isotherms from the coast almost to Hawaii. However, on the Los Angeles route, with a lesser change in latitude, the downward slope towards Hawaii of the 10C-15C isotherms occurs in the California Current region, i.e., about the eastern one-third of the section.

In late summer on the San Francisco and Los Angeles sections thermostad regions (nearly isothermal layers between the surface thermocline and the permanent thermocline) are present in the Transition Zone. On the late summer San Francisco section (Fig. 7.3) this layer can be recognized in the vertical profiles at observations 7-14, and on the Los Angeles section these occur at observations 14-23. These thermostad regions are found near the outer portion of the California Current and the Transition Zone where higher salinity ENP water lies below California Current waters of about the same temperature. In the spring and early summer temperature inversions often appear in this region.

On all horizontal profiles of surface salinity the lower salinities are observed near the continental west coast. The salinities reach a maximum northeast of Hawaii at 27N-30N, where evaporation (minus precipitation) is greatest the year round. The salinity then decreases somewhat towards Hawaii. The steeper gradients and fronts which occur in the Transition Zone and the front appearing in the late summer sections about 200-400 nm (370-740 km) northeast of Hawaii will be discussed in Part II which deals with longer time-series observations on the San Francisco route.

PART II. SURFACE SALINITY, SURFACE TEMPERATURE, AND HEAT STORAGE ALONG THE SAN FRANCISCO TO HONOLULU ROUTE

Surface salinity and XBT observations have been made on the route between San Francisco and Honolulu since June 1966. Sampling intensity has been much greater since March 1972 than in earlier years. Table 7.1 summarizes by year the number of transects and the total number of observations through 1975. This part of the paper discusses long term means and monthly anomalies of surface salinity, surface temperature, and heat storage.

Table 7.1.--Summary of observations,
San Francisco-Honolulu route

Year	Surface salinity Transits	Surface salinity Total obs.	Temperature (XBT's) Transits	Temperature (XBT's) Total obs.
1966[1]	10	151	10	192
1967	15	299	16	342
1968	20	452	19	549
1969	15	360	15	433
1970	18	522	19	562
1971[2]	9	169	12	252
1972	18	385	18	381
1973	28	625	28	635
1974	43	1147	44	1259
1975	43	1199	47	1275
Totals		5309		5880

[1] 7 months, June-December.
[2] Project inactive several months during 1971 due to prolonged shipping strikes.

Analysis of Data to Standard Grid

Because of the variability of locations of observations between sections and of the time intervals between transects, the various time series of observations were computer analyzed year by year to obtain values on a time-space grid of 24 intervals/yr by 92.5 km (50 nm).

The year 1971 was deleted from the analysis because of insufficient data (Table 7.1). Gridded values were thus computed for eight years of data, June 1966-December 1970 and January 1972-June 1975. The mean fields shown are based on this 8-yr period. The full year of 1975 was analyzed when all observations had been received, but the means were not recomputed.

The annual means and the anomalies presented here have been smoothed by a centered 5x3 point [2 mo by 100 nm (193 km)] weighted smoother to emphasize the time continuity of the features without greatly suppressing important horizontal gradients. Neighboring grid values were weighted by the inverse square of their distance, d, from the grid point being smoothed:

$$w = [(1-d/d^*)]\text{squared}$$

where d* was 1.1 times the distance to the farthest point used in each smoothing calculation. The smoothing had little effect on the means. For anomaly fields the smoothing suppressed small scale variability which probably resulted from both real variability and observational error.

Long-Term Means

Mean annual cycles are shown for surface salinity and surface temperature in Figure 7.5, and for heat storage (represented by average temperature in the layer from the surface to 100 m) in Figure 7.6.

The mean surface salinities are primarily related to position along the route and only secondarily to time during the year. Salinities below 33.0 o/oo occur throughout the year in the low salinity core of the California Current. Those above 35.0 o/oo occur in the region of the ENP central waters. Strongest horizontal gradients occur between salinities of 33.75 o/oo and 34.75 o/oo and are indicative of the Transition Zone.

The mean surface temperature has a strong seasonal cycle. The heat storage has a similar but more subdued seasonal cycle due mainly to flattening of the summer maximum. The flattening is greatest in the eastern half of the section, where it was seen in Part I that the summer thermoclines are shallow and strong. Here the 0-100 m average temperature is about 3-4C lower than the surface temperature, but towards Hawaii the difference is about 1C.

Between-year standard deviations of salinity and temperature (Fig. 7.7) indicate that lowest year to year variability of salinity occurs in the salinity maximum of ENP waters and, secondarily, in the low salinity core of the California Current. Highest variability occurs in the Transition Zone (133W-139W) where horizontal gradients are largest. Temperature variability is more related to time than to position along the route. Lowest variability of temperature occurs in March-April when temperatures are at a minimum and mixed layers deepest, while highest variability occurs in August-September when surface temperatures are highest and mixed layers shallowest or nonexistent.

Time-Series of Anomalies

Anomalies of surface salinity, surface temperature, and heat storage (0-100 m) exhibit large coherent patterns, but of differing natures. Salinity anomalies (Fig. 7.8) exist as relatively narrow bands with long time persistence. Surface temperature anomalies (Fig. 7.9) occur over greater distances along the route, but are of shorter duration. Heat storage anomalies (Fig. 7.10) appear generally similar to the surface temperature anomalies. However, in the eastern half of the route heat storage anomalies appear to have a superimposed pattern of time persistence similar tc the salinity ancmalies.

The most striking feature of the time-series anomalies is in the salinity data, where there are coherent patterns east of 140W whose axes appear to progress along the route at a speed of about 2.5 cm/sec. They appear first in the California Current, move through the Transition Zone where they reach maximum intensity, and disappear into the ENP waters. A major anomaly regime arises about once a year. The wavelength <u>along the route</u> is short enough that the two anomaly regimes may exist at the same time.

Scme other characteristics cf the ancmaly patterns for the two surface variables are:

1. When strong salinity anomalies were observed in 1972, 1973, and 1974, between 135W and 140W, the anomalies near Hawaii were of opposite sign.

2. When strongly negative salinity anomalies occurred in the Transition Zone from January 1972 through June 1973, below normal temperature occurred along most of the route.

3. Conversely, strongly positive salinity anomalies from March 1974 to June 1975 were associated with above normal temperatures during fall and winter of 1974-75.

4. The near-normal fall and winter of 1973-74 was the period of reversal in sign of the anomalies.

5. About June 1975, below normal temperature anomalies appeared over most cf the route at the time negative salinity anomalies appeared in the California Current.

<u>Heat Storage</u>

Heat storage is a measure of subsurface thermal structure, which can be analyzed in the same manner as surface salinity and surface temperature. It indicates the longer term availability of heat energy for exchange with the atmosphere, whereas surface temperature anomalies might be superficial and misleading. Also the changes in average ocean current are related to horizontal changes in thermal structure. I have chosen to use here the average temperature of a designated layer as the measure of heat storage.

Thus far, I have computed means and time series of anomalies of heat storage for only the surface-to-100-m layer (Fig. 7.10). These show a complex pattern but generally correspond well with surface temperatures, especially in the eastern half of the section, i.e., east of 140W. Ccupled with the previously noted relation of surface salinity and surface temperature, these indicate that the major anomalies in these variables are caused by changes in advection. This agrees with the conclusion by Tabata (1976) that advective phenomena are the primary causes of anomalies in eastern boundary currents.

Summary for 1975

The year 1975 began with a relatively deep layer of warm water in the central portion of the San Francicso-Honolulu route and slightly negative temperature anomalies near the coast. Surface salinity anomalies were positive, and especially strong in the outer part of the California Current and in the Transition Zone. Positive salinity and temperature anomalies seem to be associated with a diffuse Transition Zone having weak and variable fronts, such as occurred in 1974 (Saur 1976).

At the end of winter 1975, below normal salinities and significant cold anomalies appeared in the core of the California Current (Figs. 7.8, 7.9). This resulted in the formation of a strong salinity and temperature front which was observed between 131W and 132W in late March (Fig. 7.3). Although the temperature front dissipated during the summer warming, the salinity front remained fairly strong and moved slowly southwestward along the route. By late September (Fig. 7.3) it was between 136W and 137W and had moved about 250 nm (450 km). With this movement the negative salinity anomalies became more widespread between the front and the west coast. The largest negative anomaly was -0.25 o/oo. Cold anomalies appeared in the California Current area and the Hawaii area in early spring and spread across the entire route in late summer (August-October). However, by the end of the year the cold temperatures and low salinity anomalies were waning and conditions had returned to near normal.

ACKNOWLEDGMENTS

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Brian Jarvis (PEG), Tiburon; Hilary Hogan and J. R. Renner, SWFC, NMFS, La Jolla.

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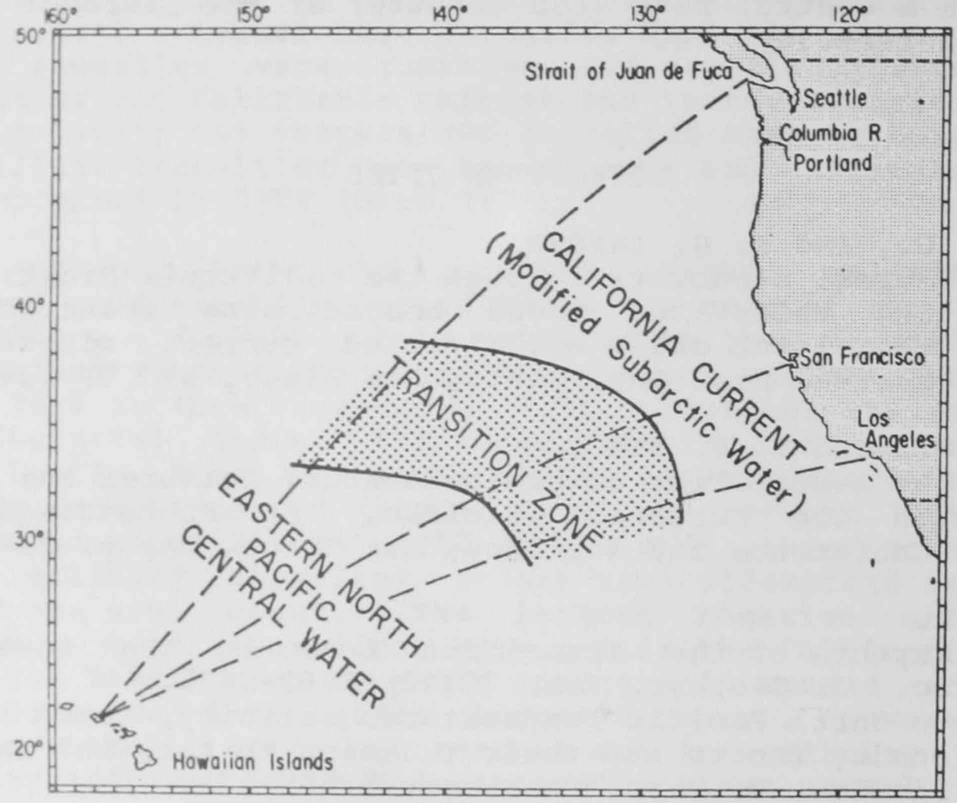

Figure 7.1.—Three great circle routes between Honolulu and U.S. west coast ports, on which surface salinity and expendable bathythermograph observations are currently made by cooperating merchant ships, and the three oceanic regimes (schematized) crossed.

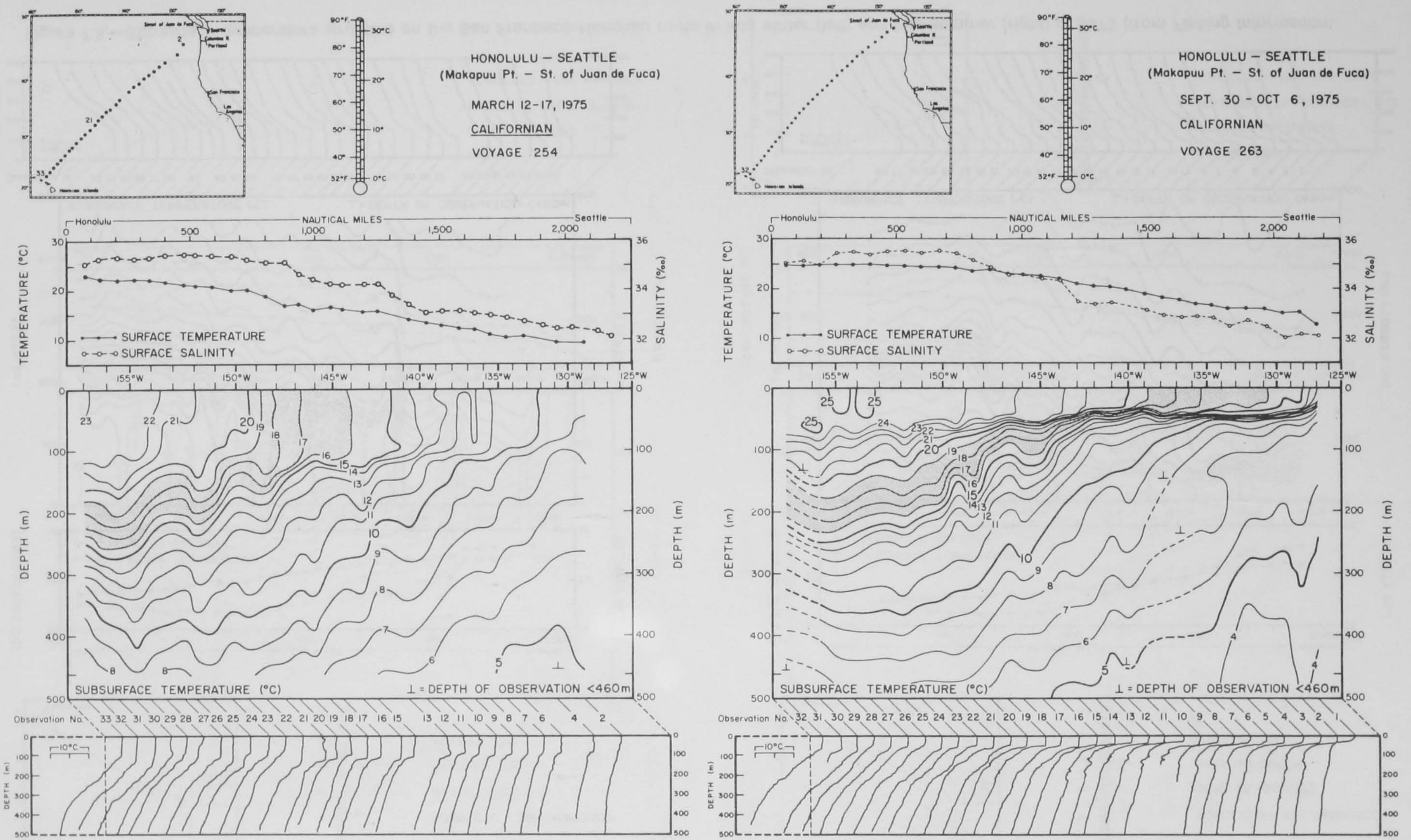

Figure 7.2.—Subsurface temperature structure on the Seattle-Honolulu route in late winter (left) and late summer (right) of 1975 (from *Fishing Information*).

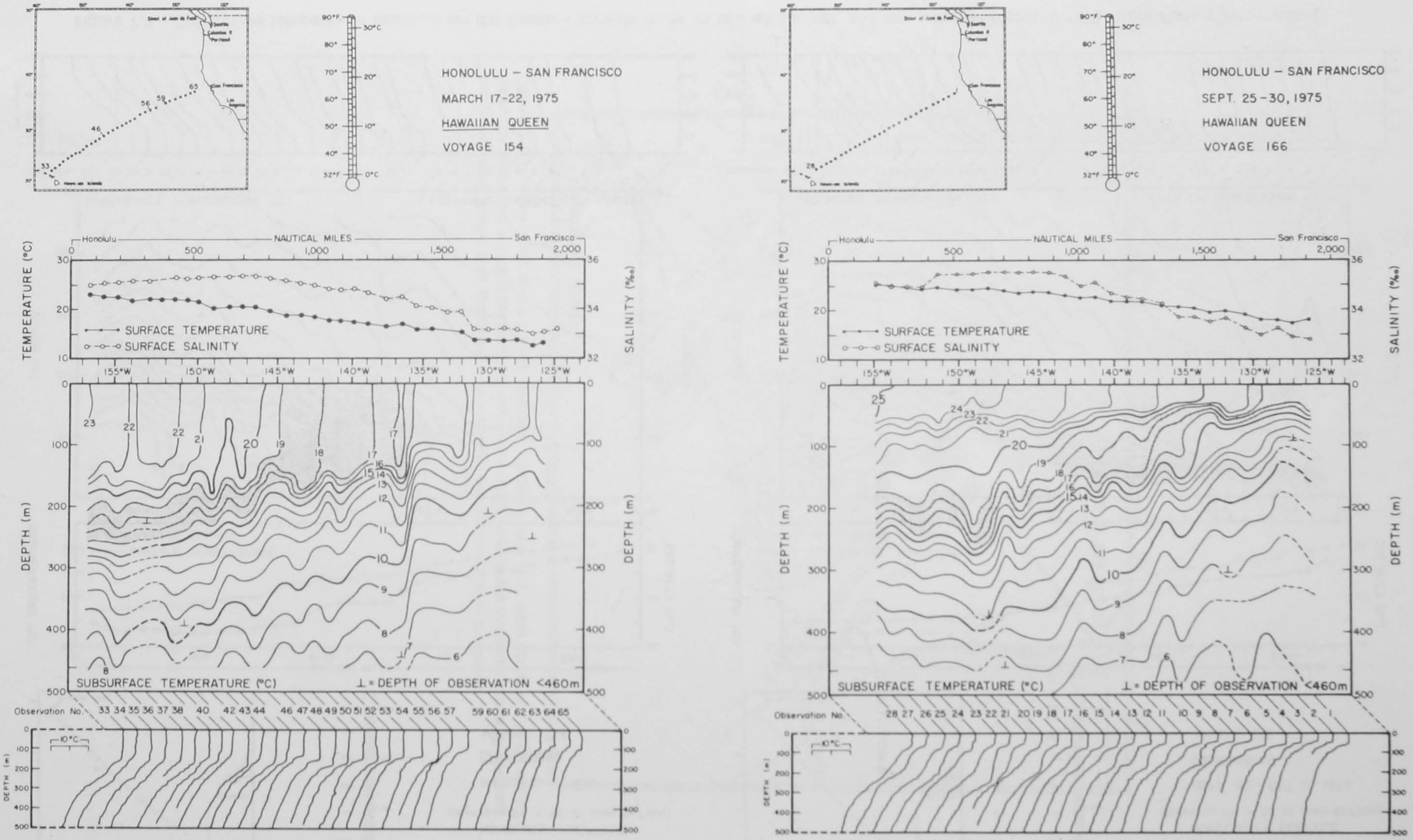

Figure 7.3.—Subsurface temperature structure on the San Francisco-Honolulu route in late winter (left) and late summer (right) of 1975 (from *Fishing Information*).

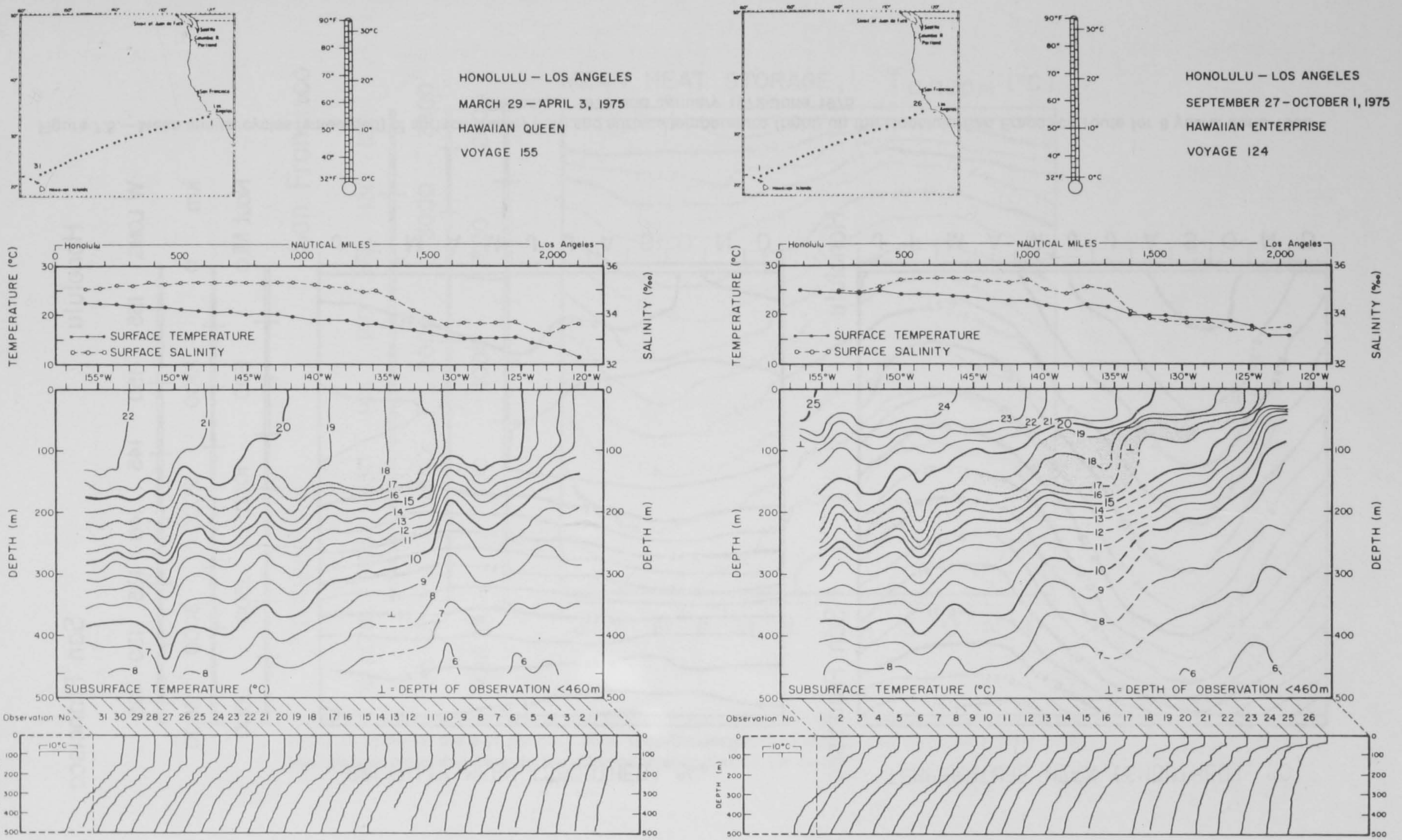

Figure 7.4.—Subsurface temperature structure on the Los Angeles-Honolulu route in late winter (left) and late summer (right) of 1975.

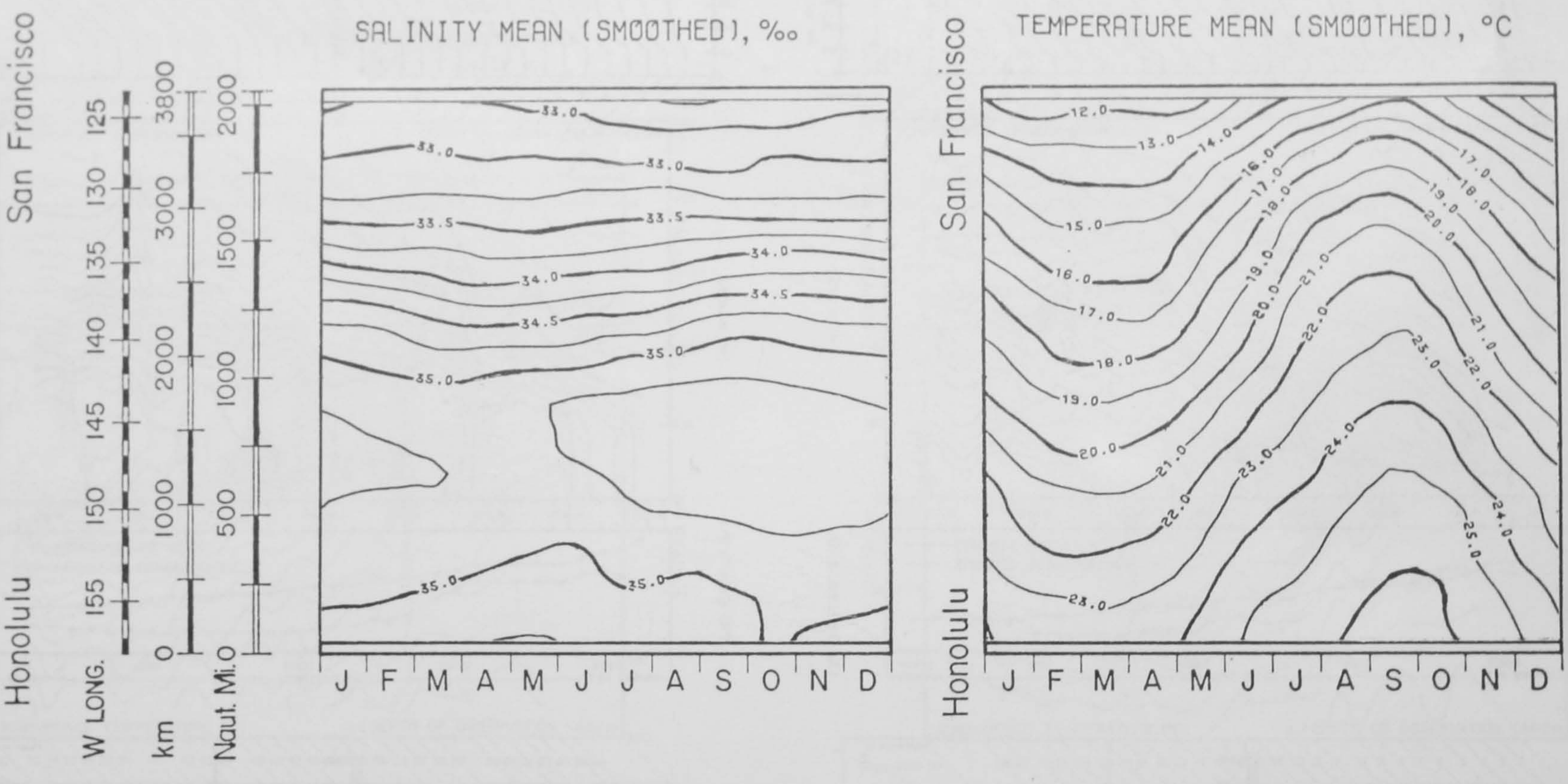

Figure 7.5.—Mean annual cycles (smoothed) of surface salinity (left) and surface temperature (right) on the Honolulu-San Francisco route for 8 years: June 1966-December 1970 and January 1972-June 1975.

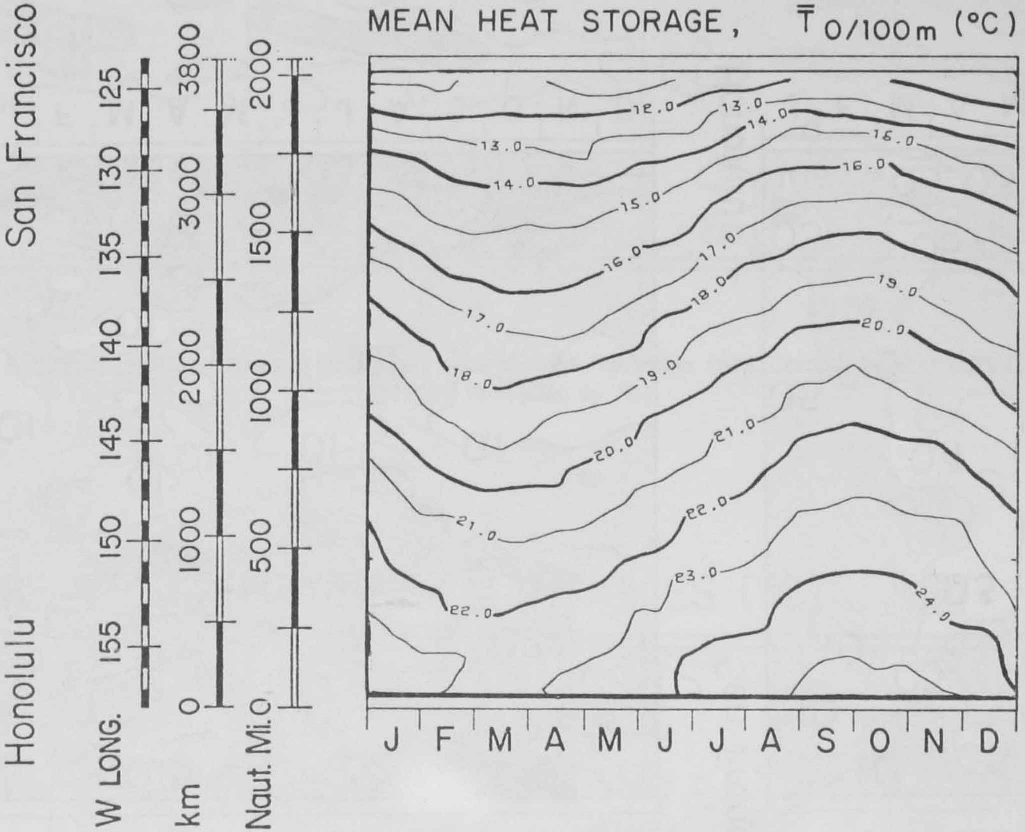

Figure 7.6.—Mean annual cycle of heat storage in the surface to 100-m layer on the San Francisco-Honolulu route for the 8-yr period: June 1966-December 1970 and January 1972-June 1975. Heat storage is represented here by the average temperature of the layer.

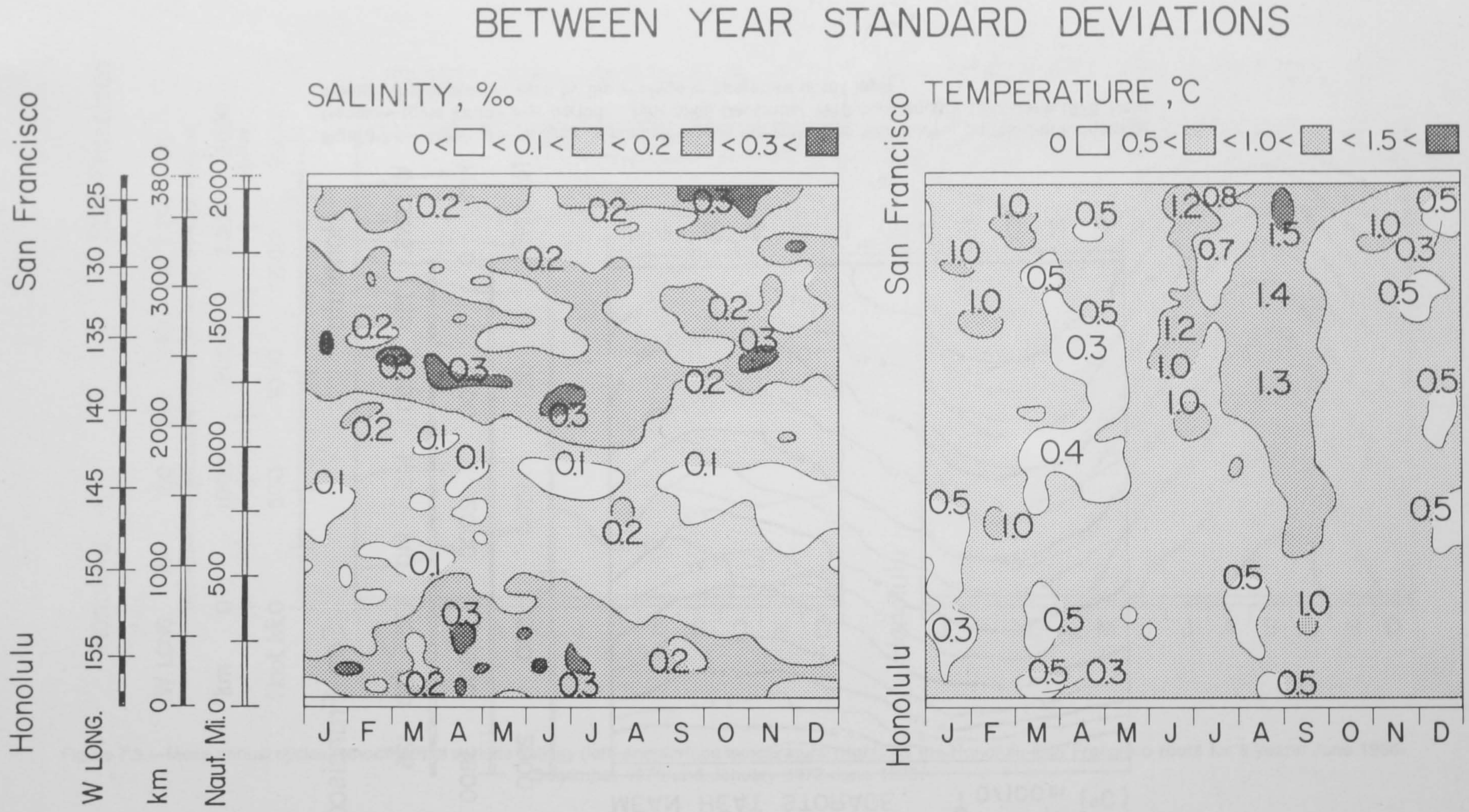

Figure 7.7.—Between-year standard deviations of salinity (left) and temperature (right) on the San Francisco-Honolulu route for the 8-yr period: June 1966-December 1970 and hanuary 1972-June 1975.

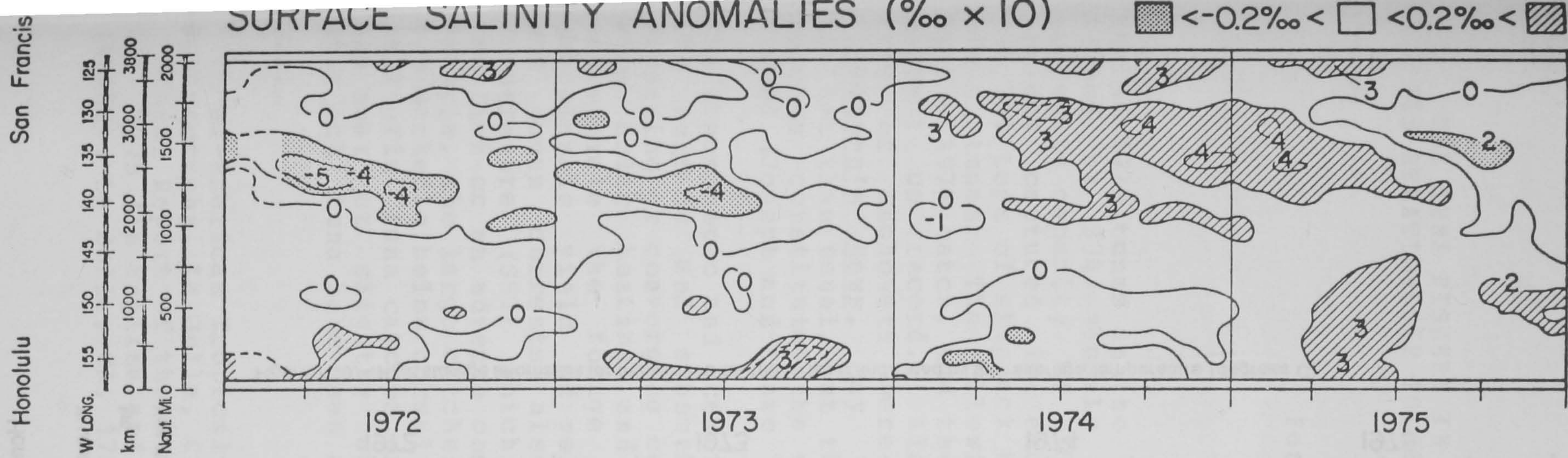

Figure 7.8.—Salinity anomalies on the San Francisco-Honolulu route for January 1972 through December 1975. Contour interval, 0.2°/oo. (Note: Labels on contours are the anomaly multiplied by 10.)

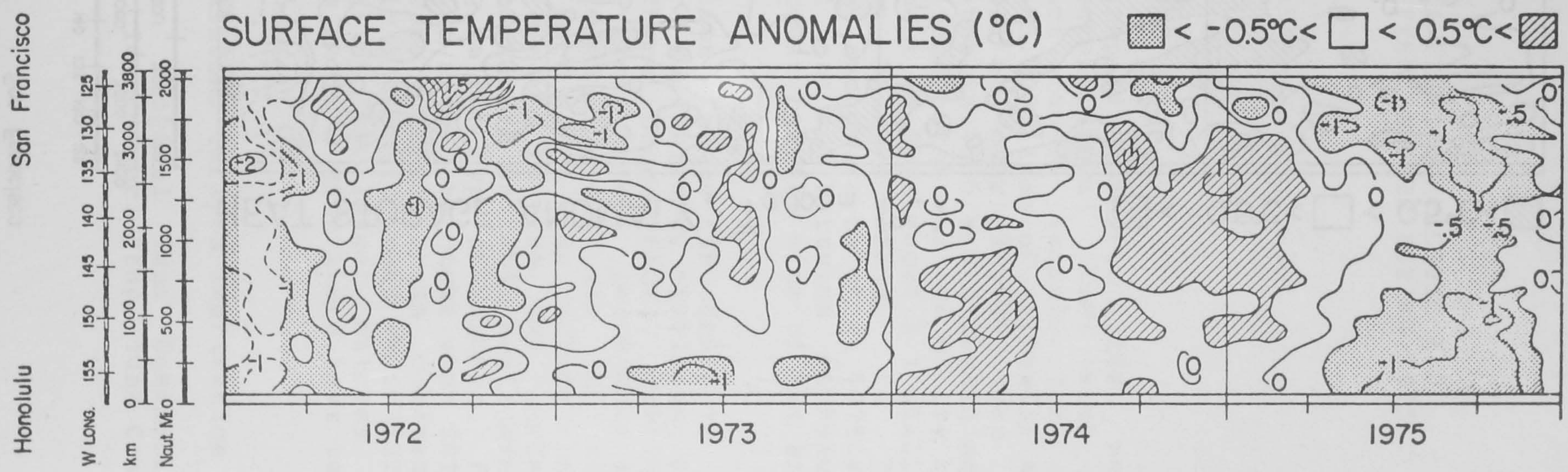

Figure 7.9.—Surface temperature anomalies on the San Francisco-Honolulu route for January 1972 through December 1975. Contour interval, 0.5C.

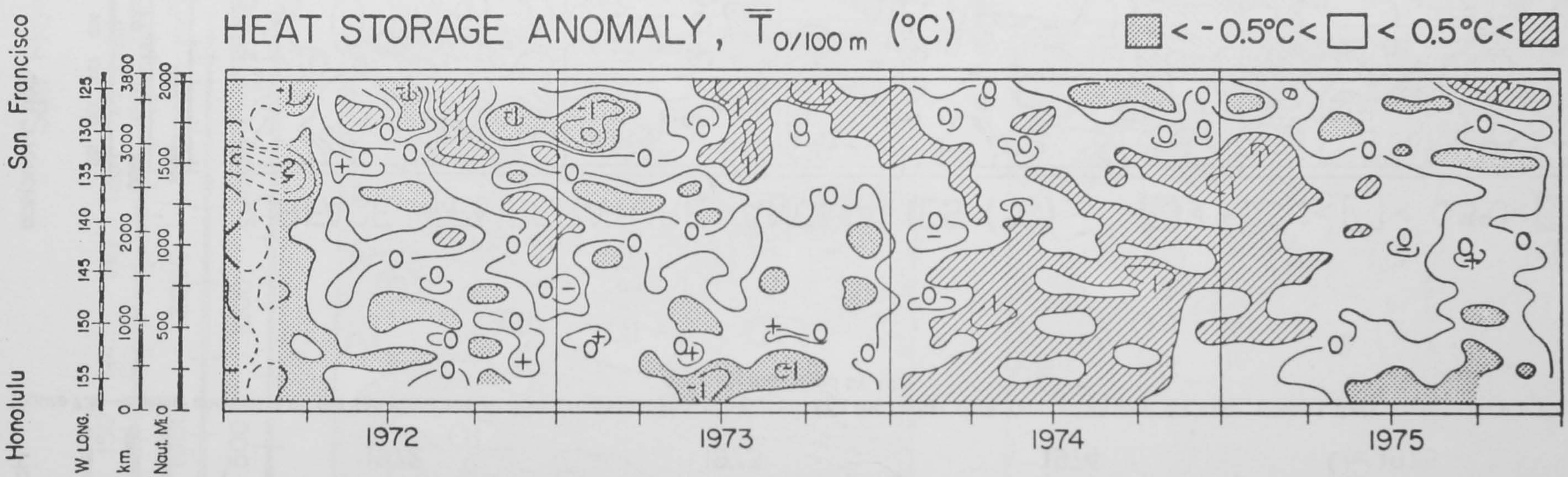

Figure 7.10.—Heat storage anomalies for the surface-to-100-m layer, indicated by the average temperature (degrees C).

Section 8

THE TUNA FISHERY IN THE EASTERN TROPICAL PACIFIC AND ITS RELATIONSHIP TO SEA SURFACE TEMPERATURES DURING 1975

Forrest R. Miller[1]

INTRODUCTION

During 1975 tunas in the eastern tropical Pacific (ETP) were fished by 334 vessels in the international fleet with an aggregate capacity of 169,000 short tons.[2] Vessels from 15 nations captured in excess of 175,000 tons of yellowfin and 134,000 tons of skipjack tunas as well as over 30,000 tons of other tunas. The yellowfin tuna catch in 1975 was exceeded only by the 1974 catch, and the skipjack tuna catch was one of the two largest on record. Along the coast of Peru about 3.1 million tons of anchoveta were landed in 1975 according to The Fishermen's News, May 1976. The anchoveta catch in 1975 was smaller than usual, but the combined tuna and Peruvian anchoveta catches constituted the world's largest for the size of the area fished (Joseph and Klawe 1974).

The atmospheric and oceanic circulations in the ETP generate in the surface and subsurface layers wind mixing, upwelling, and diverging or converging currents. These circulations, combined with solar heating and nutrient rich water, perpetuate and concentrate the forage supply needed to maintain a high sustainable yield of pelagic fish each year. The surface winds and ocean currents also cause changes in the sea surface temperature (SST) which either provides a suitable environment for fish or an adverse one depending on the type of fishery. For example, the large catches of Peruvian anchoveta occur when SST's are markedly below normal in the Peru Current. In contrast, yellowfin tuna catches are generally higher in areas where SST's are near or slightly above normal. The larger catches of skipjack tuna have been made during periods when there have been

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[1]Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, CA 92037.
[2]Annual Report of the Inter-American Tropical Tuna Commission for 1975 (in English and Spanish). Inter-Amer. Trop. Tuna Comm. (IATTC), La Jolla, CA, 176 p.

large areas with upwelling and below normal SST's along the equator and to the west of Baja California for several months prior to and during the skipjack's appearance. This occurred in the last part of 1975 off the coast of Ecuador. Forsbergh (1969) found that zooplankton concentrations and tuna abundance are greatest 3 months following periods of upwelling which usually occur in February and March. During winter periods of upwelling and northerly winds in the Gulf of Panama, SST's are often below normal. By April or May the SST's warm considerably.

The geographical range of the several species of tropical tunas in terms of oceanographic and biological properties has been described by Uda (1957), Broadhead and Barrett (1964), Blackburn (1965), and Williams (1970). These authors noted that tropical tunas are found in commercial quantities in waters bounded on the north and south by the 68F (20C) isotherms. In the ETP the 68F (20C) isotherm is found at the surface along the southern boundary of the California Current and along the cold side of the equatorial ocean front which delimits the northern boundaries of the Peru Current and equatorial upwelling. The literature also suggests that the subsurface thermal structure influences the vertical distributions of tuna. Hester (1961) and Green (1967) pointed out that the tuna's swimming layer may be restricted vertically by strong temperature gradients in the thermocline. Green also suggested that variations in the depth of the thermocline may result in measurable differences in the tuna catches by purse seining depending on whether the net hangs through the thermocline. Brock (1959) observed that surface fishing for tuna is usually confined to those regions with shallow mixed layers or where there is a ridging of the thermocline. Brandhorst (1958) and Blackburn (1962) showed that there is a close relationship between the temperature structure in the thermocline and zooplankton standing crops in the ETP.

Surface wind stress is the prime modifier of the ocean's vertical thermal structure. An increase in surface wind stress results in both vertical (upward or downward) and horizontal movements in the water column. The upward motion brings cold subsurface water rich in nutrients to the surface layers. The upwelled water supports primary production, and converging wind-driven surface currents concentrate the forage.

APPLICATION OF DATA FROM FISHERMEN

In January 1971, the Tuna Oceanography Group at the Southwest Fisheries Center (SWFC) implemented a program (FAX) designed to exchange data with fishermen purse seining for tuna in the ETP. Surplus radio facsimile recorders, obtained from the U.S. Navy, were installed on cooperating purse seiners. Summaries and predictions of weather and sea state on the fishing grounds were prepared and transmitted via radio facsimile to fishing vessels on a regular schedule. The fishermen, in turn, sent in weather and expendable bathythermograph (XBT) observations to the SWFC via radio station WWD at La Jolla, CA. In the period from 1971 through 1975 as many as 77 seiners (25 equipped with XBT recorders) participating in the FAX program recorded more than 20,000 weather and over 5,000 XBT observations. These data came from areas where environmental data traditionally had been sparse, and they were routed into the data collection systems of the U.S. Navy Fleet Numerical Weather Central (FNWC), Monterey, and the National Weather Service, Redwood City, CA. The data were used also at the SWFC as input into the environmental products prepared routinely and were added to the environmental data bases for fishery oceanography research.

Recent statistical studies completed at the SWFC[3] revealed that during four fishing seasons (1971-74) catches of yellowfin and skipjack tunas in the ETP were greater in those areas where the depth of the thermocline was 150 ft (46 m) or less both inside and outside the Inter-American Tropical Tuna Commission Regulatory Area (CYRA). These studies also established the fact that the most successful tropical tuna fishing was done in waters with temperatures ranging from 79F (26.1C) to 83F (28.3C) from the surface to the thermocline.

Approximately 73% of all successful purse seining sets in 1975 occurred in water with surface temperatures between 79F (26.1C) and 84F (28.9C). Less than 20% of the sets were made where temperatures were less than 79F (26.1C); and only about 7% of the sets were made in warm water of 85F (29.4C) or greater off Mexico. Based on the tuna boat SST observations, the distribution of successful sets on tuna, as a function of SST (Fig. 8.1), was similar in all areas and fishing seasons from 1970 through 1975 in the ETP.

The Inter-American Tropical Tuna Commission publishes in its annual report the distribution of the total yellowfin and skipjack catches by 1 degree quadrangles. Figure 8.2 shows the distribution of yellowfin captured by the international tuna fleet in 1975. The composite positions of the 68F (20C) and 79F (26.1C) isotherms have been superimposed also on the yellowfin catch in Figure 8.2. The position of each isotherm represents the annual, composite position determined from surface temperatures published in Fishing Information (SWFC, La Jolla, CA 92038) and observed by tuna boats and commercial ships. In order

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[3]Miller, F. R., and R. Evans 1976. The ocean environment of the eastern tropical Pacific as related to purse seining. MS. SWFC, La Jolla, CA 92038.

to obtain properly the most representative composite location of each isotherm, maximum weight was given to SST's observed by tuna boats in areas of most active fishing. After yellowfin tuna fishing became regulated east of 120W, in March 1975, the tuna fleet expanded its fishing westward to 145W. The positions of the 79F (26.1C) isotherms west of 120W, for example, were based primarily on data from May through November 1975. Figure 8.2 shows that the 79F isotherms enveloped those areas where most of the yellowfin were captured in 1975. The areas from 5N to 10N between 115W and 120W and to the west of 145W all had surface temperatures greater than 79F, but these were areas of limited fishing effort. Of course, there may have been tunas in fishable abundance to the north or south of these areas, but ocean conditions were not suitable for purse seining.

In other years studied (1970-74), average distributions of annual yellowfin tuna catch and the 79F (26.1C) isotherms were similar. However, the distributions of catch and temperature were different from year to year, especially south of 10N, in the CYRA. Surface temperatures in 1975 were below 79F in the Gulf of Panama and around the Costa Rica dome (centered near 9N, 90W). These areas were associated with vertical ocean mixing and upwelling.

TUNA CATCH AND TEMPERATURE

Along the southwest coast of Baja California the 68F isotherm marked the northern limit of yellowfin tuna catches (Fig. 8.2), and there was considerable fishing effort in the central and northern areas west of Baja California. In the Gulf of California the best catches were south of 23N in 1975, but in 1974 yellowfin fishing was good to 25N in the Gulf where SST's were slightly above normal. Some yellowfin tuna were captured in and north of the Gulf of Guayaquil during periods when temperatures were above 79F (26.1C). Skipjack tuna fishing was particularly good along the coast of Ecuador during November and December 1975 when SST's were below normal. However, from February to June SST's were above normal between the Galapagos Islands and Ecuador. During this period large catches of yellowfin tuna were made in this area which usually experiences colder SST's associated with upwelling in the equatorial extension of the Peru Current. Along the coast of southern Equador and Peru south of 6S, SST's remained below 68F (20C) all year. During 1974 and 1975 the anchoveta fishery was recovering from a record low catch of 1.96 million t in 1973 following the devastating 1972-73 El Nino (<u>The Fishermen's News</u>, May 1976).

Figure 8.3 shows the annual, composited patterns of positive and negative SST anomalies. The anomaly patterns were obtained by graphically compositing the anomaly charts published monthly in Fishing Information. Other areas where temperatures remained below normal during 1975 were south and west of Baja California and from 8N to 10N near 90W. Apparently (Fig. 8.2) fishing in these areas was not good in 1975.

A comparison of Figures 8.2 and 8.3 reveals that the most productive yellowfin fishing areas in 1975 had SST's greater than 79F which were near or slightly above normal. In the Gulf of Panama and near the Costa Rica dome, strong northeast trade winds increased ocean mixing and kept surface temperatures below normal during the most active yellowfin tuna fishing period. Along the coast of Peru temperatures were also low, but this condition in 1975 helped to restore the anchoveta fishery. Between 5N and 5S from 80W to 90W yellowfin tuna catches were very good in the first half of 1975 when SST's were above normal (Fig. 8.3). This was the period of most active yellowfin tuna fishing in the ETP.

Research has not revealed any significant relationships between SST's and apparent abundance of yellowfin tuna in specific areas of the ETP. However, SST's and their deviations from the long-term means (anomalies) provide good indicators of large-scale ocean-atmosphere changes which occurred during the fishing season. The most active yellowfin tuna fishery is found where seasonal temperatures remain in the 79F (26.1C) to 84F (28.9C) range. The largest year to year changes in SST occur on the periphery of the traditional fishing grounds and occasionally inshore along Central America. Therefore, monitoring ocean surface temperature on a continuous basis can provide useful information about tropical ocean conditions and where fishing could be successful. Conventional surface and subsurface temperature data combined with the high resolution (thermal infrared) satellite temperature data[4] which are now available, provide an improved data base for monitoring the ocean SST's over the entire fishing ground of the ETP.

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[4]Stevenson, M. R., and F. R. Miller. 1975. Application of satellite data in fishery oceanography. Inter-Am. Trop. Tuna Comm. Final Report for SPOC, NOAA Grant No. 04-4-158-28, 98 p.

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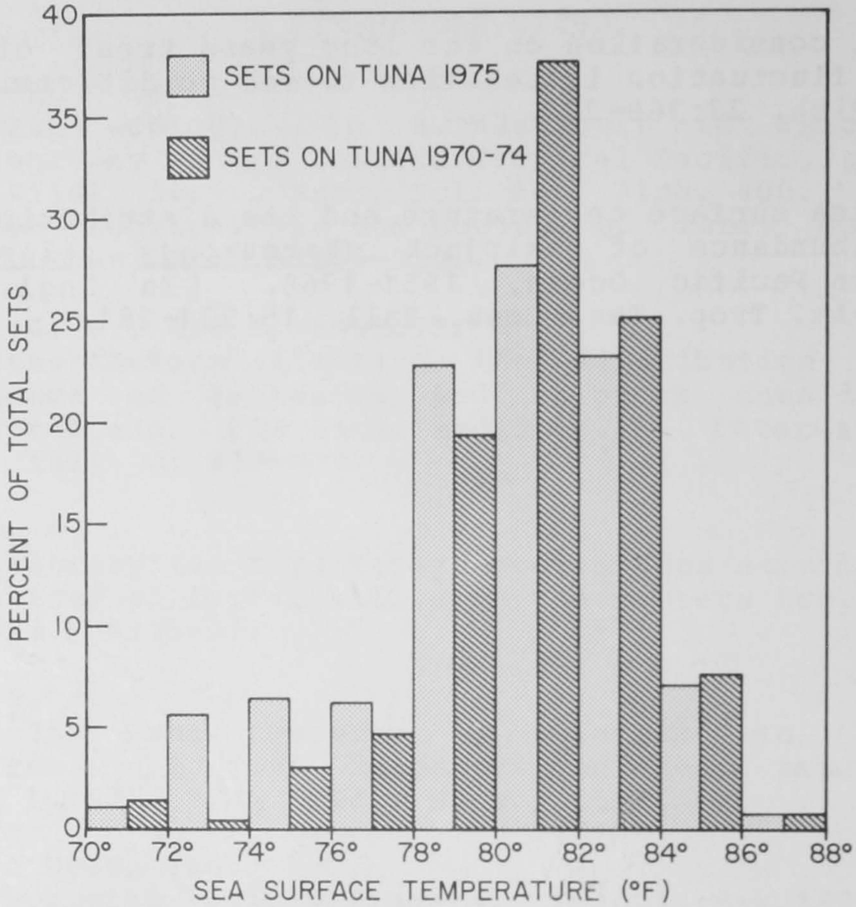

Figure 8.1.—Percentage distribution of the total successful purse seine sets on yellowfin and skipjack tunas as a function of sea surface temperature in the eastern tropical Pacific for 1970-74 and for 1975.

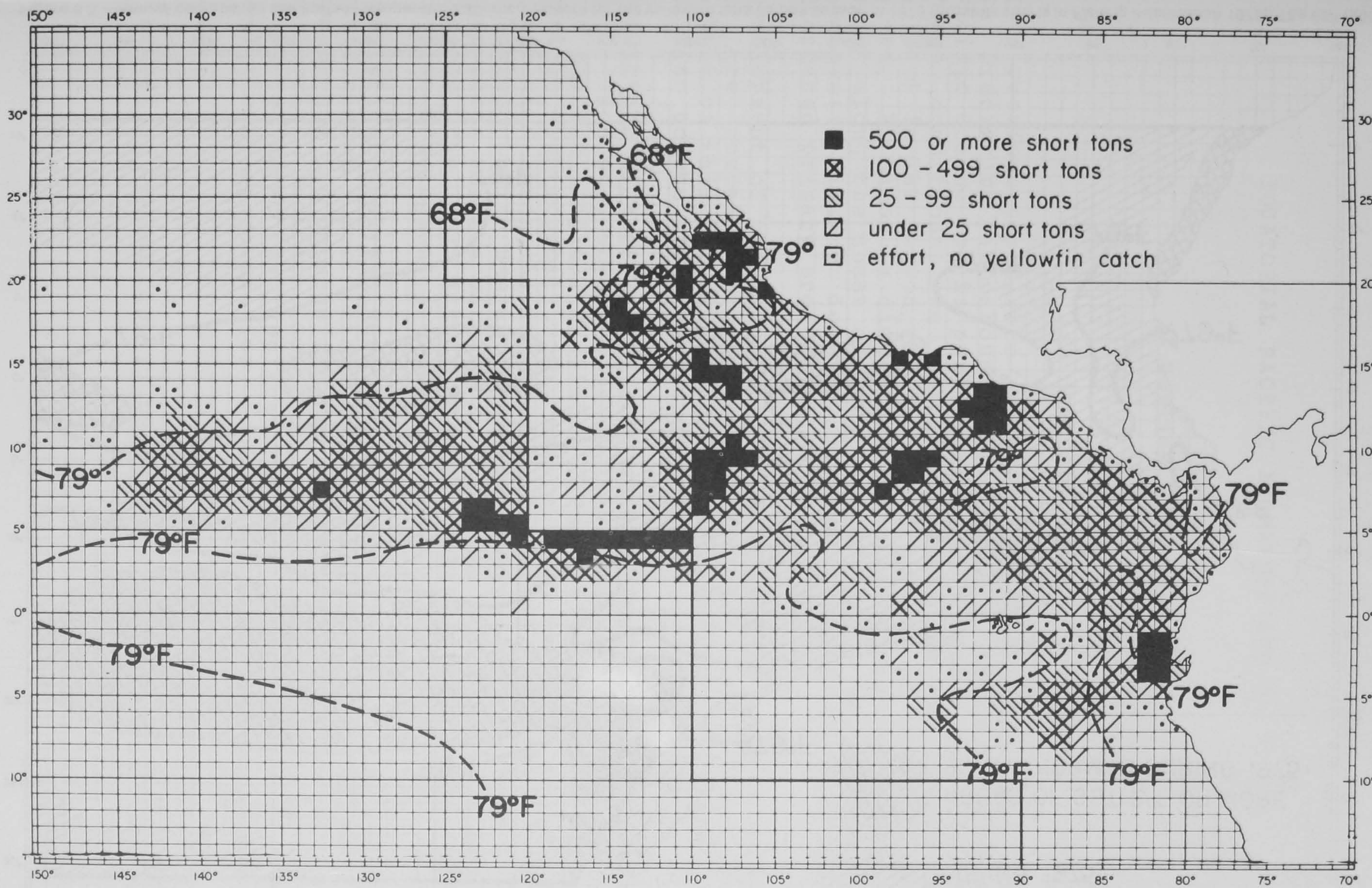

Figure 8.2.—Catch of yellowfin tuna in the eastern Pacific Ocean in 1975 (taken from Inter-American Tropical Tuna Commission Annual Report, 1975). Annual composited positions of the 68F (20C) and 79F (26.1C) SST isotherms (from monthly charts in *Fishing Information* 1975).

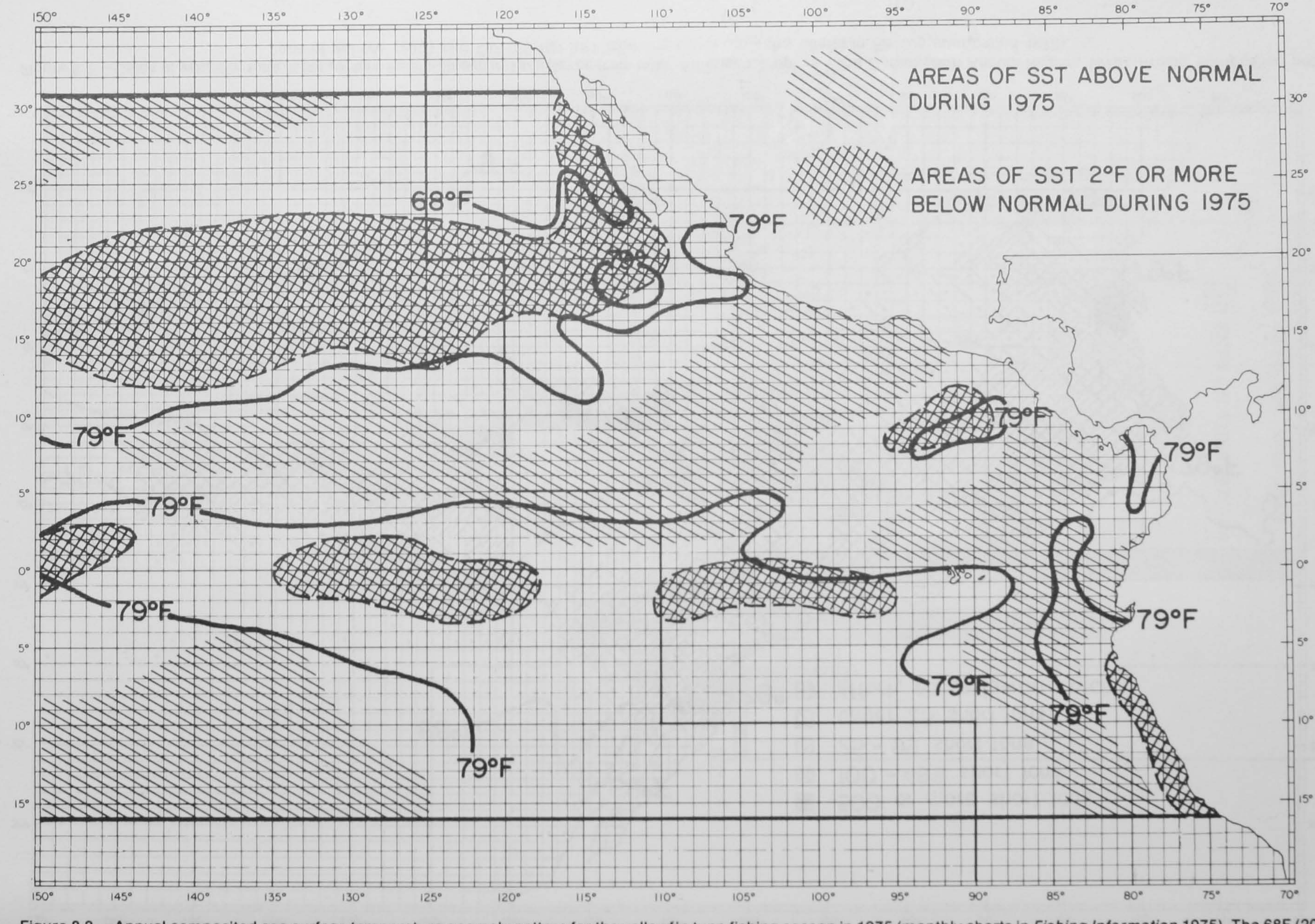

Figure 8.3.—Annual composited sea surface temperature anomaly pattern for the yellowfin tuna fishing season in 1975 (monthly charts in *Fishing Information* 1975). The 68F (20C) and 79F (26.1C) isotherms (Fig. 8.2) are included.

Section 9

EQUATORIAL PACIFIC ANOMALIES AND EL NINO

William H. Quinn[1]

INTRODUCTION

In a previous paper, the author (Quinn 1976) described progress in predicting anomalous conditions in the eastern equatorial Pacific Ocean, and in particular the phenomenon known as El Nino. These conditions are anomalously warm sea surface temperatures (SST's) in the region with abnormally heavy precipitation and at times, El Nino, a disastrous invasion of unusually warm surface water along the coast of Peru which leads to failure of the anchoveta fishery due to slackening of upwelling activity and decreased primary production.

Development of these conditions is brought about by a relaxation of the normally strong southeast trade winds. The timing and extent of this relaxation appears to determine whether or not El Nino occurs along the Peruvian coast.

Prediction of these conditions uses several Southern Oscillation (S.O.) indices, comparisons of sea level pressures in the western and eastern tropical Pacific. These are measures of the South Pacific subtropical high pressure cell, which is consistent with trade wind strength, and they lead El Nino by 6 to 12 months, allowing their use as predictive tools. In this paper, running mean plots for the various S.O. indices have been extended to include the 1975 data, and their relationships to the weak 1975 El Nino development are discussed.

Statistical analyses were performed to determine lag correlation coefficients pertaining to the relationships between index components and between indices and rainfall amounts at western equatorial Pacific locations, and some of the results are presented here. The applicability and value of this time-series analytical approach for monitoring and predicting equatorial

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Pacific changes are discussed in the light of these results. The most recent trends in the indices are considered with regard to expected developments.

RESUME FOR THE EARLY 1975 EL NINO EVENT

In the previous report, results from legs 1 and 2 of the El Nino Watch cruise of 11 February-31 March 1975 verified the occurrence of a weak early 1975 El Ninc development as predicted several months earlier by the author (Quinn 1976). Wyrtki and Patzert (Wyrtki et al. 1976) reported a massive transgression of warm (>27C), low salinity (<33 o/oo) water southward east of the Galapagos. The Galapagos oceanic front was noted to shift almost 500 km to the south; vertical profiles of temperature and salinity showed this overlying layer to be only 10-25 m thick. Weak upwelling was still present along the coast of northern Peru to the south of Punta Parinas (4S), but no cool water was advected northwestward from this upwelling area as in normal years. Stroup (Wyrtki et al. 1976), after completing legs 3 and 4 of the El Nino Watch cruise between 17 April and 27 May, reported that nearly all the evidence of the southward intrusion of warm, low salinity surface water, noted during legs 1 and 2, had vanished and that the cold coastal upwelling conditions had been reestablished. Also, as in normal years, a well-developed tongue of cold water extended from the north Peruvian coastal area north-northwest to the Equator east of the Galapagos Islands. Temperatures along the equator and in the coastal upwelling zone were some 4C lower than observed during legs 1 and 2, approximately 2 months earlier. The 15C isotherm had also returned toward its normal shallow position both in the equatorial region and in the coastal upwelling zone. West of the Galapagos Islands the isotherm depths indicated much weaker development of the equatorial undercurrent than was noted during leg 1. This shift between conditions found in the oceanographic data for cruise legs 1 and 2 in February-March 1975 and those for legs 3 and 4 in April-May was surprisingly large and rapid.

With regard to pressure indices, pre-El Nino peaks in the 12-mo running mean plots occurred about the end of 1973 (Fig. 9.1), indicating that peaks in the annual and interannual fluctuations were in phase. (Note the resulting unusually high 3-mo running mean peak for January 1974 in Fig. 9.2.) This meant that the S.O. period would have to be near 3 years if troughs of the two fluctuations were to be in phase about 18 months later. (We must remember that the regular annual fluctuation has its lowest index near the middle of the year since the Easter Island pressure is on the average lowest in May and the Darwin pressure highest near the middle of the year.) However, in this case the S.O. period turned out to be significantly shorter than it was for the situation leading up to the strong 1972 El Nino event; this was evidenced by the shallow 12-mo running mean trough occurring near the end of 1974 for indices involving components from the westernmost sites along the ridge (Totegegie-Darwin, Rapa-Darwin) and in early 1975 for indices involving components from the two easternmost sites (Fig. 9.1). Therefore, in this case the Southern Oscillation period shortened to near 2 years, the troughs of the two fluctuations were not in phase, and the resulting El Nino event was weak. The tip-off for this developmental change was the rapid rise from the previous trough to the preevent peak which took place over about a 12-mo period and thereby indicated that the S.O. period was shortening.

The weak early 1975 El Nino event occurred about as forecast with respect to time of occurrence and intensity in the region between the Galapagos Islands and northwestern South America; however, associated activity in the western equatorial Pacific was much weaker and occurred much earlier than expected. Nevertheless, index trends appear to represent what actually happened. Note how the shallow index trough correlates with the small peak in Tarawa rainfall (Fig. 9.3). This case was quite unusual since the small Tarawa rainfall peak preceded the El Nino, and the small Darwin component peak preceded the Rapa component trough (Fig. 9.4).

STATISTICAL EVIDENCE

In the past the largest S.O. index variations (considering 12-mo running mean values) have usually been noted when using the Easter-Darwin index. In general, this one appears to be the best (Quinn and Zopf 1976), not only for monitoring what is occurring, but also for anticipating what will occur in the eastern equatorial Pacific, At times the Juan Fernandez-Darwin index is also of great value for these purposes. For activity in the western equatorial Pacific, the other indices are particularly useful.

Statistical analyses were performed to obtain correlation coefficients, at various lags, between index components and between the indices and rainfall for various sites in the western equatorial Pacific (considering 12-mo running mean values). Table 9.1 shows the highest negative correlations when the equatorial low component (Darwin) lags the subtropical high components (Juan Fernandez, Easter, Totegegie, and Rapa) of the indices by 2-5 months. These figures also reflect the high degree of correlation between changes taking place in the two core areas. Table 9.2 shows highest negative correlations when rainfall peaks and troughs at Tarawa (1N21', 172E56') lag about 2-3 months behind index troughs and peaks respectively.

Table 9.3 shows the same general relationship between the Washington Island (4N 43', 160W25') rainfall and the various indices. Similar relationships have been noted between the indices and rainfall data for other western equatorial Pacific sites. Statistical evaluations show that the Rapa-Darwin index usually gives the earliest indication for equatorial activity since the highest negative correlations between it and the associated rainfall features occur when rainfall lags 3-4 months behind the index. Likewise, changes in the Rapa component usually show up further in advance of the complementary Darwin changes (5 months) than do the other ridge component changes (2-4 months).

DISCUSSION

The remarkable consistency between trends of the various indices (Fig. 9.1), the high negative correlation coefficients between 12-mo running mean values of indices and rainfall amounts at western equatorial Pacific sites (Tables 9.2, 9.3), and the favorable lag indications between index and rainfall trends, indicate that this time-series analytical approach can be very useful for monitoring and predicting large-scale changes in the equatorial Pacific and certain associated changes in neighboring regions (e.g., El Nino invasions). It appears that the approach is compatible with the type, quality, and quantity of the data available over the poorly sampled equatorial and South Pacific, since it makes full use of the higher quality time-series data which is very scarce over all oceanic regions. When one uses this approach in conjunction with the routinely prepared synoptic weather analyses, SST analyses, and satellite cloud cover photos, one can realize more fully not only what is currently taking place in the atmospheric and oceanic tropospheres over this sparsely sampled region, but can also anticipate the changes in thermal, circulation, and weather patterns that are likely to take place in the future. The use of additional indices in this time-series analytical method increases one's insight into the sequence and intensity of changes taking place in the equatorial Pacific and adds confidence to the outlook when there is general agreement between the index trends. Darwin and Broome, Australia, have been found particularly effective for representing the equatorial low core of the Southern Oscillation; however, Djakarta, Indonesia, and other sites in the general vicinity have been noted (as expected) to show similar 12-mo running mean trends in their pressure values. The islands Juan Fernandez, Easter, Totegegie, Rapa, and Tahiti have been found highly effective for registering the pressure changes in the South Pacific subtropical high core of the Southern Oscillation. Ship N (30N, 140W) data (Quinn and Zopf, in press) and data taken from analyses for the former position of Ship N (Ship N ceased operation in June 1974) have been used to reflect S.O. effects on the northeast Pacific subtropical high.

THE FORECAST METHOD

The forecast method applies primarily to the nature of the initial El Nino event following relaxation from a high 12-mo running mean peak and not to the occurrence or recurrence of a later El Nino-type event when running means of the indices remain low or return to a low value after a short excursion upward into a smaller secondary peak (Quinn and Zopf, in press). In cases of the latter nature, outlooks must be of a much shorter duration, or the alternative is a much more speculative long-range outlook which must reach beyond the indications of the existing trend and depend heavily on experience gained from case history studies of analogous developments, along with an assumed or projected S.O. period. (Here it must be realized that the time involved in relaxation from the high preevent peak to the projected trough determines to a large extent how far in advance of an event occurrence a fairly firm outlook can be given.)

If conditions are such that a large interannual fluctuation is underway and all signs [e.g., the 12-month running mean peak value for the index is 13 mb or more, the Easter component of this peak is 1022 mb or more, the rise to the preevent peak takes near 18 months or more, the falling trend from the peak reaches a rate near 0.33 mb/mo, the preevent 3-mo running mean trend is similar to that for the pre-1957 and pre-1972 cases (Fig. 9.2)] indicate the likelihood that the interannual trough will occur near the midpart of the following year (and thereby be in phase with a regular annual trough), then it is likely that a strong El Nino invasion will occur. If the fluctuations are out of phase (i.e., the interannual trough occurs near the beginning of the following year), the El Nino event will be a weak one.

RECENT INDEX TRENDS AND INDICATIONS

By mid-1975 a change from the falling or level trend near the beginning of 1975 in the 12-mo running mean trends of the indices (considering that these running mean points fall 6 months behind the latest month of data) was indicated, and an outlook was prepared which called for the plots to rise to a secondary peak by middle to late 1975 and then to start falling off in late 1975 to a trough in 1976 with a likelihood of heavy western equatorial Pacific precipitation in the latter half of the 1976-early 1977 period. The outlook for the secondary peak was quite firm; it was based primarily on the immediate trends of the indices and their components (Figs. 9.1, 9.4), but also on an assumed S.O. pericd of a little less than 2 years, and an assumed analcgy to the 1963-64 index trends (Fig. 9.1). The fall to the trough in 1976 was more speculative and based on the assumed short S.O. period and an assumed analogy to the 1964-65 index trends (Fig. 9.1). The outlook did not change and was presented as such on 2 October 1975 at the Eastern Pacific Oceanic Conference. The rise tc seccndary peaks in the indices has proceeded pretty much as expected so far and accompanying Peruvian coastal and equatorial sea temperatures have also reacted as expected.

CONCLUDING REMARKS

The time-series analytical approach, as applied to the S.O. indices and their components, appears to be quite effective for monitoring large-scale metecrolcgical and oceanographic changes in the equatcrial Pacific and certain closely associated changes that occur in neighboring regions (e.g., El Ninc). It also shows considerable promise fcr use in foreshadowing these changes in circulation and weather activity 1-6 months in advance. Its use was predicated on the exceptionally poor synoptic surface data coverage over the southeast Pacific. The methcd seems to be particularly suited to coping with the severe surface data limitation over this large and important oceanic region, since the 12-mo running means of the indices bring out quite clearly the more subtle long-term trends which appear to be very closely associated with large-scale changes in southeast trade wind strength and their effects on equatorial Pacific meteorolcgical and oceanographic conditions. It is believed that this approach can add much to the value cf the routinely prepared snapshot-type products, e.g., synoptic weather analyses (which have a poor and highly variable coverage over this region), satellite weather, and sea temperature analyses, by providing developmental continuity and an indication of the direction and magnitude of the long-term changes taking place over this region.

ACKNOWLEDGMENTS

I thank the Chief of the Naval Weather Service and the Director of the Hydrcgraphic Institute of the Armada de Chile; the Chief of the Meteorological Service of Polynesie Francaise; the Director of the Meteorological and Geophysical Institute, Djakarta, Indonesia; the Director of the Australian Bureau of Meteorology; and the National Climatic Center, Environmental Data Service, NOAA, for their invaluable support to this study. I am greatly indebted to Forrest R. Miller of the Inter-American Tropical Tuna Commission and Richard Evans of the Southwest

Fisheries Center, NMFS, for their timely information on sea temperatures and weather conditions over the eastern tropical Pacific. I also thank Clayton Creech for his excellent support in data processing and David Zopf for his participation in this project. Support by the National Science Foundation under the North Pacific Experiment of the International Decade of Ocean Exploration through NSF Grant No. OCE 75-21907 is gratefully acknowledged.

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Table 9.1.--Lag correlation coefficients between 12-mo running mean pressure at ridge sites (Juan Fernandez, Easter, Totegegie, Rapa) and at Darwin.

Lag in Months		Juan Fernandez and Darwin	Easter and Darwin	Totegegie and Darwin	Rapa and Darwin
-1	(Darwin ahead of ridge site)	-0.463	-0.593	-0.613	-0.495
-0	(no lag)	- .478	- .653	- .656	-.586
1	(ridge site ahead of Darwin)	- .494	- .703	- .686	-.663
2		- .504	- .741	- .701	-.730
3		- .508	- .758	- .699	-.778
4		- .504	- .759	- .682	-.809
5		- .493	- .744	- .652	-.825
6		- .473	- .713	- .604	-.819
7					-.795
Period of record		1911-75	1948-75	1952-75	1951-75

Table 9.2.--Lag correlation coefficients between 12-mo running mean pressure indices (Juan Fernandez-Darwin, Easter-Darwin, Totegegie-Darwin, Rapa-Darwin) and Tarawa rainfall.

Lag in Months		JF-D Index and Tarawa Rainfall	E-D Index and Tarawa Rainfall	T-D Index and Tarawa Rainfall	R-D Index and Tarawa Rainfall
-1	(rain ahead of pressure)	-0.664	-0.682	-0.675	-0.550
0	(no lag)	- .702	- .731	- .722	- .619
1	(pressure ahead of rain)	- .722	- .765	- .752	- .676
2		- .723	- .780	- .762	- .714
3		- .707	- .776	- .751	- .733
4		- .674	- .754	- .720	- .732
5		- .626		- .670	
6		- .566	- .655	- .605	- .677
Period of record		1948-75	1948-75	1952-75	1951-75

Table 9.3.--Lag correlation coefficients between 12-mo running mean pressure indices (Juan Fernandez-Darwin, Easter-Darwin, Totegegie-Darwin, Rapa-Darwin) and Washington Island rainfall.

Lag in Months		JF-D Index and Wash. Rainfall	E-D Index and Wash. Rainfall	T-D Index and Wash. Rainfall	R-D Index and Wash. Rainfall
-1	(rain ahead of pressure)	-0.627	-0.663	-0.671	-0.601
0	(no lag)	- .651	- .708	- .714	- .667
1	(pressure ahead of rain)	- .660	- .740	- .742	- .725
2		- .655	- .754	- .752	- .764
3		- .631	- .751	- .741	- .784
4		- .593	- .733	- .713	- .783
5		- .545		- .673	- .771
6		- .504	- .658	- .618	- .739
Period of record		1946-73	1948-73	1952-73	1951-73

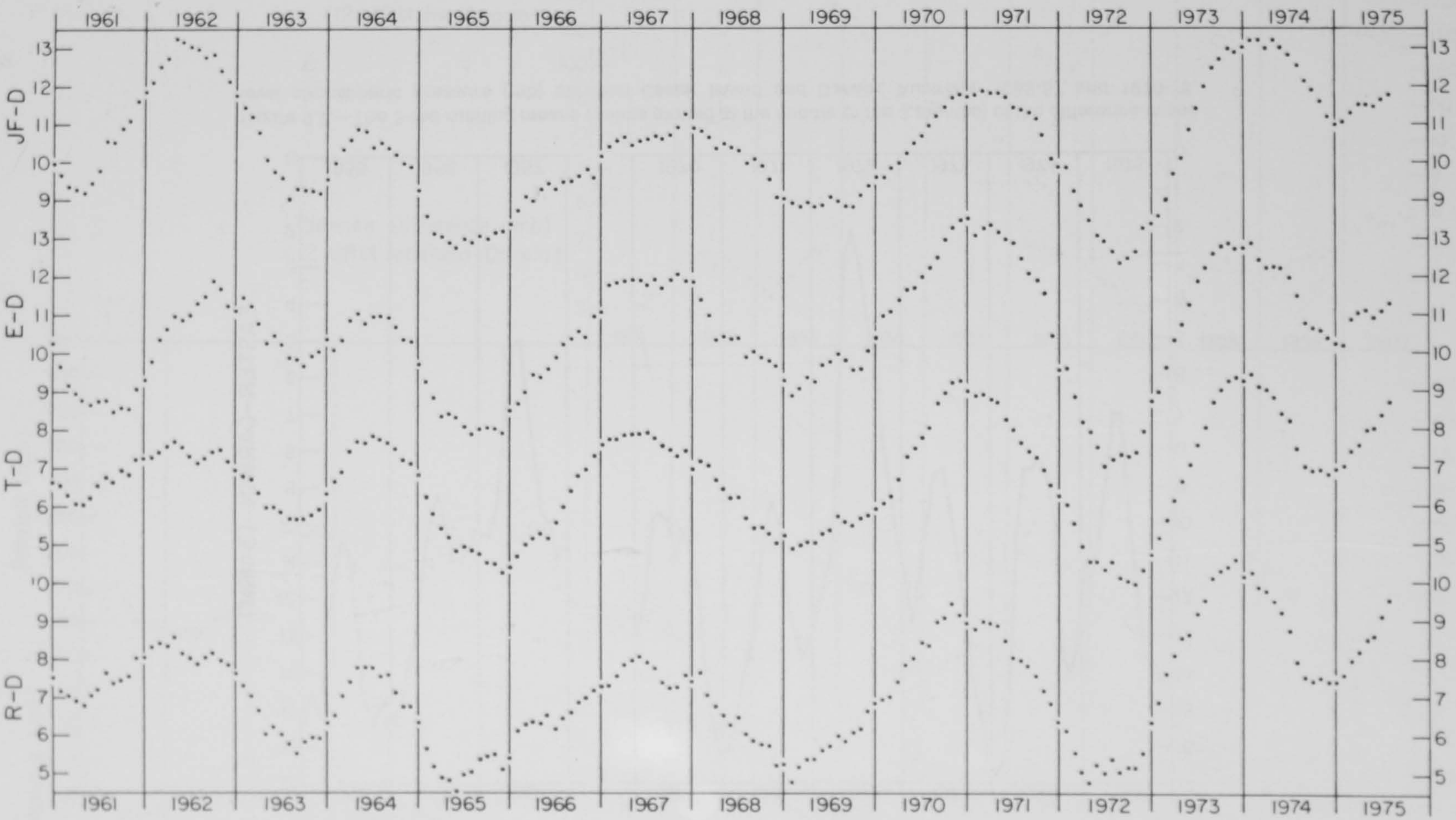

Figure 9.1.—The 12-mo running means (points plotted at the middle of the 12 months) for difference in sea level atmospheric pressure (mb) between Juan Fernandez Island and Darwin, Australia (JF-D), between Easter Island and Darwin (E-D), between Totegegie, Gambier Islands, and Darwin (T-D), and between Rapa, Austral Islands, and Darwin (R-D), 1961-75.

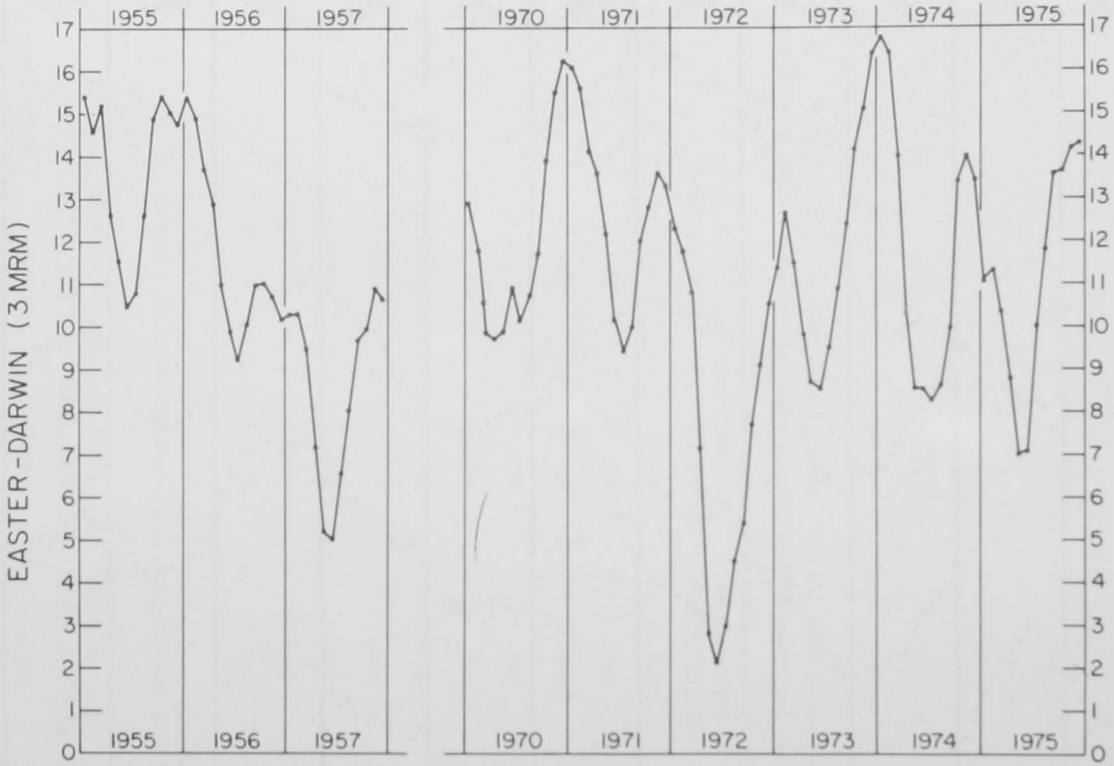

Figure 9.2.—The 3-mo running means (points plotted at the middle of the 3 months) of the difference in sea level atmospheric pressure (mb) between Easter Island and Darwin, Australia, 1955-57 and 1970-75.

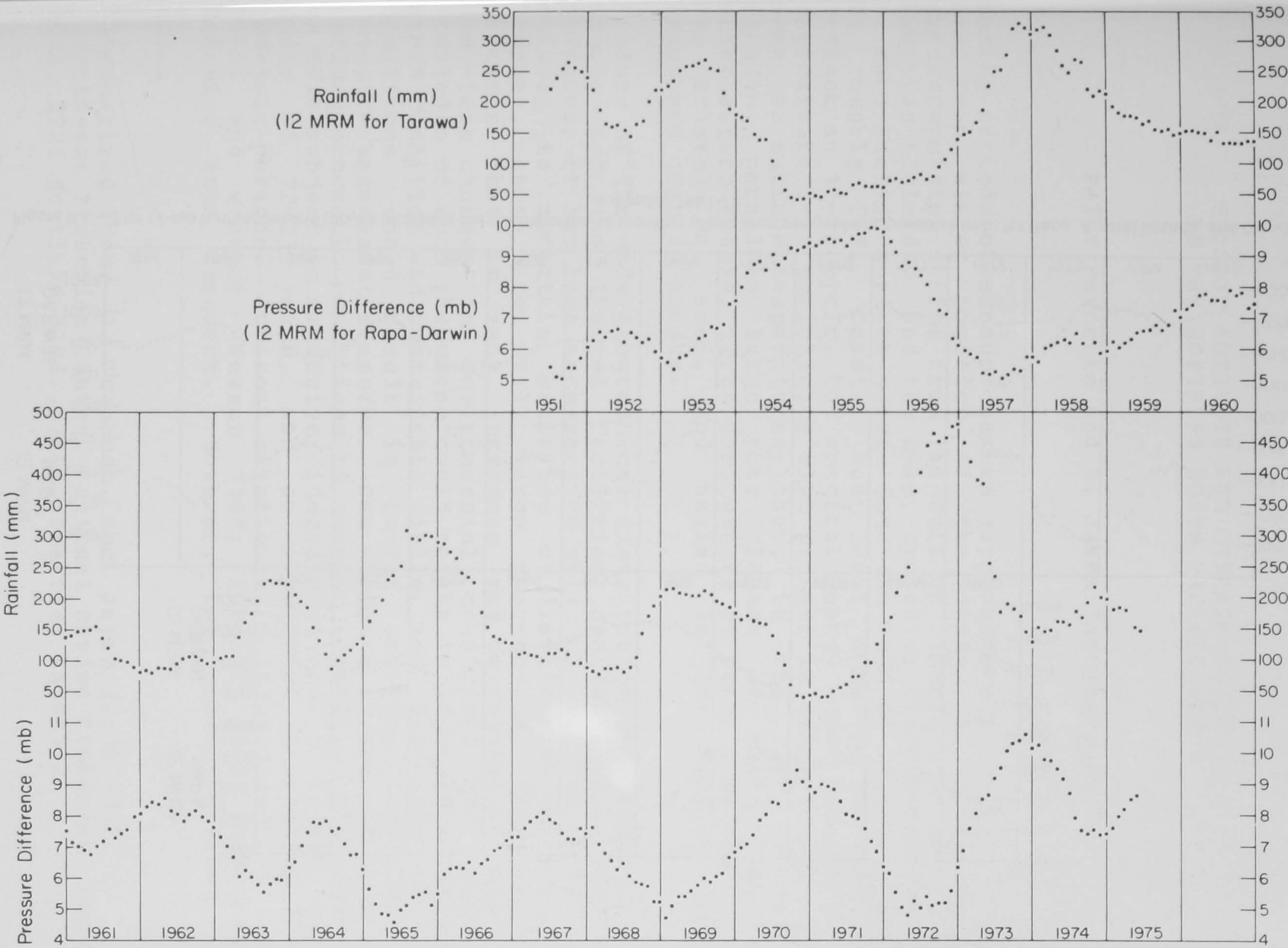

Figure 9.3.—The 12-mo running means (points plotted at the middle of the 12 months) of rainfall (mm) for Tarawa, Gilbert Islands, and of difference in sea level atmospheric pressure (mb) between Rapa, Austral Islands, and Darwin, 1951-75.

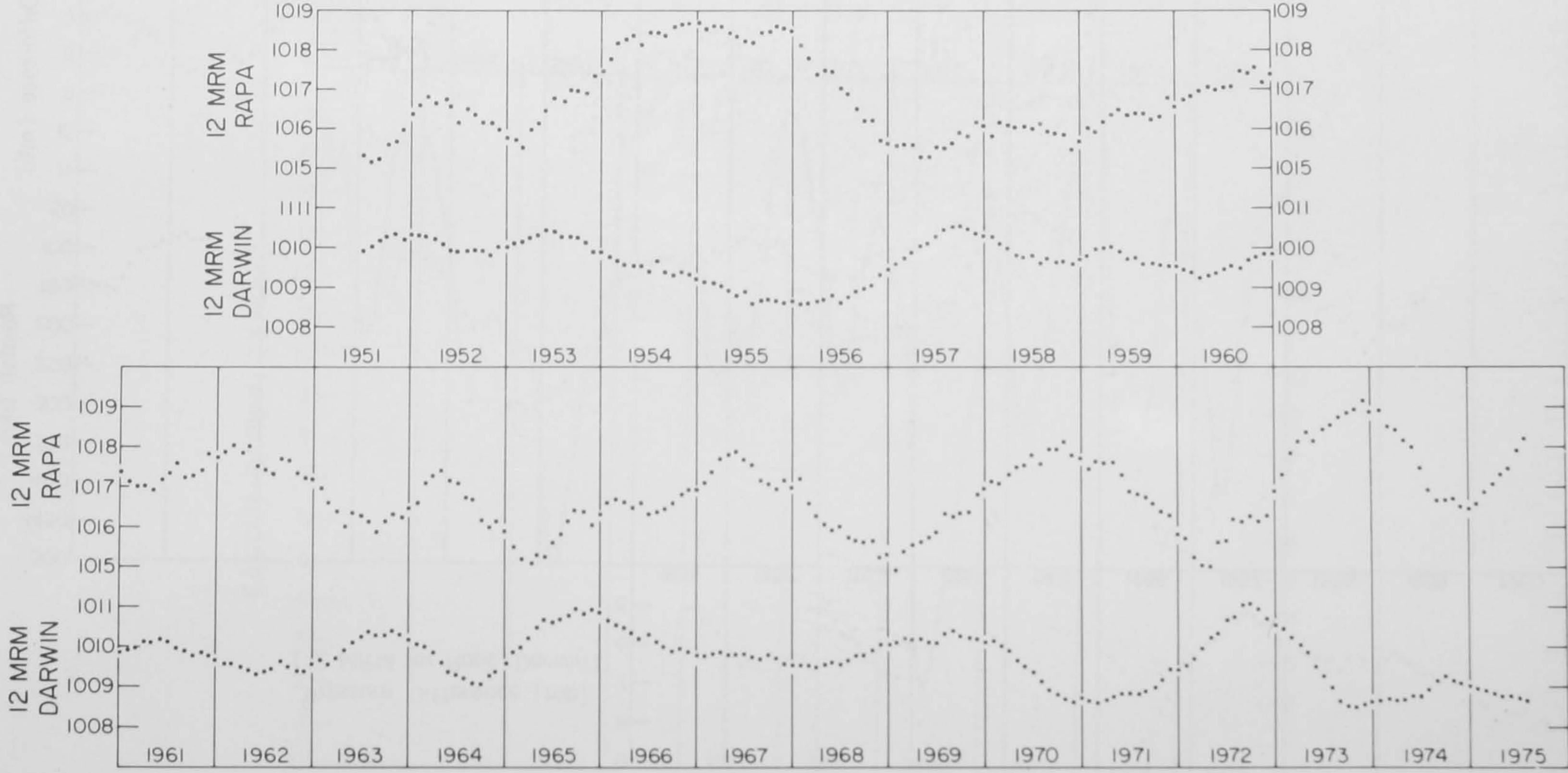

Figure 9.4.—The 12-mo running means (points plotted at the middle of the 12 months) of sea level atmospheric pressure (mb) for Rapa, Austral Islands, and Darwin, Australia, 1951-75.

SUNSPOT ACTIVITY AND OCEANIC CONDITIONS IN THE NORTHERN NORTH PACIFIC OCEAN[1]

Felix Favorite and W. James Ingraham, Jr.[2]

During periods of sunspot maxima (approximately every 11 years) the mean winter position of the center of the Aleutian low pressure system shifts from the Gulf of Alaska to the western Aleutian Islands, and the mean, cyclonic, wind-stress transport of warm Pacific surface waters into the Gulf of Alaska is reduced by roughly 20%. Coastal sea level data in the Gulf do not reflect an 11-yr cycle, but spectral energy densities indicate an approximate 6-yr periodicity also present in trans-Pacific annual mean sea surface temperatures that, in the last one or two decades, parallels large year classes of Pacific herring in southeastern Alaska, large escapements of sockeye salmon fry in the Bristol Bay area, and maxima in the January catch of Dungeness crab in Alaska.

Because of the wide geographical distribution of individual fish stocks and the limited facilities available for assessment purposes, it has been necessary to rely on various statistical methods to ascertain estimates of distribution and abundance. However, there are still large year-to-year differences in patterns that in many instances may be related to short- or long-term changes in environmental conditions and processes. Knowledge of such phenomena could result in improved estimates of stock condition and sustainable yields, and forecasts of these conditions could result in better sampling techniques and resource management measures. One periodic phenomenon that might influence oceanic conditions is sunspot activity. The literature on this subject is extensive, identifying also a double sunspot cycle of 22-23 years, and an a cycle of alternating 80- and 100-year periods. Apparent relations to biological (Gilhousen 1960) and weather (Newman 1965; Mitchell 1965) phenomena are becoming more frequent. However, few investigations have

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[1]Summarized from: J. Oceanogr. Soc. Japan 32:107-115.

[2]Northwest Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd., East, Seattle, WA 98112.

considered possible effects of sunspot activity on ocear conditicns.

Mean pressure data from the winter half-years (October-March) of 3-yr periods centered arcund the sunspot maxima, and 3-yr periods centered arcund the minima, indicate a pronounced westward shift in the mean position of the Aleutian low pressure system from the Gulf of Alaska to the western Aleutian Islands during years of sunspot maxima (Fig. 10.1). Wind-stress transport calculations indicate a 20% reduction in northward transport into the Gulf during periods of sunspot maxima compared to that during sunspot minima, but there are no direct current measurements available to permit showing any actual changes in flow patterns. Nor is there any indication in coastal sea level data to suggest a dominant 11-yr periodicity, but this is nct considered proof that changes in circulation and upwelling do not occur. There is an approximate 5- to 6-yr fluctuation in trans-Pacific sea surface temperature maxima that is largely in phase not only with mean sea level maxima in the Gulf of Alaska (most clearly evident at Prince Rupert during 1950-74), but also with solar phenomena. Although deviations of about 5 cm in sea level can be accounted fcr as a result of changes in specific volume of the surface layer due to seasonal heating and cooling frcm winter to summer (temperature range of 5-10C), the observed deviations in excess of 10 cm cannot be attributed solely to the 1-2C changes in temperature associated with the 5- to 6-yr temperature cycle.

The 5- to 6-yr cycle does have subtle, if not direct, relations to living marine resources. Reid (in press) has shown that dominant year classes of Pacific herring in southeastern Alaska from 1950 to 1958 occurred in 1953 and 1958, years of temperature maxima in that area (Favorite and McLain 1973). Hoopes (1973) has shown that the Alaskan Dungeness crab landings in January reached maxima in 1963 and 1964, and again in 1968 that were nearly 3 times the minima in 1961, 1966, and 1971--roughly 12-1[illegible] vs. 4-5 million pounds (Favorite, in press). Finally, the 5- to 6-yr temperature cycle appears to have a parallel in sockeye salmon abundance in river and lake systems in Bristol Bay. The annual pack of canned sockeye salmon in western Alaska for 1950-74 (Fig. 10.2) shows maxima in 1952, 1956, 1961, 1965, and 1970 that are obviously out of phase with the temperature cycle, but if one considers the critical early life stages in lake and river systems 2 to 4 years earlier, a parallel is evident. Considering only the three recent maxima, 83% of the sockeye salmcn returning to Bristol Bay in 1960 grew in fresh water from spring 1957 to spring 1958; 88% of those returning in 1965, from spring 1961 to spring 1963; and 82% of those returning in 1970, from spring 1966 to spring 1968.[3] Although in terms of numbers, spawning success is certainly dependent on the number of spawning adults and other factors, this pattern of fish returns suggests that the sea surface temperature maxima phase of the recent and prolonged trans-Pacific cycle could have a salutary effect on spawning survival.

Unfortunately, any teleconnections or servomechanisms between sunspot activity and physical or biological phenomena on earth are not clear at this time. It should be obvious that the search for cause and effect relations between environmental conditions and fluctuations in fishery data is exceedingly complex, requiring not only extensive data, but multidisciplinary approaches as well, before accurate forecasts will be possible. Forecasts of conditions based on trends indicated in this paper would be imprudent because the end of the 100-year sunspot cycle will occur in the mid-1970's. This should result in two consecutive negative maxima, and deviations from established conditions may occur.

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[3]Percentage data obtained from: Donald E. Rogers. Forecast of the sockeye salmon run to Bristol Bay in 1973 and 1975. University of Washington College of Fisheries, Fisheries Res. Inst. Circ. No. 73-1, 33 p., and Circ. No. 73-3, 45 p.

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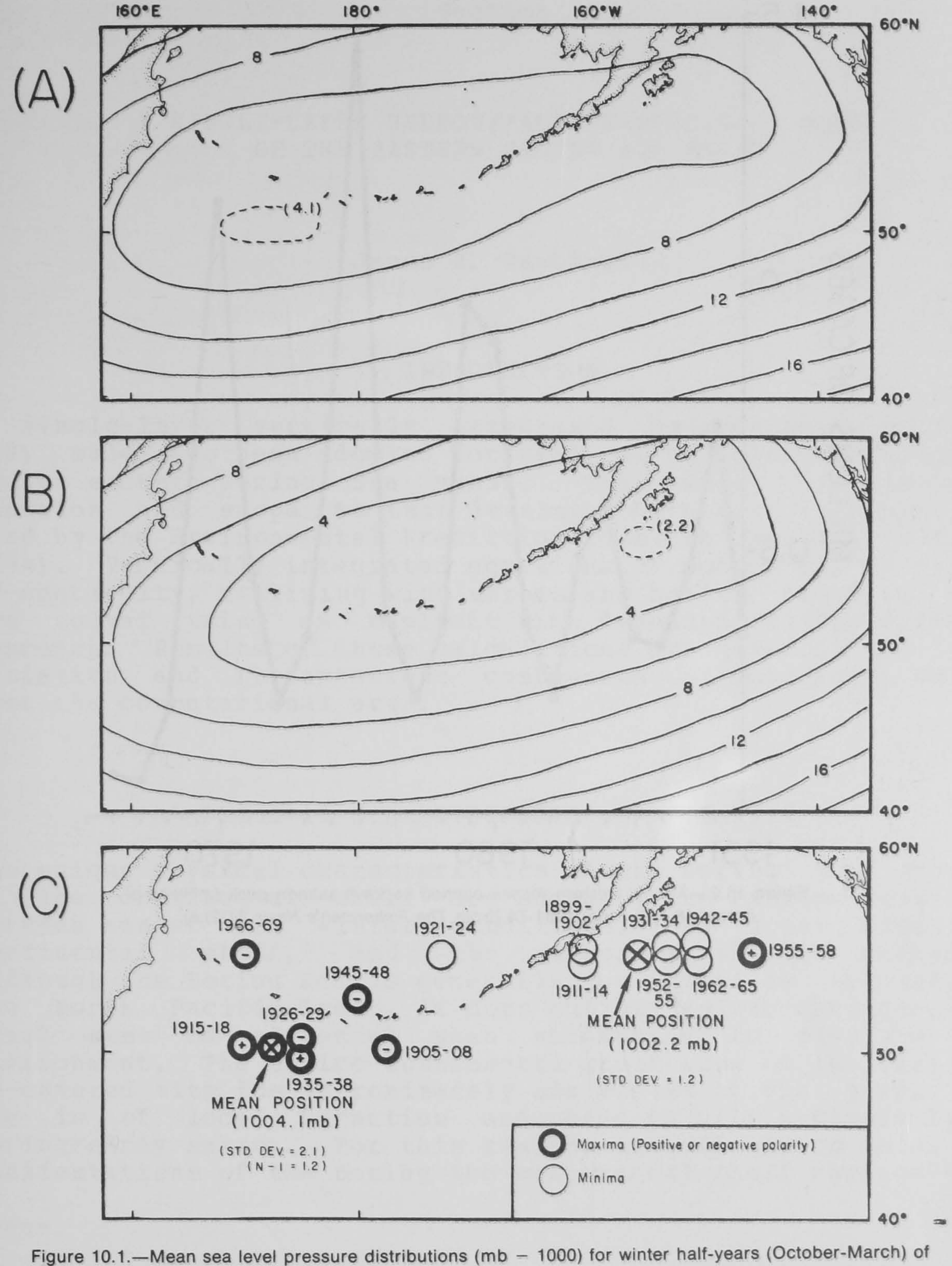

Figure 10.1.—Mean sea level pressure distributions (mb − 1000) for winter half-years (October-March) of 3-yr periods centered around sunspot maxima (A) and sunspot minima (B), and locations of centers of the Aleutian low for individual periods (C), 1899-1974.

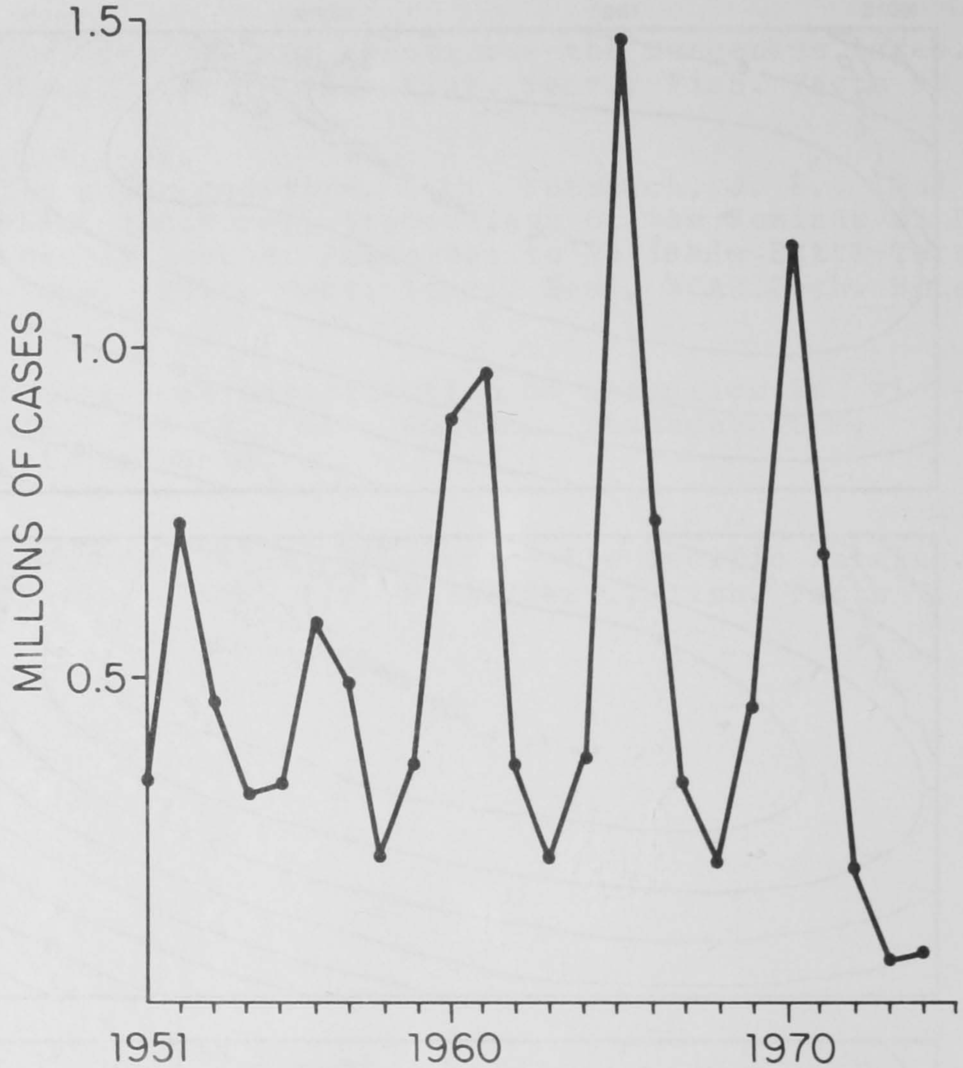

Figure 10.2.—Annual western Alaska canned sockeye salmon pack (millions of cases; 48 1-lb cans) 1951-74 [from *The Fisherman's News* 31(2):4].

Section 11

A SINGLE-LAYER HYDRODYNAMICAL-NUMERICAL MODEL OF THE EASTERN BERING SEA SHELF

James R. Hastings[1]

INTRODUCTION

A single-layer vertically integrated hydrodynamical-numerical (HN) model has been adopted for study of the characteristic flow of the eastern Bering Sea shelf. This model is similar in function and scope to that developed by Hansen,[2] and currently used by the Environmental Prediction Research Facility (U.S. Navy 1974). Vertically integrated equations of motion and an equation of continuity, utilizing wind stress and bottom friction terms, are solved using an explicit time dependent finite difference approach. Results of these calculations are given as sea surface variation and instantaneous components of integrated velocity over the computational area.

PHYSICAL CHARACTERISTICS OF THE AREA

The unique physical characteristics of the Bering Sea shoreward of the continental shelf are shown by the extreme delineation between summer and winter conditions, the great expanse of continental shelf, and the extremely shallow bathymetry. Although the Bering Sea is generally considered an extension of the North Pacific Ocean, it does exhibit unique characteristics which must be addressed when attempting to simulate this environment. The entire continental shelf area of the Bering Sea is covered with ice approximately six months of the year. This ice is of local formation and tends to melt entirely by late spring/early summer. For this reason, the efforts to model tidal manifestations of the Bering Sea continental shelf surface waters

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[2]Hansen, W., Institut fur Meereskunde, University of Hamburg, Hamburg, Federal Republic of Germany.

were concentrated on those conditions which are indicative of the summer months. Along the southeastern Siberian coast the tides are diurnal, becoming mixed at about 60N; northward of 62N simidiurnal tides occur. Mixed tides occur along the Alaskan coast from Bering Strait to the Alaska Peninsula. Except in the major embayments around the margins of the Bering Sea the tidal amplitudes are generally small, with most tides being less than 1 m.

GRID SYSTEM

The grid system used for the solution of these finite difference equations is staggered in both time and space (Fig. 11.1). There are three different sets of grid points in this system. The z-points (water elevations) are at the intersections of the grid, the u-points (u-components of horizontal velocity) are to the right of the z-points, and the v-points (v-components of horizontal velocity) are below the corresponding z-points. These points are used to provide the computational matrix and real depth inputs to the model.

The computational network imposed over the continental shelf of the Bering Sea consists of 1,204 units, each 38 km square. This 28x43 array has a horizontal extent greater than 1,500 km in an east-west direction, and extends from Amaknak Island in the southeast through the Bering Strait (Fig. 11.2). Land areas are separated from water by a straight line boundary (dashed line, Fig. 11.2) which passes through either the u-points, in a north-south direction, or the v-points, in an east-west direction. The southern boundary, extending from Amaknak Island to Cape Navarin, is the tidal input boundary.

PARAMETERIZATION AND INITIALIZATION OF INPUTS

Precision is built into the model in the form of the forward-looking finite difference scheme, but accuracy is dependent upon the selection and interpretation of the natural phenomena which make up the boundary conditions. At the inception of this model, several assumptions and simplifications of the boundary conditions were made; but as our knowledge of the Bering Sea environment increases, it will be possible, and mandatory, to make further refinements in these boundary conditions.

The most important single input parameter which the HN model employs in shallow water is the tidal input. The tidal amplitude and phase speed variance are two of the driving impetuses in the numerical computation scheme. Also, the geostrophic wind component may be represented by prescribing a longitudinal and/or ransverse slope to the sea surface at each time step. Data from wo tidal stations are usually required; and, because of the oundary conditions at the shelf edge, these should be located at he extremities of the shelf. Amaknak Island data are available t the southeast edge of the shelf, but data from Port Sibir and nadyr Bay were interpolated to derive data at Cape Navarin in he west. A lag time of 8 hours exists between high tides at the ast and west boundaries (Fig. 11.3). This variation was assumed o be linear over the extremely long (1,500 km) lateral extent of he input boundary, as few open ocean tidal observations have een reported which could provide greater control across this ea. Therefore, the initial tidal inputs to this model consist f an interpolation between Cape Navarin in the west 2N30', 177E) and Amaknak Island in the east (54N30', 166W30').

IMULATED TIDAL HEIGHT AND CURRENT DATA

pplying this particular model over such a large area should and oes show considerable spatial variations in sea surface heights nd tidal currents that should be substantiated by additional idal data. After computational stability has been achieved, nstantaneous sea surface height and tidal current variation may e studied. Three particular instances are examined: variation f the entire system approximately 4 hours before low tide at the astern input boundary; approximately 4 hours before the ubsequent high tide; and 4 hours before low tide with boundary onditions changed to simulate a typical summer southerly wind of m/s blowing steadily over the entire area for 2 days. This rovides an indication of the temporal and spatial variation of he system while under the influence of an additional nvironmental variable.

ur hours before low tide at the eastern boundary, sea surface ight variations show several interesting features (Fig. 11.4). er the open portion of the Bering Sea shelf there appears to be smooth, even variation in sea surface perturbation due to tidal fluence; with no land masses to impose horizontal flow strictions and a minimum of frictional resistance due to the fluence of bottom topography, the tidal height variation is an derly transition between the influences of the tidal inputs. nivak Island, northwest of Bristol Bay in the north central rtion of the system, indicates major tidal height differences ound the island, with maximum elevations at the northeast rner of the island. The influences of land boundaries, bottom iction, and tidal confluence cause a tidal difference around e island of greater than 60 cm. This is in contrast to nditions at St. Matthew Island in the south central portion of e grid, where spatially the absolute variation is small, but e temporal variation is considerable. Tidal height variations were concentrated on those conditions which are indicative of the summer months. Along the southeastern Siberian coast the tides are diurnal, becoming mixed at about 60N; northward of 62N simidiurnal tides occur. Mixed tides occur along the Alaskan coast from Bering Strait to the Alaska Peninsula. Except in the major embayments around the margins of the Bering Sea the tidal amplitudes are generally small, with most tides being less than 1 m.

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SIMULATED TIDAL HEIGHT AND CURRENT DATA

Applying this particular model over such a large area should and does show considerable spatial variations in sea surface heights and tidal currents that should be substantiated by additional tidal data. After computational stability has been achieved, instantaneous sea surface height and tidal current variation may be studied. Three particular instances are examined: variation of the entire system approximately 4 hours before low tide at the eastern input boundary; approximately 4 hours before the subsequent high tide; and 4 hours before low tide with boundary conditions changed to simulate a typical summer southerly wind of 5 m/s blowing steadily over the entire area for 2 days. This provides an indication of the temporal and spatial variation of the system while under the influence of an additional environmental variable.

Four hours before low tide at the eastern boundary, sea surface height variations show several interesting features (Fig. 11.4). Over the open portion of the Bering Sea shelf there appears to be a smooth, even variation in sea surface perturbation due to tidal influence; with no land masses to impose horizontal flow restrictions and a minimum of frictional resistance due to the influence of bottom topography, the tidal height variation is an orderly transition between the influences of the tidal inputs. Nunivak Island, northwest of Bristol Bay in the north central portion of the system, indicates major tidal height differences around the island, with maximum elevations at the northeast corner of the island. The influences of land boundaries, bottom friction, and tidal confluence cause a tidal difference around the island of greater than 60 cm. This is in contrast to conditions at St. Matthew Island in the south central portion of the grid, where spatially the absolute variation is small, but the temporal variation is considerable. Tidal height variations north of St. Lawrence Island are small, generally less tha 20 cm. An instantaneous view of the tidal currents associate with these tidal heights (Fig. 11.5) indicates a genera northwestward flow over the shelf in the southern portion of th area; cross shelf flow exists in the area between Nunivak Islan and St. Matthew Island. Higher velocities are exhibite northwestward around St. Matthew Island and southwestward in th area northeast of Nunivak Island. This cross shelf flow is als apparent in the western portion of the shelf, whereas th currents flow in a general southwestward direction out of th Gulf of Anadyr. North and east of St. Lawrence Island a genera northeastward flow exists, with currents funneling into Norto Sound. Currents flow northeastward into Bristol Bay, divergence from the general northwestward flow over the shelf Over the open portion of the Bering Sea shelf, average current are less than 20 cm/s; this approximates speeds determined b Goodman et al. (1942) and Arsen'ev (1967).

Four hours before the subsequent high tide at the easter boundary, tidal elevations are generally reversed (Fig. 11.6) Maximum elevations at Nunivak Island occur at the southwester end of the island. At St. Matthew Island surface height is maximum, whereas a minimum was manifest earlier. Minimum height are observed in northern Bristol Bay. Tidal currents show a almost complete reversal in direction but similar speed (Fig. 11.7). The southern portion of the area shows a genera southeastward flow over the shelf; cross shelf flow in northeastward direction exists in the area between Nunivak Islan and St. Matthew Island. Flow over the western area of the shel is generally northward. Tidal currents between Nunivak Islan and the Alaskan mainland exhibit a total reversal of flow, as d the currents in northernmost Bristol Bay. Although current between St. Lawrence Island and southern Norton Sound now flo southward, flow into Norton Sound is still indicated.

Although in winter most of the area is covered with ice, i summer wind stress plays an important role in the formation o current patterns. After the model reached stability a mea southerly wind of 5 m/s was imposed on the system. This was don in an attempt to simulate more accurately the actual condition during this period. When comparing the change in the circulatio pattern due to the influence of the wind, several importan manifestations are observed. Generally speaking, the flow nea the land masses shows a significant increase in velocity, a shown by the currents near Nunivak Island and the norther portion of the area between Norton Sound and Bering Strai (Fig. 11.8). A reversal in flow is observed through the Berin Strait and adjacent to the continental land mass south of Norto Sound. The influence of the wind has served to set up tw anticyclonic gyres in the circulation system, one southeast o the Gulf of Anadyr in the west and another in the souther portion of Bristol Bay in the east.

Figure 11.9 indicates the predominant tidal current field in the northeast portion of Bristol Bay over a 44-h time period. The more intense flow occurs as maximum flood and maximum ebb stages of the tide are approached. The less intense, more confused flow corresponds to high and low slack water. This flow is characteristic of that reported by Dodimead et al. (1963) from drift stick observations in northeastern Bristol Bay.

In an attempt to equate data generated by the HN model with conditions which exist in the natural environment, grid point 28x16 (MxN) north of St. Lawrence Island was analyzed over a 60-h time period. Records indicate that the tide in this area has a mean range of approximately 30 cm. Data from the model show a variation of approximately 27 cm and variation over time corresponds closely to actual tidal data (Fig. 11.10).

Apparently the most pressing problem concerning the use of this model involves the northern boundary conditions through the Bering Strait. The initial assumption of zero flow through Bering Strait yields unrealistic current values in this portion of the model. Coachman and Aagaard (1966) suggest a permanent northward flow of approximately 50 cm/s through Bering Strait. This prescription of flow was not applied in this model; thus the results with reference to currents near Bering Strait are not entirely realistic.

CONCLUSIONS

This study has shown temporal variations of flow over a large area by simplifying the inputs and by making certain initial assumptions about the system. Results of this model indicate that it could be a useful tool in studying and predicting tidal variations, even considering the scale limitations inherent in a model of this size. Nowhere else are even gross patterns of oceanic tidal currents of this area presented. These results may be used to determine critical areas where current meter studies should be conducted, and to verify unusual features (e.g., the cross shelf flow between Nunivak Island and St. Matthew Island); they may also serve in their present form for initial studies of fish larvae transport and dispersion. Further advances in model simulation will be made as additional boundary conditions, i.e., river runoff, permanent currents, variable wind fields, and verifications by direct current measurements, are incorporated into the model. A more definitive study of this area will require a more comprehensive solution to the complex tidal inputs of the system and the evolution from this existing single-layer model into a multi-layer model.

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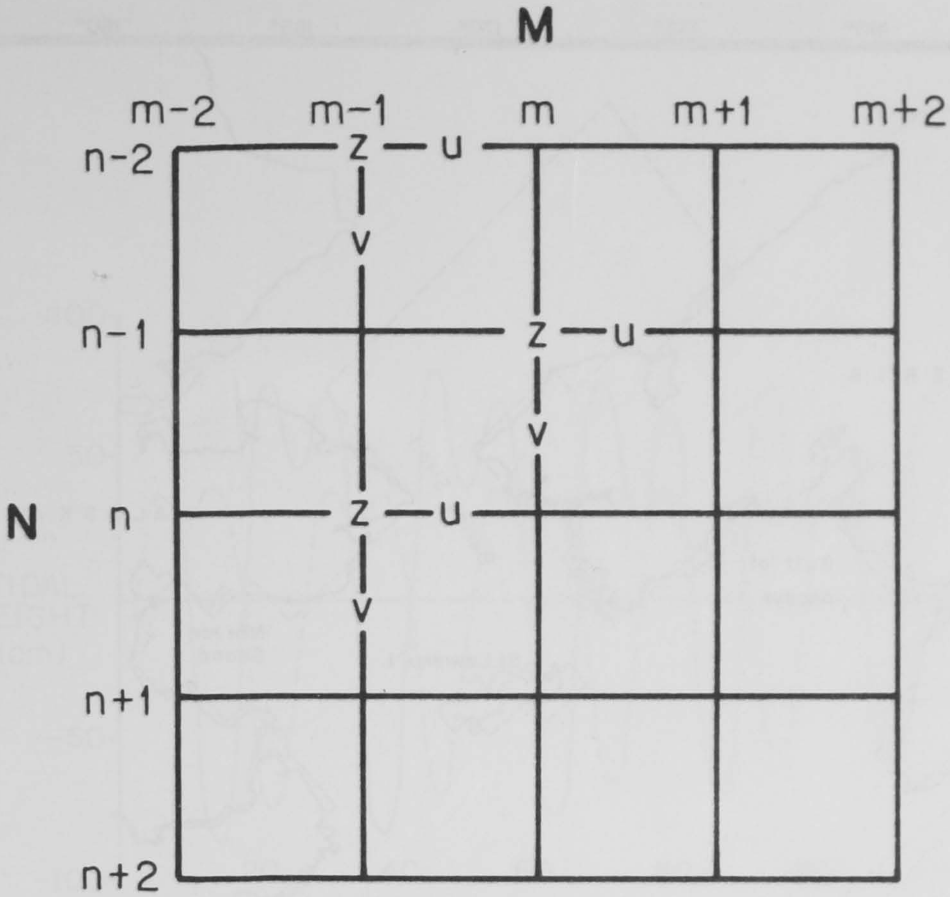


Figure 11.1.—Computational grid for the finite difference scheme of the hydrodynamical-numerical model. M coordinates are in the x-direction; N coordinates are in the y-direction; z = water elevation; u = x-component of horizontal velocity, on right of z; v = y-component of horizontal velocity, below the corresponding z.

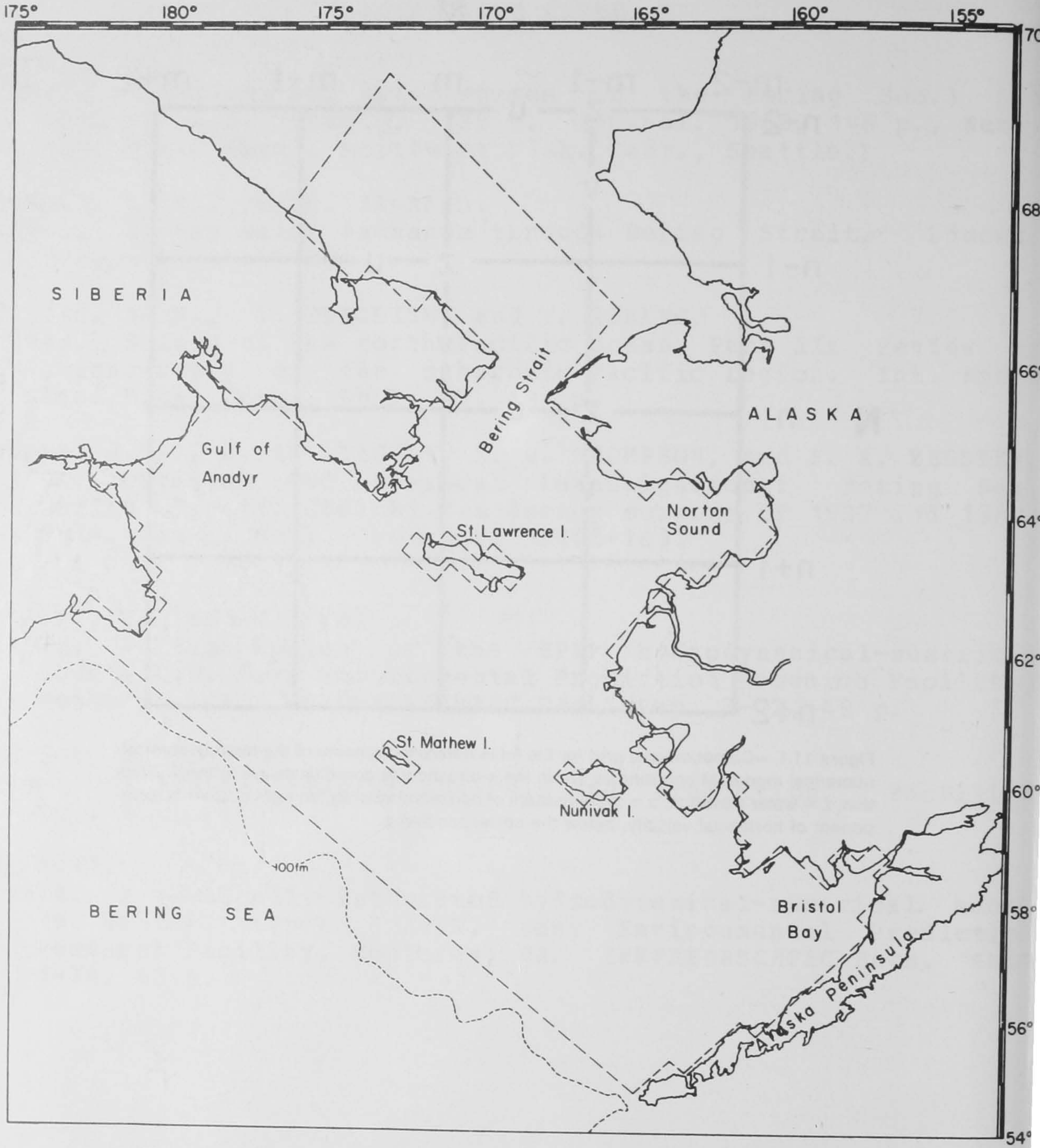


Figure 11.2.—Computational grid boundaries imposed on the eastern Bering Sea shelf.

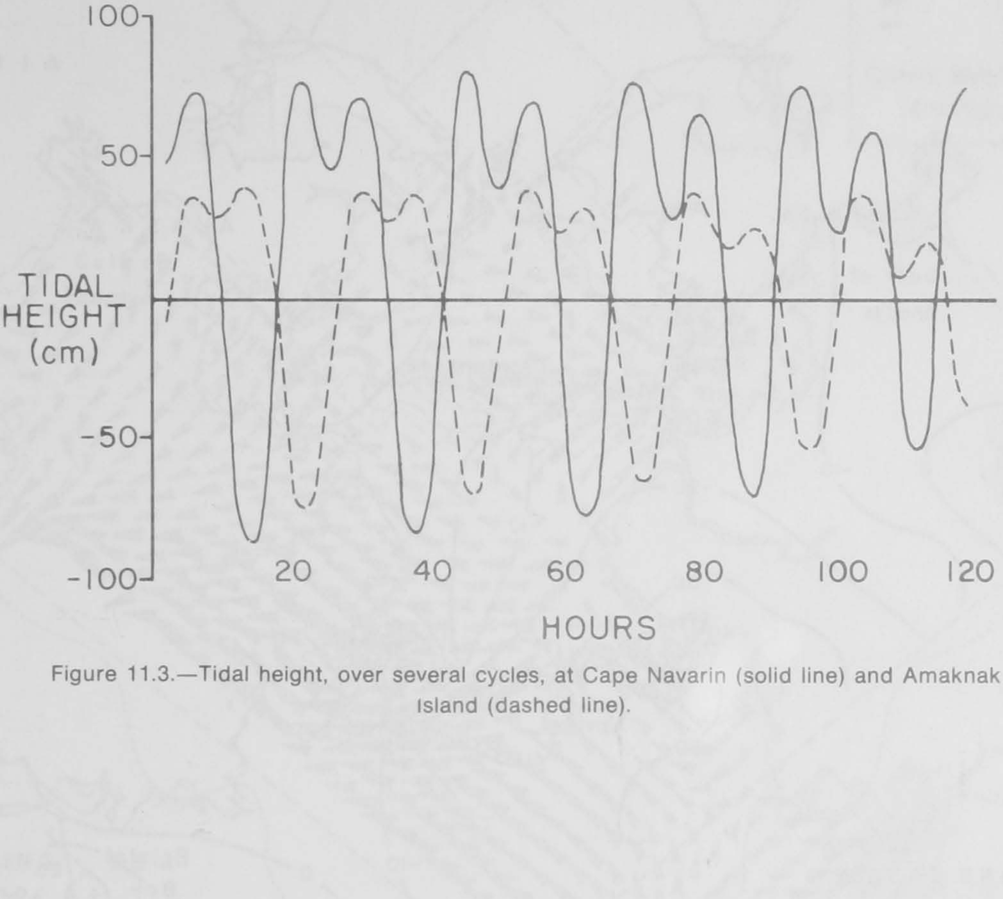
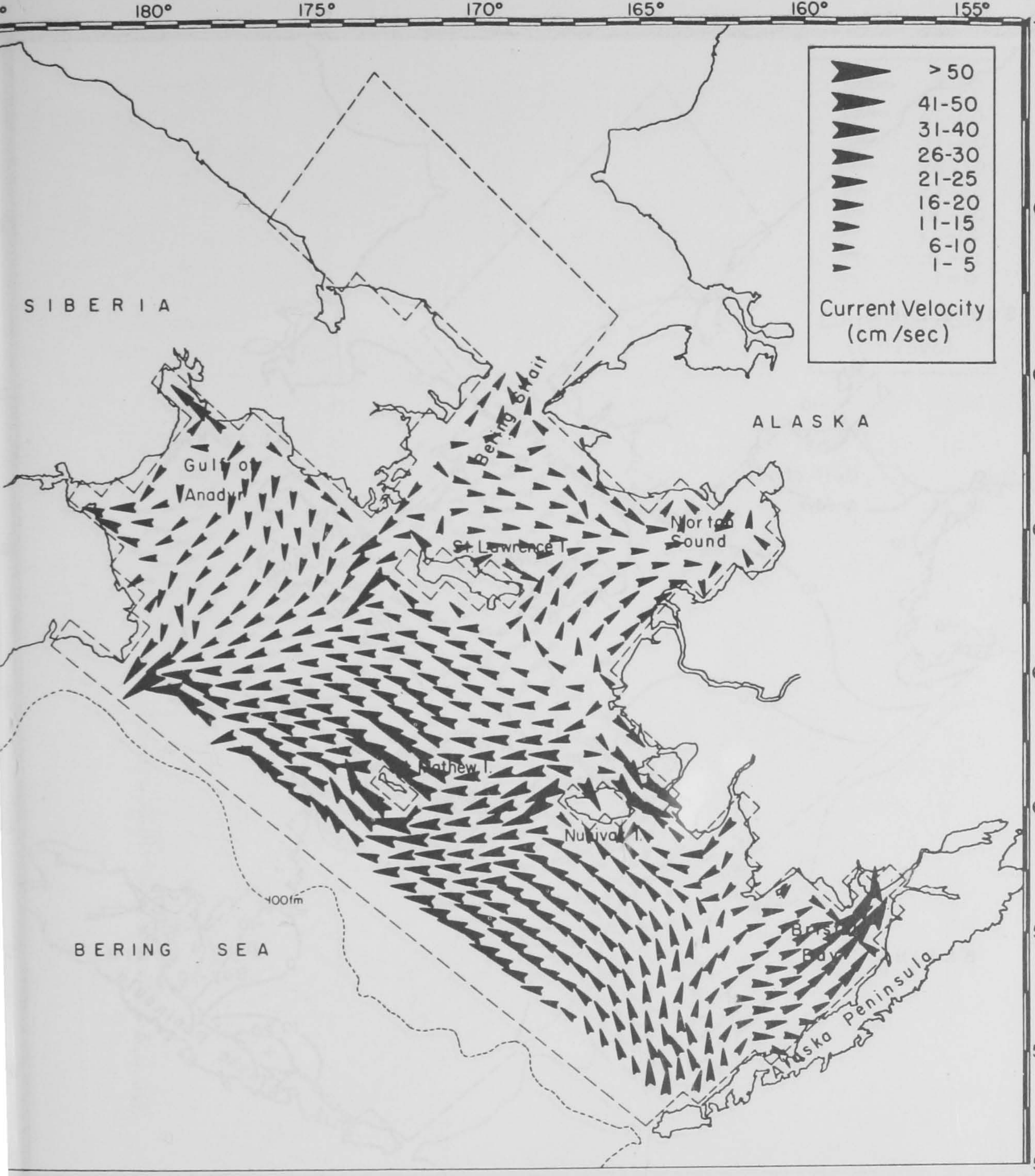


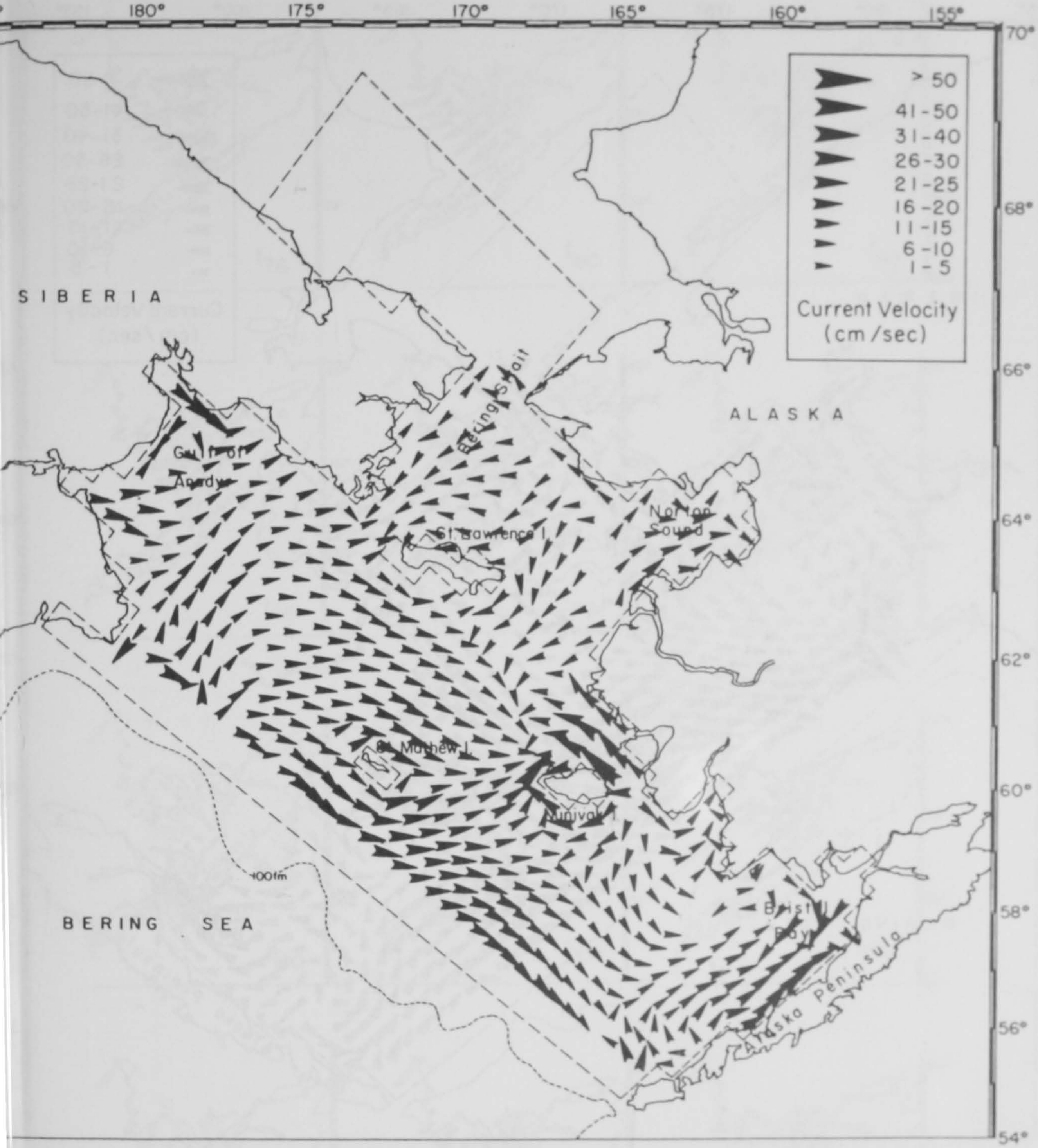
Figure 11.3.—Tidal height, over several cycles, at Cape Navarin (solid line) and Amaknak Island (dashed line).

Figure 11.4.—Tidal heights (cm) over the eastern Bering Sea shelf 4 hours before low tide at the eastern boundary; initial condition of zero wind.



ure 11.5.—Tidal currents over the eastern Bering Sea shelf 4 hours before low tide at the eastern boundary; initial condition of zero wind.

Figure 11.6.—Tidal heights (cm) over the eastern Bering Sea shelf 4 hours before high tide at the eastern boundary; initial conditi[ons] of zero wind.



ıre 11.7.—Tidal currents over the eastern Bering Sea shelf 4 hours before high tide at the eastern boundary; initial condition of zero wind.

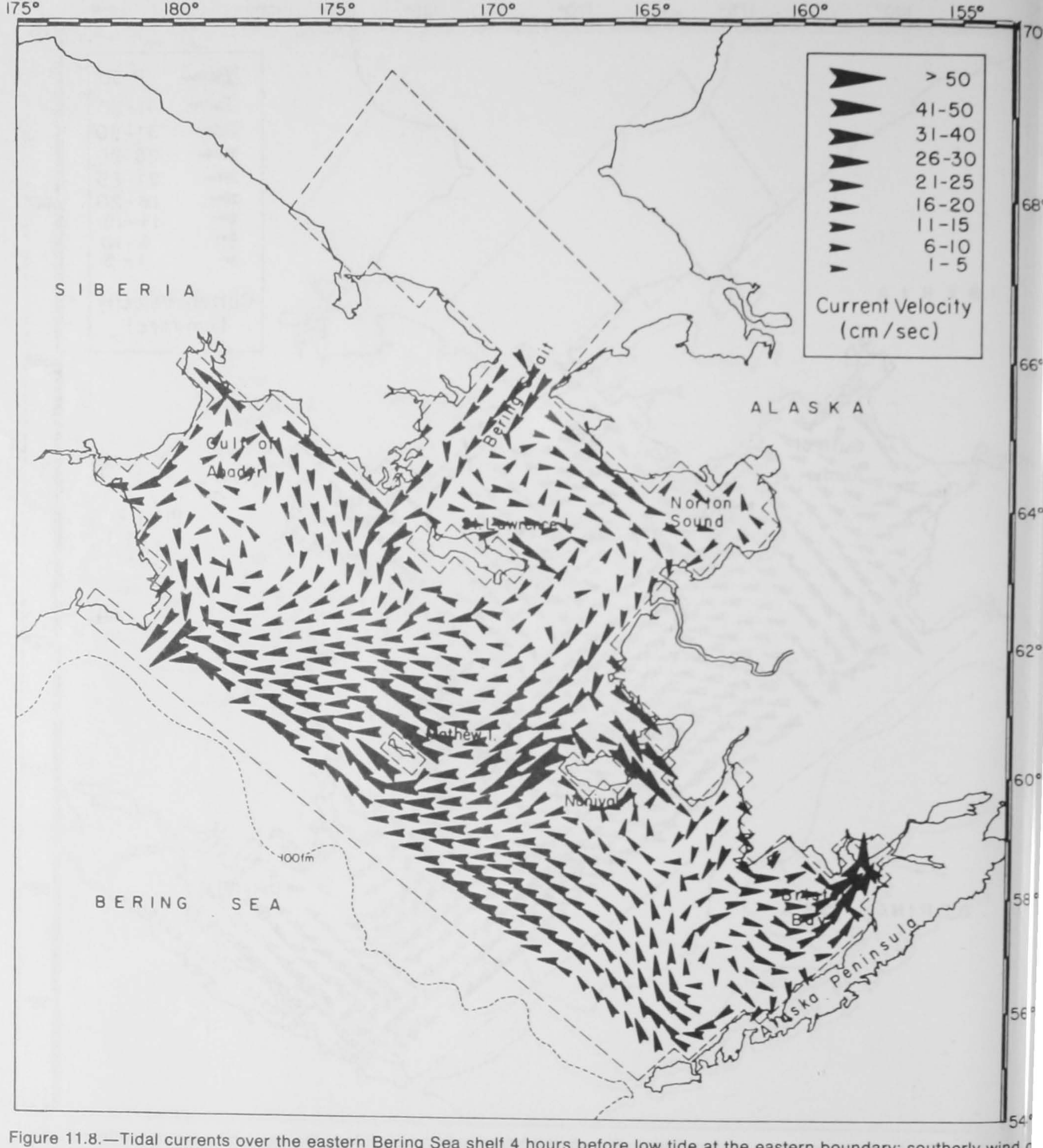


Figure 11.8.—Tidal currents over the eastern Bering Sea shelf 4 hours before low tide at the eastern boundary; southerly wind of 5 m/s.

Figure 11.9.—Surface tidal currents in the northeast portion of Bristol Bay over a 44-h time period; initial condition of zero wind.

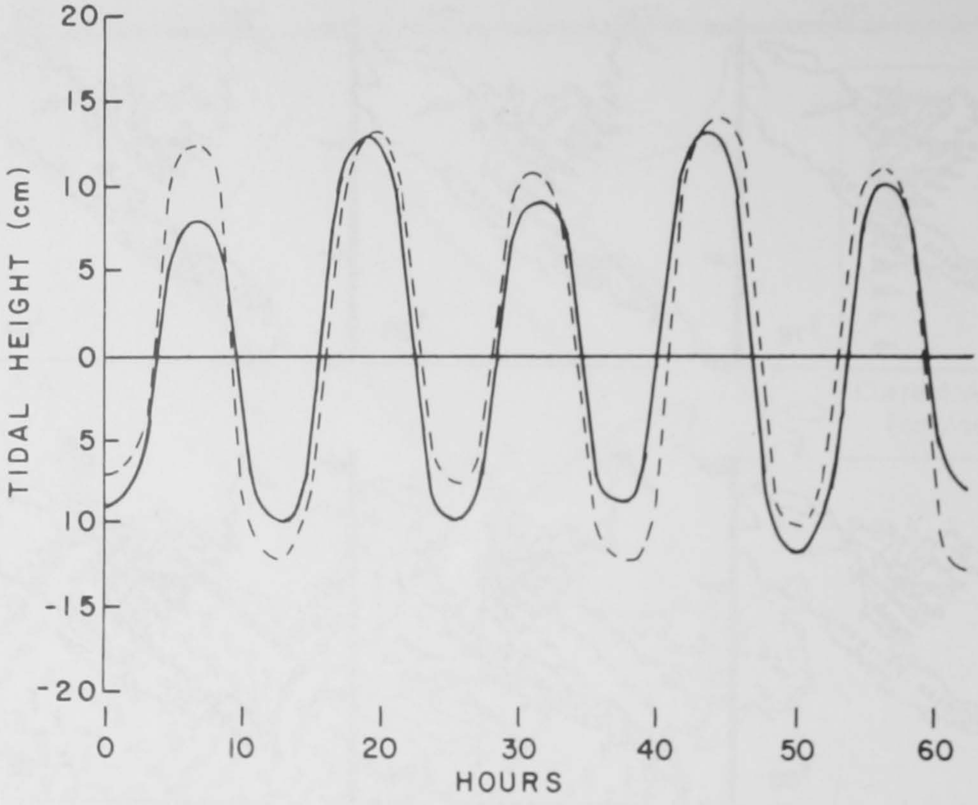


Figure 11.10.—Tidal heights on the north side of St. Lawrence Island. Solid line is data generated by the model; dashed line is actual tidal data.

Section 12

VARIATIONS IN THE POSITION OF THE SHELF WATER FRONT OFF THE ATLANTIC COAST BETWEEN CAPE ROMAIN AND GEORGES BANK IN 1975

John T. Gunn[1]

INTRODUCTION

Monitoring of the temporal variations of the Shelf Water front position provides important information for understanding the concentration of fish stocks, because of the accumulation of lower food chain organisms associated with the convergence zone of the front. Since the front may extend to the bottom over the continental shelf, as revealed by expendable bathythermograph (XBT) transects, its variations may affect the distribution, and thus the harvesting, of benthic and demersal organisms. Also, the frontal position may contribute to variation in recruitment and year class strength of species whose spawning and nursery areas are affected by the different water mass characteristics on either side of the front.

An analysis of the position of the Shelf Water front for the period from June 1973, when appropriate satellite data first became available, through 1974 was presented previously by Ingham (1976). The present analysis for 1975 is similar, but includes a comparison of the trends in the frontal position between 1974 and 1975.

SOURCE OF DATA

The basis of this study is a weekly series of frontal charts (Fig. 12.1).[2] These charts are drawn from the best infrared NOAA satellite image of the week or a composite of several partial

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[1]Atlantic Environmental Group, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.

[2]Experimental Gulf Stream Analysis Charts, Environmental Science Group, National Environmental Satellite Service, NOAA, Washington, DC 20233.

satellite images. The charts show the position of the following thermal features at the surface: Shelf Water, Slope Water, Gulf Stream, and warm and cold core Gulf Stream eddies ("rings"). The satellite imagery is recorded by an infrared radiometer, sensing in the 10.5-12.5 micron range, with a resolution at the sea surface of approximately 1 km at nadir.

PRIMARY DATA ANALYSIS

To portray the variation of the shelf water frontal position, distances were measured to the front along standard bearing lines from selected coastal points (Fig. 12.2). The distances measured (in mm) from each satellite chart are converted to km and corrected for scale variation (ca + or - 5%) from chart to chart. These distances are then diminished by the distance along each bearing line to the 200-m isobath. The resulting values represent the distance from the shelf edge to the front; positive values are seaward and negative values shoreward from this isobath.

TRENDS IN WEEKLY FRONTAL POSITIONS

The graphs of weekly values for each bearing line (Figs. 12.3-12.14) reveal both spatial and temporal trends in the frontal position. By comparing adjacent graphs, events which occur at more than one position can be identified, and by consulting the original satellite charts, possible causes can be discerned. In general, there is fair agreement between adjacent bearing lines regarding the onshore or offshore direction of excursions and general trends, although the magnitudes are sometimes quite different.

New England: Along the bearing lines out of Casco Bay (Figs. 12.3-12.5) two major events occurred on all three lines. In July there was a 25-60 km shoreward intrusion of the front from the 200-m isobath. No anticyclonic eddies were detected in the area during this time, and the only noteworthy feature was a large Gulf Stream meander to the southeast. The distance of this meander from the front (186 km), however, reduces the likelihood that it caused the July intrusion. In September, another shoreward intrusion appears on all three Casco Bay bearings. Considerable Gulf Stream meandering and eddy activity at this time could have produced the intrusion.

Middle Atlantic: The middle Atlantic coast region, from off Nantucket to Cape Henry, was affected by strong fluctuations of the front in April and August. The excursion in April reached a ximum cf 140 km seaward on some bearing lines igs. 12.6-12.10) resulting in a considerable decrease in the ea of Slope Water. No eddies were detected in the immediate ea at this time. The shoreward intrusion in August (up to 5 km) was mainly due to an intrusion from the Gulf Stream that shed the Shelf Water front closer to the coast and considerably srupted its shape. South of the Sandy Hook bearing line the ontal position could nct be detected during August because of oud cover.

e magnitude of variation in frontal position during 1975 igs. 12.3-12.10) generally increased progressively north of the bemarle Scund bearing line to the Casco Bay 120 bearing line, milar to 1974. There was, however, somewhat less variability ong the Casco Bay lines in 1975 compared with 1974.

MONTHLY MEAN FRONTAL POSITIONS

clear picture of the temporal nature of the Shelf Water front given by graphs cf the monthly mean positions versus time ig. 12.15). Note that the baseline for excursions is changed om the 200-m isobath used in the time series to the 2-yr mean lue. This offsets the time series (Figs. 12.3-12.14) for each aring differently and eases comparison of quasi-periodic riaticns.

ere is a basic seasonality in the change of frontal position ong the bearing lines from Sandy Hook 130 to Casco Bay 140. though the magnitude of the variation varies between the two ars and among the bearing lines, seaward excursions prevail in e first part of each year, January to April, and shoreward cursions during the rest of the year, May to December. There e some exceptions to this, however, such as in 1975 for Casco y 140 where almost nc variation occurred during the entire ar. Also, in late 1974, on the Montauk 150 bearing line, the ont is shoreward during October and November. Casco Bay 120 so shows this type of seasonality in 1974, but only a slight dication of it in 1975, when the changes in frontal position em to have been aperiodic.

the bearing lines south of Sandy Hook 130, the large gaps in e observations resulting from clouds, the weakness of the ermal gradient, and the limits to the area covered by the tellite are a problem in the analysis. The actual number of ese gaps north of Cape Lockout is not large, but during the mmer, cloud cover eliminated cbservations for weeks at a time om Cape May south. Despite these gaps, a seasonal pattern in e Shelf Water frontal position may be detected in the Cape May, pe Henry, and Albemarle Scund bearing lines, as evidenced in the graphs of monthly mean values (Fig. 12.16), which is opposite to that in the area to the north. Here the front tends to be shoreward in the first part of the year, January to March or April, and seaward in the latter part of the year. This seasonality is quite evident off Albemarle Sound, but less so for the other two bearing lines, due to the lack of observations. A large shoreward event, on the Sandy Hook bearing, in August 1975, when a Gulf Stream warm core eddy was passing through the area, also seems to affect Cape May and Cape Henry, but lack of data blurs definition on these last two bearings (see Figs. 12.9 and 12.10 for weekly data).

On the three most southerly bearings, Cape Lookout, Cape Fear, and Cape Romain, the lack of observations in the warm season prevents determination of whether there is seasonality in the frontal position or mainly aperiodic movements. Despite this, the displacements along these three bearing lines do parallel each other.

YEARLY MEAN FRONTAL POSITIONS

The yearly mean position of the Shelf Water front relative to the 200-m isobath and the standard deviation of these values along each of the bearing lines indicate that the Shelf Water front was farther inshore in 1975 than in 1974 (Table 12.1 and Fig. 12.16). The only exception was the northernmost bearing line. Although the differences (on the order of 10-15 km) in the mean positions between 1974 and 1975 are less than one standard deviation, the consistently more shoreward positions in 1975 and the similarity of the yearly trends in mean positions for the two years indicate that this shoreward displacement has some significance. The two years show parallelism in the relative positions of the front along each bearing line, with noticeable seaward displacements at the Montauk and Cape Henry bearing lines from the general north-south trend. The variability of the Shelf Water front's position, as indicated by the standard deviation, is shown to be fairly high, but relatively consistent for the two years, except on the bearing lines out of Casco Bay. In fact, the two lowest standard deviations in the two years occur at opposite ends of the coast, Casco Bay 140 in 1975 and Cape Lookout 135 in 1974.

INTRUSION OF SLOPE WATER OVER GEORGES BANK

In the Georges Bank region, another representation of the excursions of the Shelf Water front was produced by measuring the percentage of Georges Bank covered by Slope Water as a function of time. These measurements substantiate this seasonality of the elf Water front as demonstrated previously by the bearing lines ig. 12.16). As shown in Figure 12.17 there are no major trusicns cf the Shelf Water front onto Georges Bank from nuary through May, the largest intrusion in this pericd for 74-75 covering only 7.5% of the total area. From June to cember, the front is considerably more active, having peaks of and 17% coverage in 1974 and 34% and 35% coverage in 1975. though 1975 had larger intrusions than 1974, the two major trusions in each year cccurred in roughly the same period, ne-July and September-October. However, with only two years' rth of data it is impossible to determine if this is a gnificant pattern.

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Table 12.1.--Yearly mean and standard deviation of Shelf Water front position.

BEARING LINE [1]	Sample size [2] 1974	Sample size [2] 1975	Mean separation [3] 1974	Mean separation [3] 1975	Standard deviation 1974	Standard deviation 1975
Casco Bay 120°	30	38	45.4	72.2	70.9	59.0
Casco Bay 140°	31	38	35.4	0.4	64.0	22.6
Casco Bay 160°	36	41	6.1	-2.9	39.3	26.1
Nantucket 180°	37	35	-0.6	-5.6	38.5	37.8
Montauk Pt. 150°	34	35	19.8	8.8	36.7	38.3
Sandy Hook 130°	36	35	1.2	-4.4	46.8	45.0
Cape May 130°	38	34	4.1	-7.3	31.8	34.8
Cape Henry 95°	40	32	17.4	7.3	36.4	39.5
Albemarle Sd 90°	40	31	-11.5	-16.7	24.6	32.5
Cape Lookout 135°	24	31	-18.2	-24.5	20.1	28.9
Cape Fear 140°	19	28	-20.2	-35.8	40.5	38.4
Cape Romain 140°	21	22	-9.9	-40.2	43.4	33.3

1 See Figure 12.2

2 Number of weekly positions of front.

3 Distance (km) of front from 200-m isobath; positive is seaward.

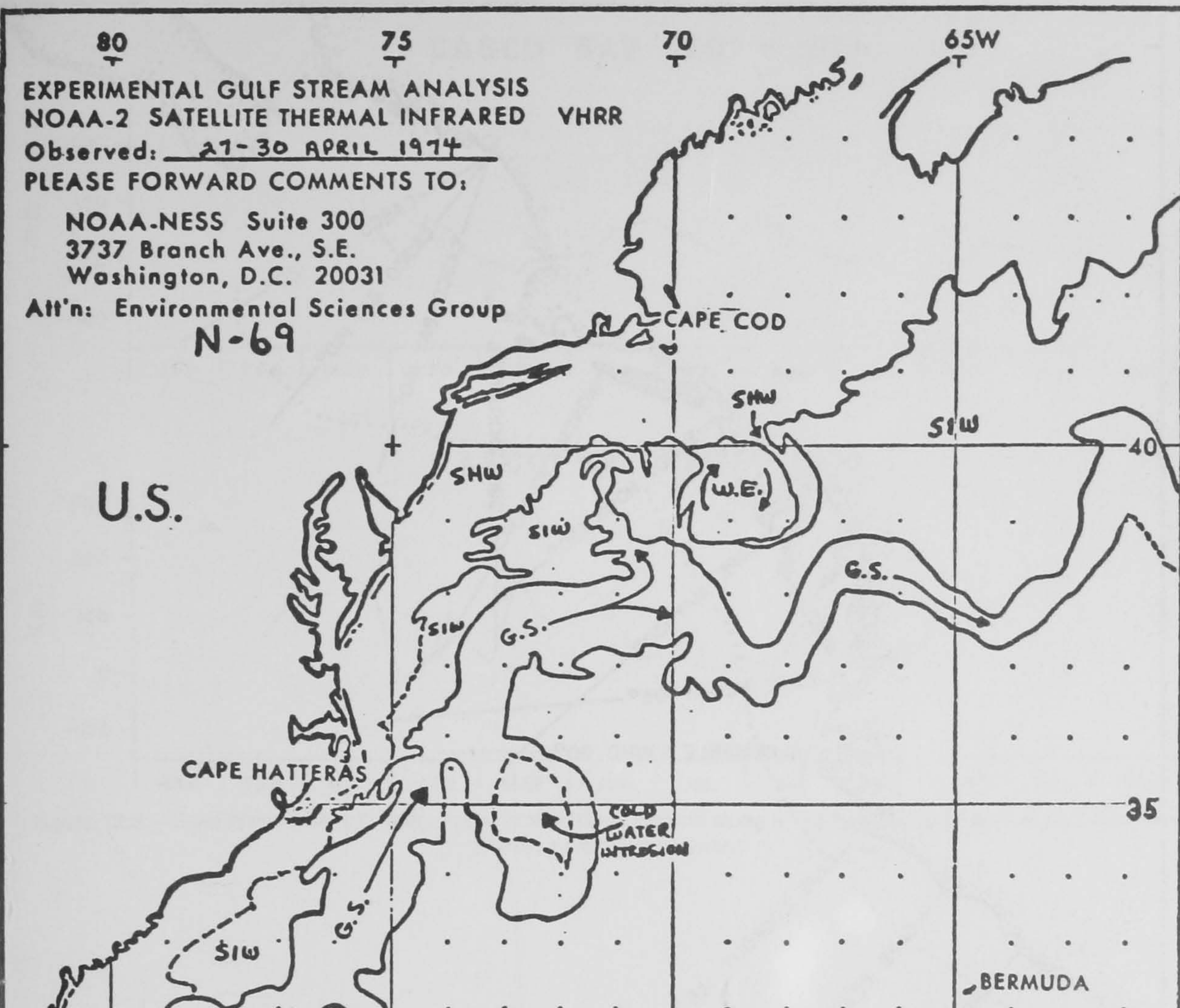

Figure 12.1.—Example of weekly Frontal Analysis Chart produced by the National Environmental Satellite Service, NOAA.

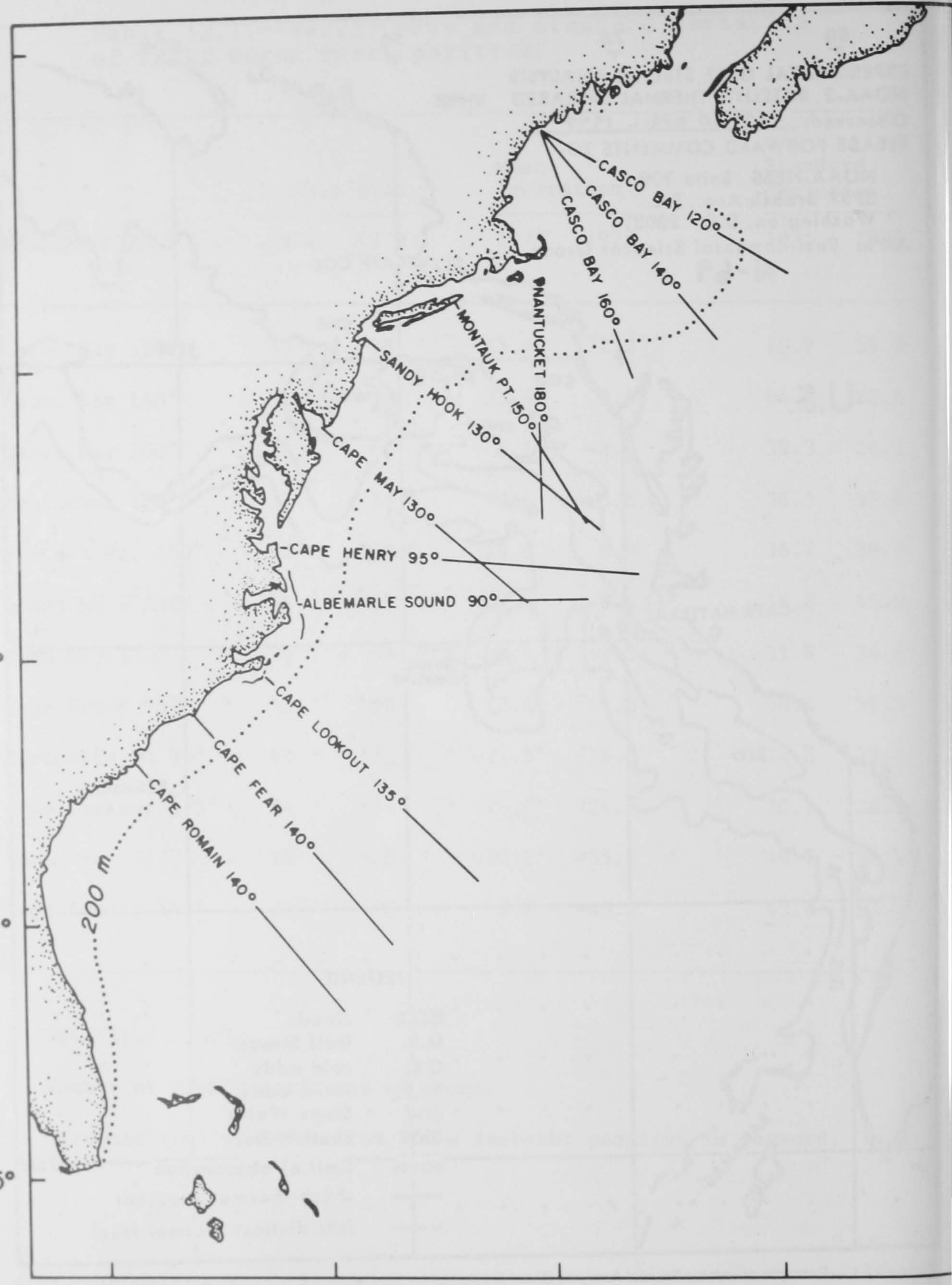

Figure 12.2.—Reference points and bearing lines used in the portrayal of the time variation of the Shelf Water front relative to the 200-m isobath (dotted line).

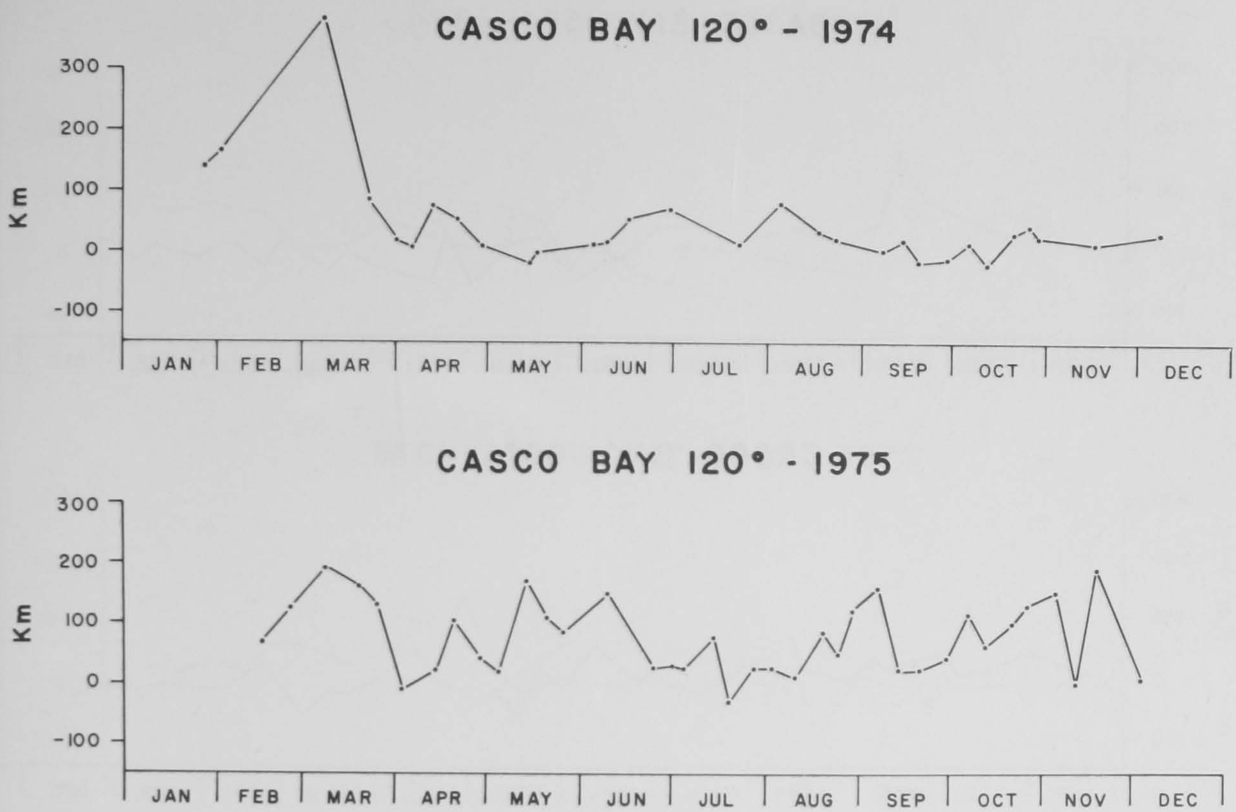

Figure 12.3.—Shelf Water front position relative to the 200-m isobath along a 120-degree bearing line from Casco Bay, Maine; positive is seaward.

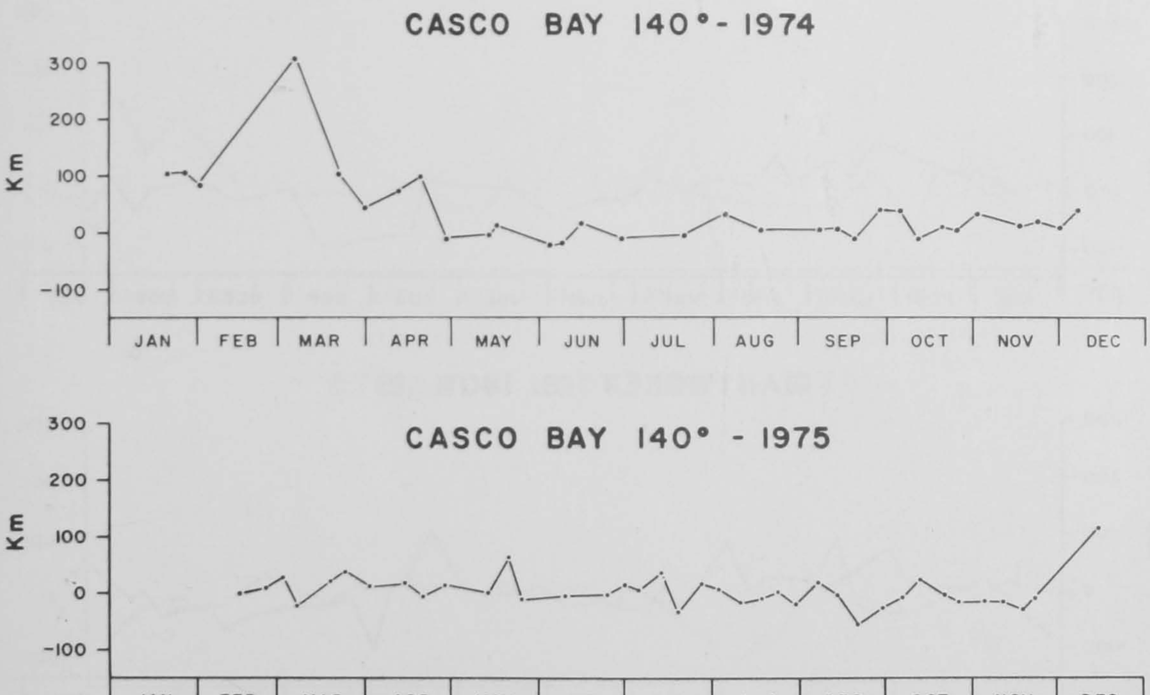

Figure 12.4.—Shelf Water front position relative to the 200-m isobath along a 140-degree bearing line from Casco Bay, Maine; positive is seaward.

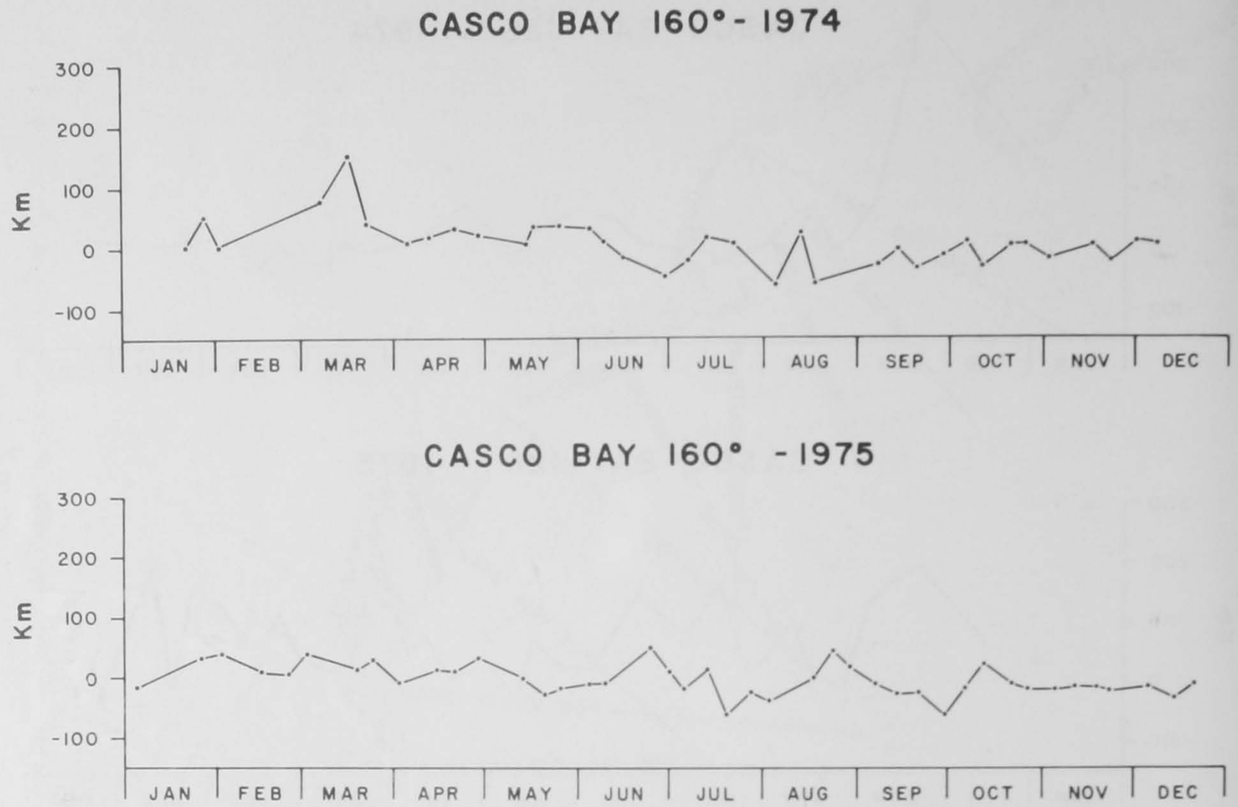

Figure 12.5.—Shelf Water front position relative to the 200-m isobath along a 160-degree bearing line from Casco Bay, Maine; positive is seaward.

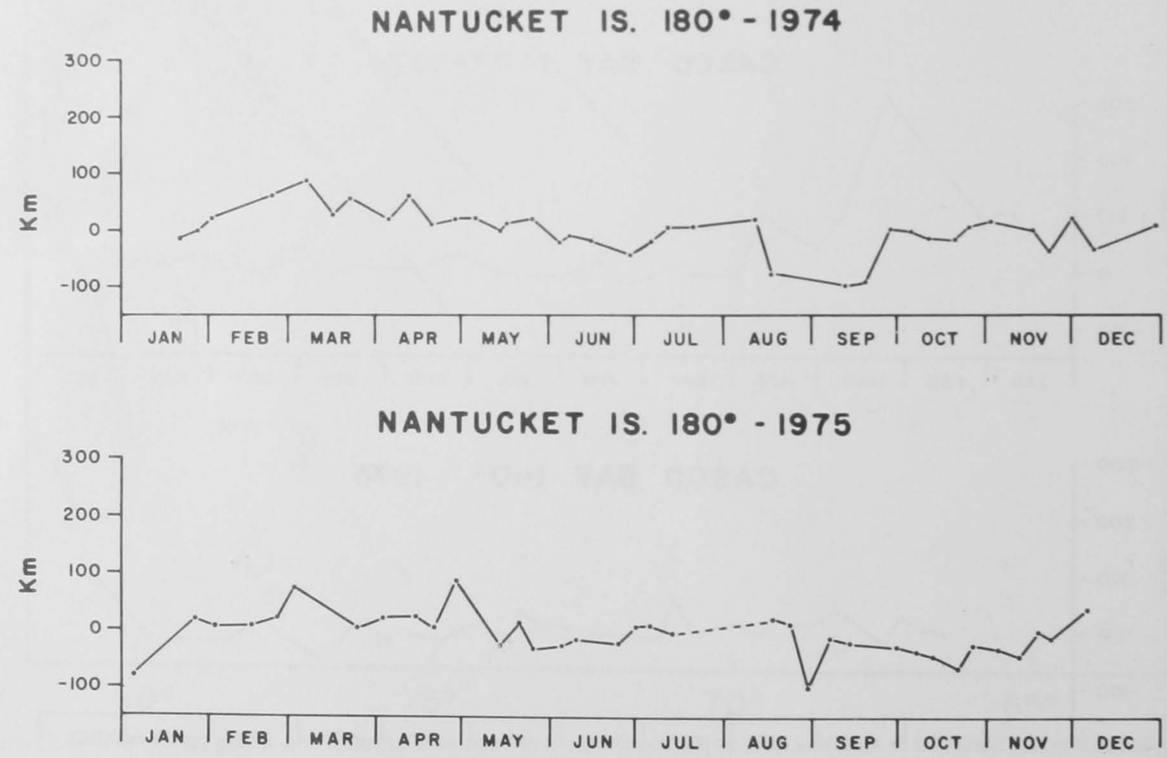

Figure 12.6.—Shelf Water front position relative to the 200-m isobath along a 180-degree bearing line from Nantucket Island, Mass.; positive is seaward.

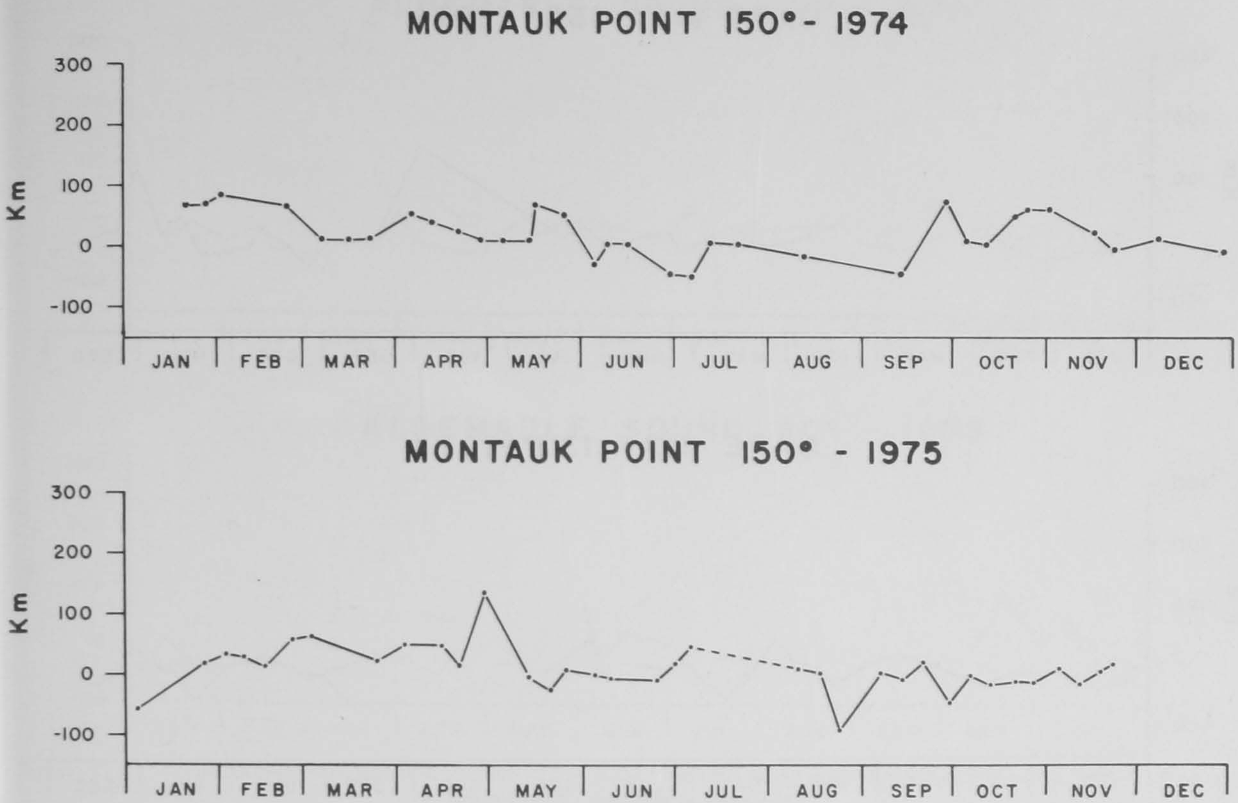

Figure 12.7.—Shelf Water front position relative to the 200-m isobath along a 150-degree bearing line from Montauk Point, N.Y.; positive is seaward.

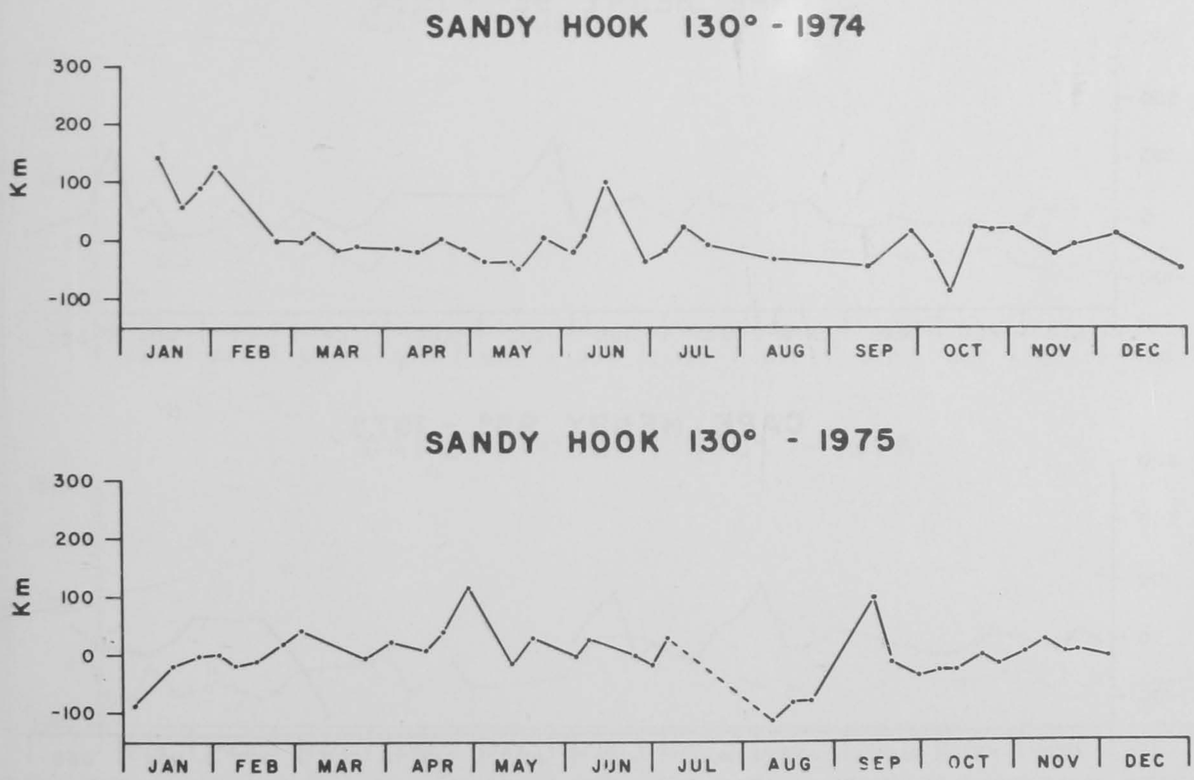

Figure 12.8.—Shelf Water front position relative to the 200-m isobath along a 130-degree bearing line from Sandy Hook, N.J.; positive is seaward.

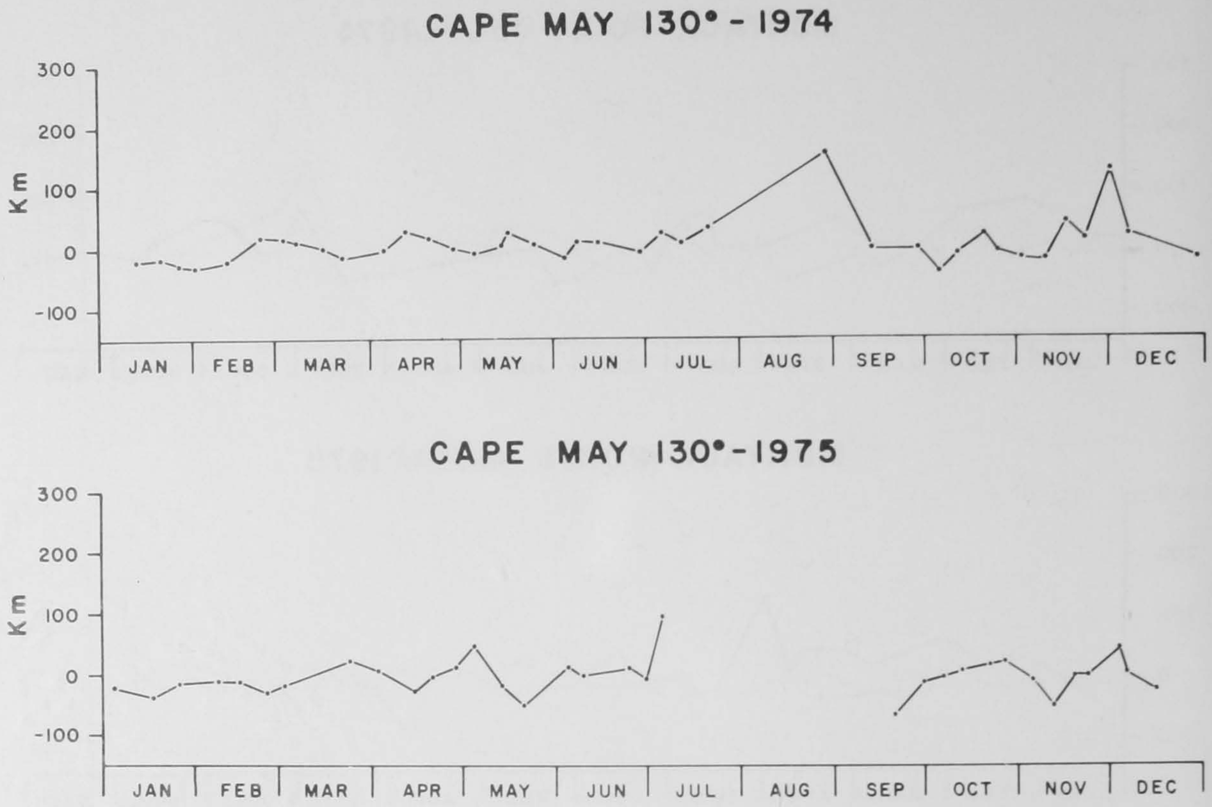

Figure 12.9.—Shelf Water front position relative to the 200-m isobath along a 130-degree bearing line from Cape May, N.J.; positive is seaward.

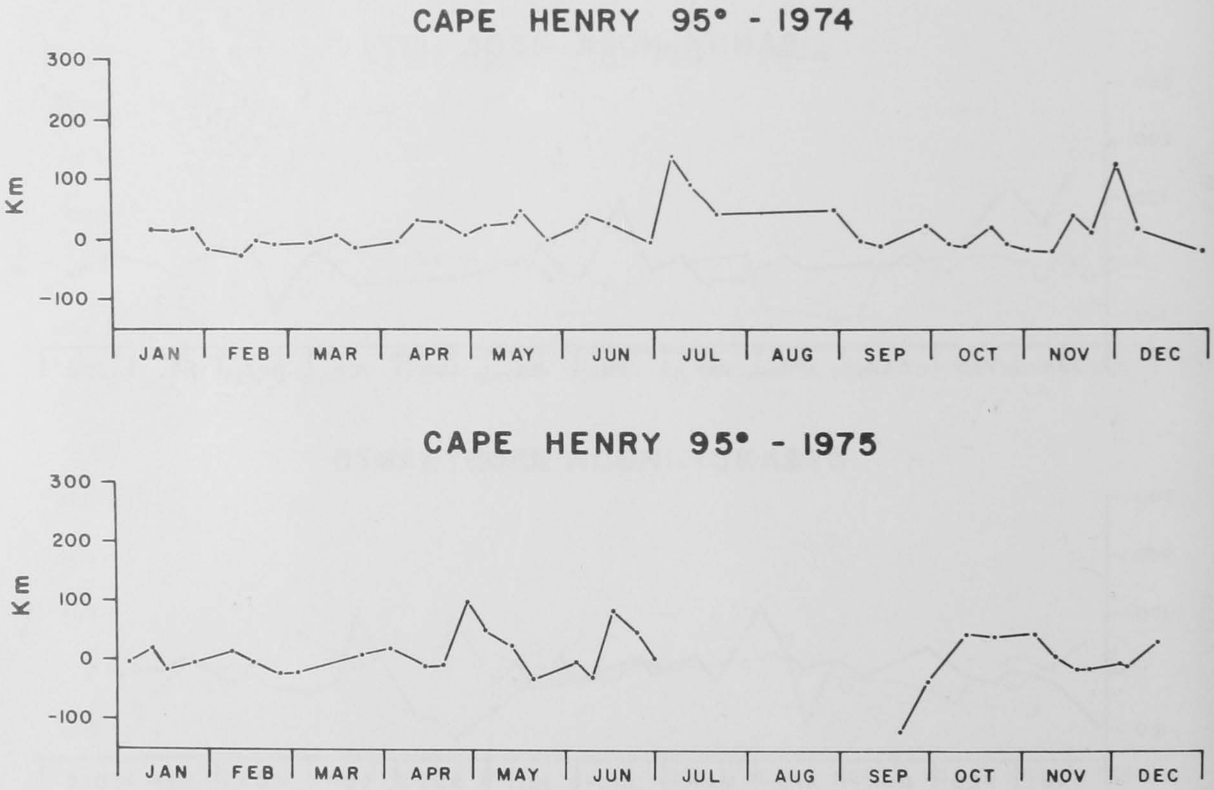

Figure 12.10.—Shelf Water front position relative to the 200-m isobath along a 95-degree bearing line from Cape Henry, Va.; positive is seaward.

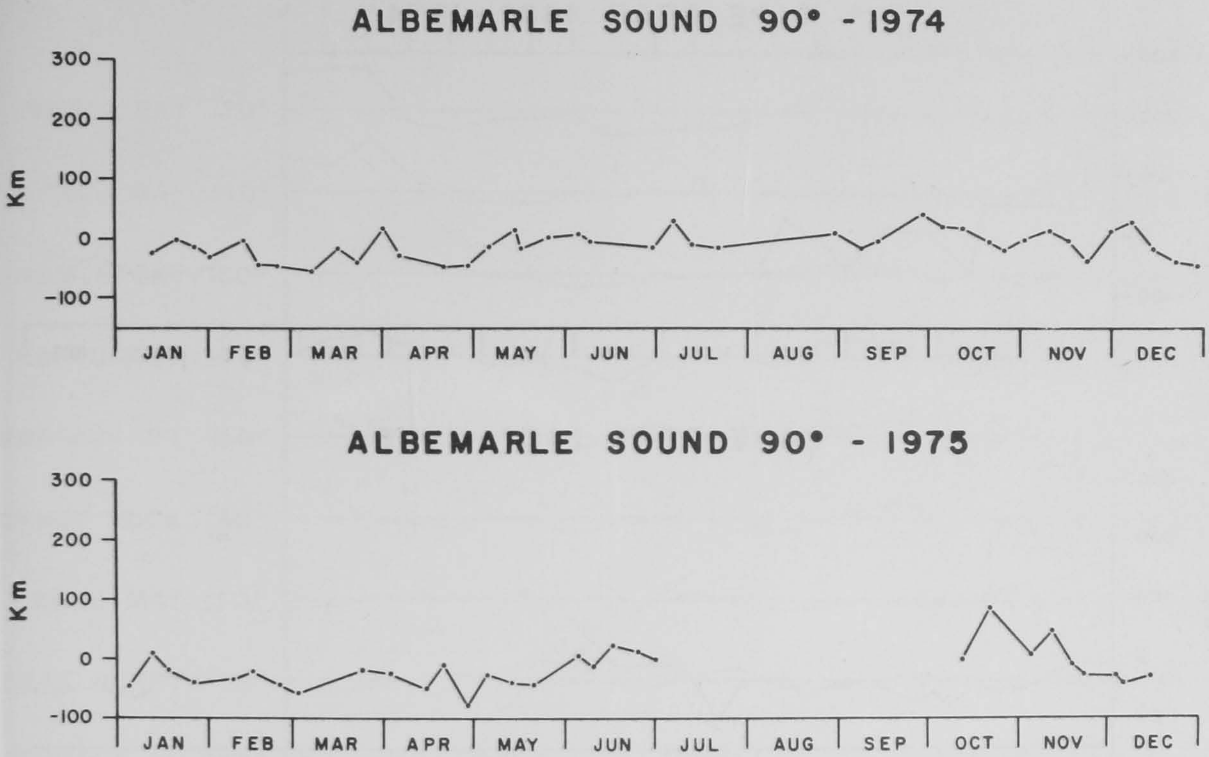

Figure 12.11.—Shelf Water front position relative to the 200-m isobath along a 90-degree bearing line from Albemarle Sound, N.C.; positive is seaward.

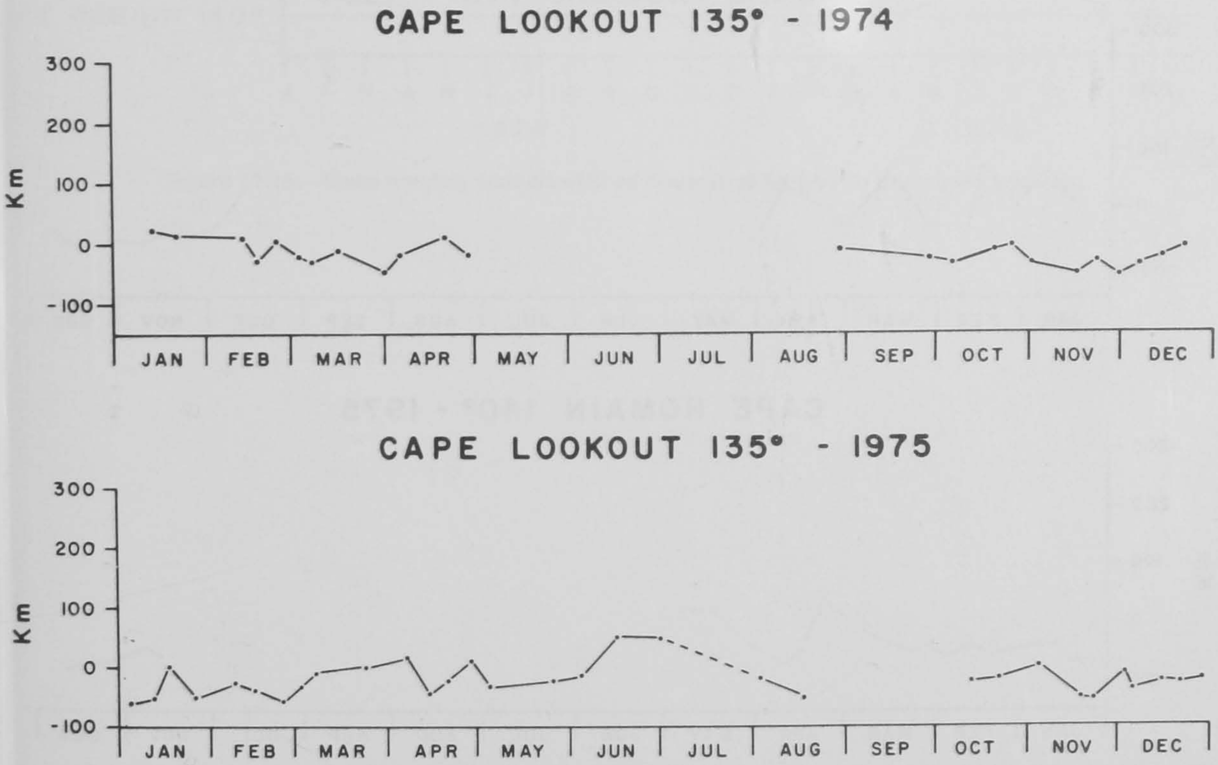

Figure 12.12.—Shelf Water front position relative to the 200-m isobath along a 135-degree bearing line from Cape Lookout, N.C.; positive is seaward.

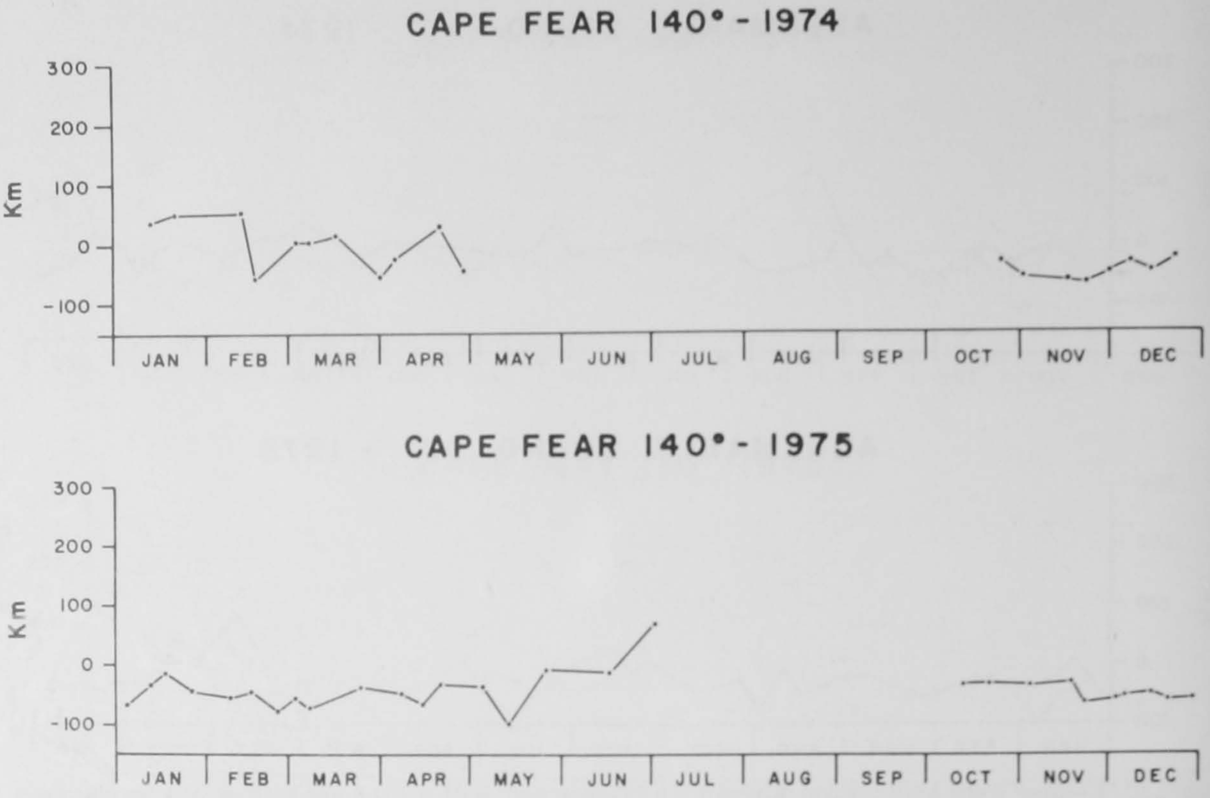

Figure 12.13.—Shelf Water front position relative to the 200-m isobath along a 140-degree bearing line from Cape Fear, N.C.; positive is seaward.

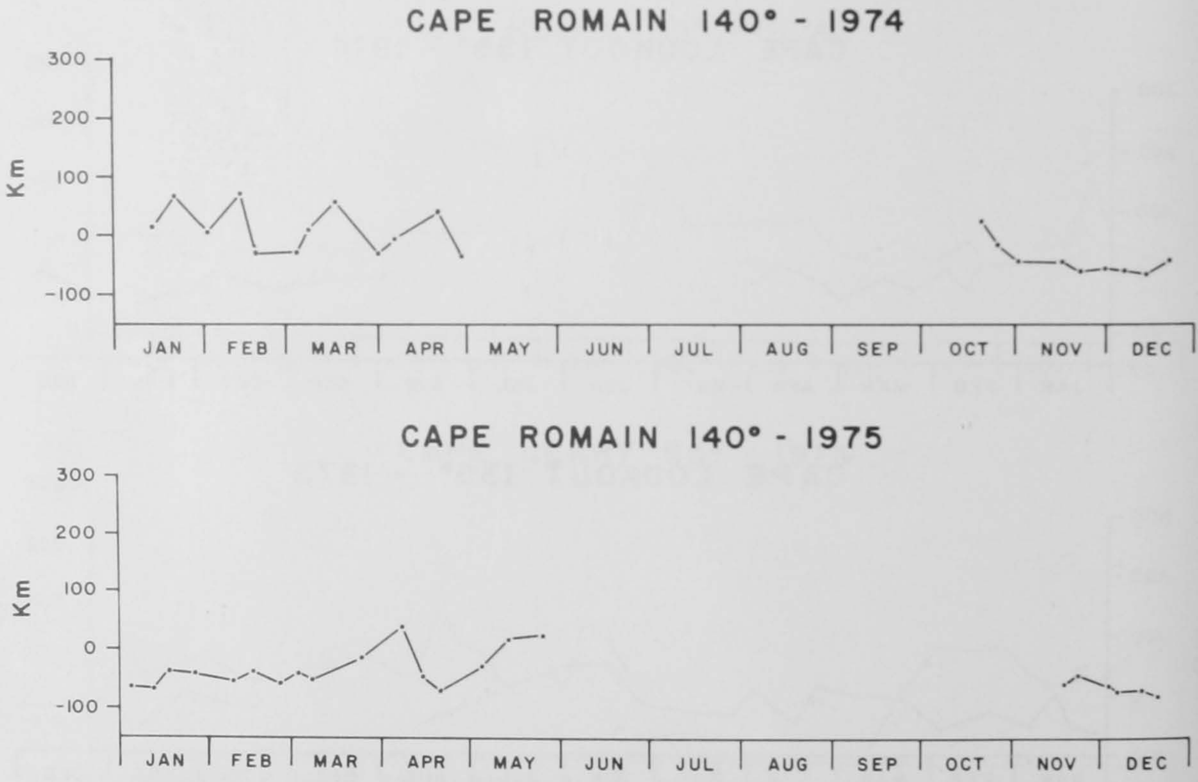

Figure 12.14.—Shelf Water front position relative to the 200-m isobath along a 140-degree bearing line from Cape Romain, S.C.; positive is seaward.

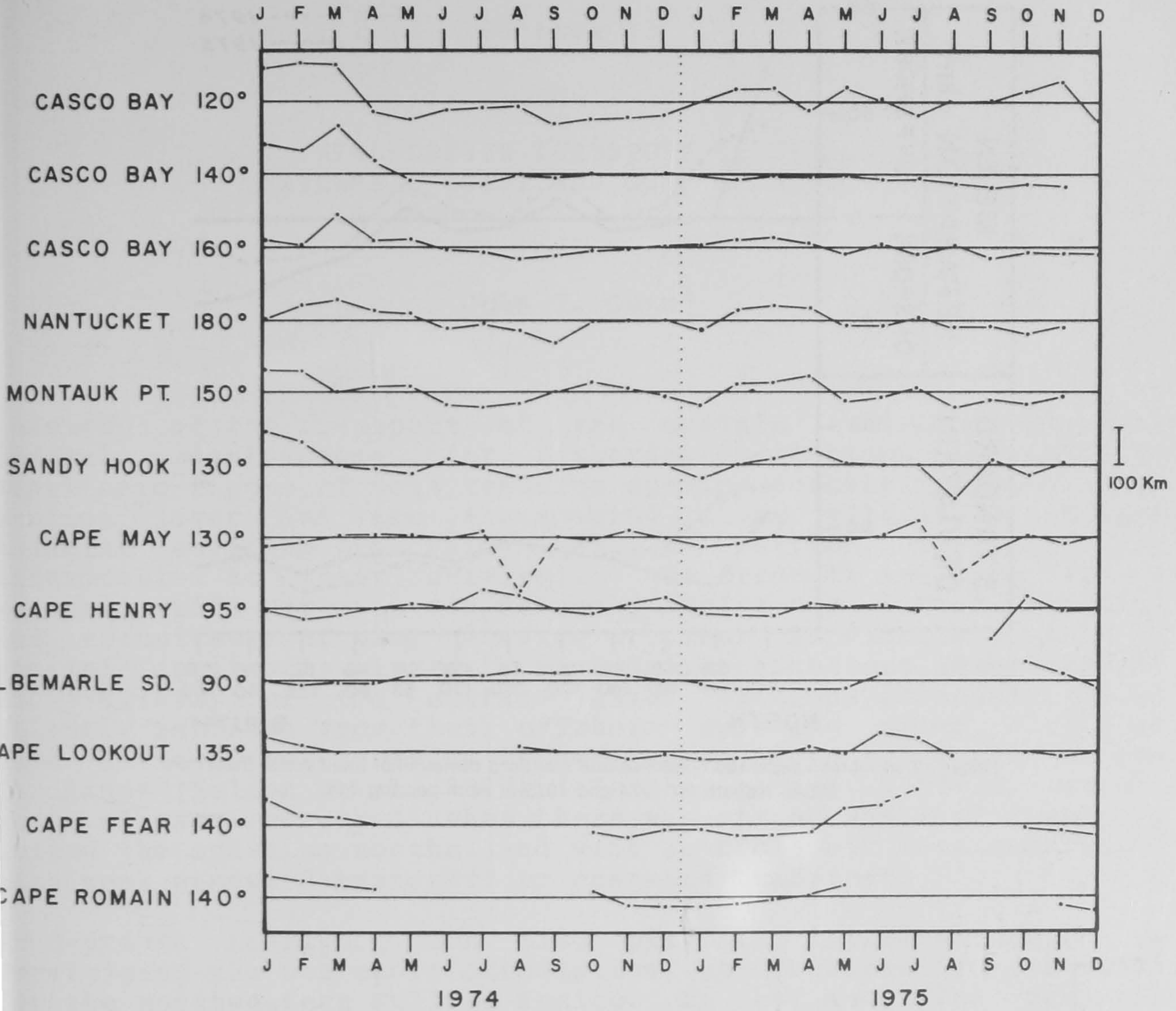

Figure 12.15.—Mean monthly position of Shelf Water front relative to 2-yr mean position.

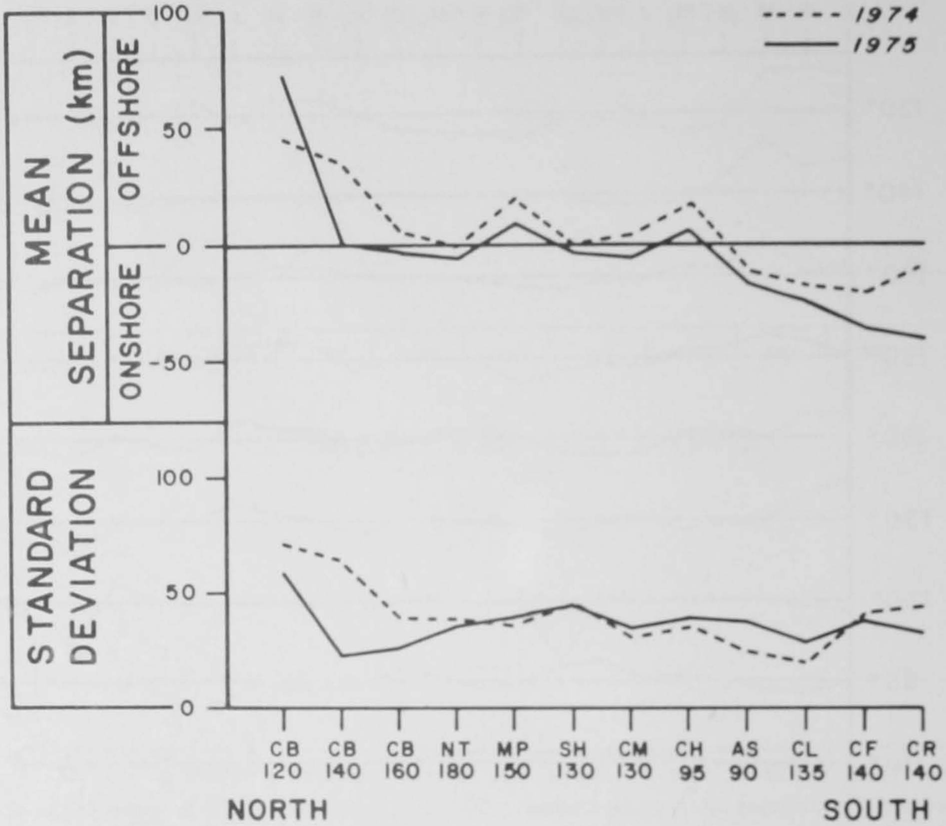

Figure 12.16.—Mean separation distance and standard deviation of Shelf Water front from 200-m isobath for 1974 and 1975 at each bearing line.

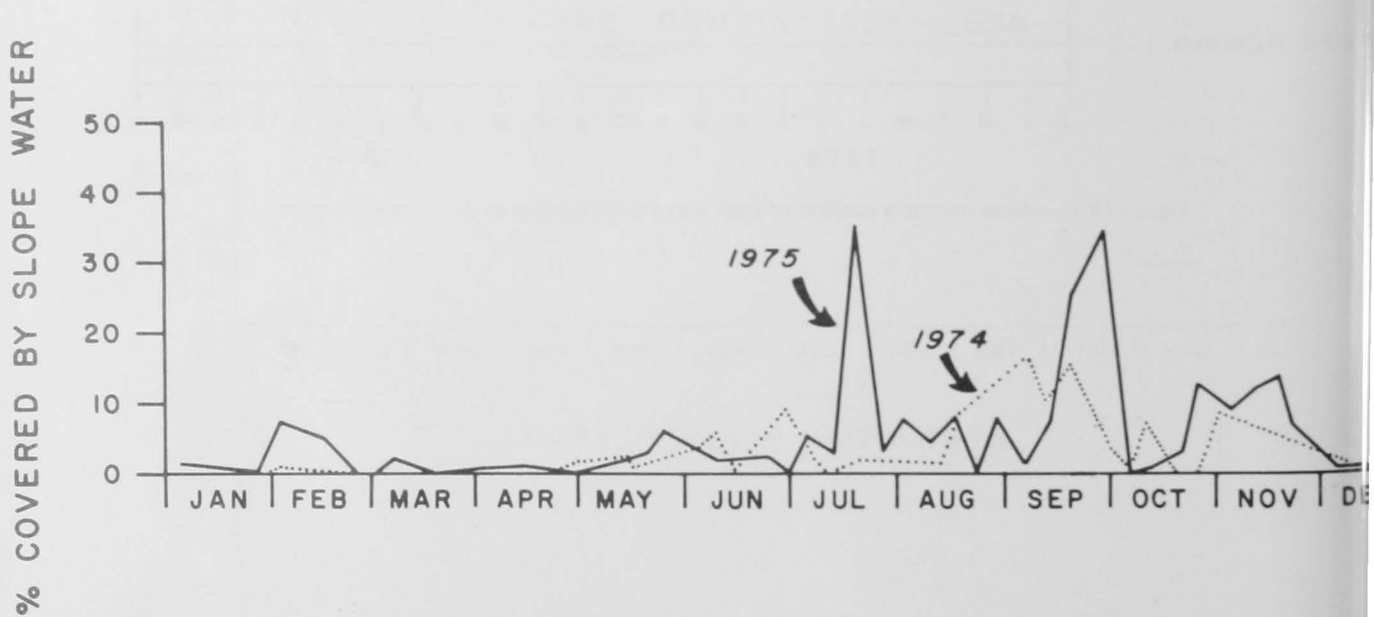

Figure 12.17.—Percentage of Georges Bank covered by Slope Water, 1974 and 1975.

Section 13

WIND-DRIVEN TRANSPORT IN 1975, ATLANTIC COAST AND GULF OF MEXICO

John T. Gunn[1]

(nowledge of the transport of the ocean's surface layer has special significance for fisheries scientists because the planktonic stages of most resource species concentrate within the surface layer and are transported along with it, often into changing environments which may be either favorable or unfavorable to their survival. The strength and direction of seasonal drift patterns can strongly influence larval survival and recruitment of many resource species. An example of this is he role apparently played by wind-driven transport (Sverdrup et 1. 1942:492) of the surface layer in transporting larvae of tlantic menhaden from their offshore spawning sites south of ape Hatteras to estuarine nursery areas along the coasts of the arolinas (Nelson et al. 1977). In the period 1955-70, strong ear classes occurred when there was strong westward transport uring the spawning months, and weak year classes were associated ith weak westward transport or eastward transport.

ind-driven transport can also play an important role in etermining the nearshore circulation, as described by Armstrong[2] or the northwestern Gulf of Mexico. In that area the seasonal luctuations in the direction and strength of the wind-driven ransport changes the direction of nearshore flow over the ontinental shelf of Texas, with possible import to shrimp urvival.

t is expected that variations in wind-driven (Ekman) transport re a significant influence on the larval survival, recruitment, nd year class strength of resource species other than Atlantic enhaden, and on the physical oceanography of areas other than he northwestern Gulf of Mexico.

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[1]Atlantic Environmental Group, National Marine Fisheries ervice, NOAA, Narragansett, RI 02882.

[2]Armstrong, R. S. 1976. Historical physical oceanography easonal cycle of temperature, salinity and circulation. MS. tlantic Environmental Group, NMFS, Narragansett, RI 02882.

Estimates of wind driven (Ekman) transports in the upper layer of the North Atlantic Ocean and Gulf of Mexico are among the suite of parameters computed from monthly average atmospheric pressure charts by the Pacific Environmental Group. The computational method employed is described by Bakun (1973). The monthly transports and related parameters are available back to 1946.[3]

WIND DRIVEN TRANSPORT IN 1975

Monthly Ekman transport values for 1975 are presented in Table 13.1 and Figures 13.1 and 13.3 for three locations off the Atlantic coast and three locations in the northern Gulf of Mexico. Ten-year monthly mean values for the period 1964-73 are also presented for comparison (Figs. 13.2 and 13.4). Major variations of the 1975 transport values from the 10-yr mean values are summarized in the following paragraphs.

Atlantic Coast

At 40N, 70W: In the first two months of 1975, the estimated Ekman transport was weaker than the 10-yr mean and had a more southerly component. By April, however, the transport peaked at a value almost four times that of the monthly mean and shifted more to the southwest. This anomaly coincided with a seaward excursion of the Shelf Water front in the New York Bight area (Section 12). The transport dropped well below the mean for the May-June period, but increased again in July to a maximum a little greater than the mean. This July increase coincided with an excursion of the Shelf Water front onto Georges Bank, an effect opposite to what might be expected from the Ekman transport. The strength of the transport coincided rather closely with the mean values for the remainder of the year, except for a lower magnitude in December. The usual transition from a southeasterly to a southwesterly direction occurred in August, approximately a month earlier than in the 10-yr mean. Because the spring transition from southwesterly to southeasterly flow occurred later than normal, the summer period of southeast flow was shorter than what would be expected from the mean values.

At 35N, 75W: The magnitudes and directions of the wind-driven transport at this location are generally correlated with

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[3] For further information regarding these data, contact Chief, Pacific Environmental Group, National Marine Fisheries Service, c/o Fleet Numerical Weather Central, Monterey, CA 93940.

those at 40N, 70W, with peaks in magnitude in April and July. The earlier peak is not present in the mean data, but the later is. In the first two months the transport was weaker than the mean and more towards the southeast, which may have had an adverse effect on the survival of the Atlantic menhaden larvae spawned south of Cape Hatteras. Good years for larval transport have had westward zonal transport values of over 500 t/s-km (metric tons per second per kilometer) for January and February, whereas in 1975 the values for these months were eastward at 75-200 t/s-km. By April, a small westward zonal component developed, but this was probably too late to provide the required transport for the bulk of the menhaden larvae. The transport for the rest of the year was fairly consistent with the ten-year mean, although generally less in magnitude and lacking a zonal component in August.

At 30N, 80W: The ten-year mean values of estimated transport for this position are weak (<150 t/s-km) from January to August, with their directions swinging around from northwest to east by March, and staying in the E-NE octant through August. The direction swings back around to the N-NW octant for the last four months of the year, with a peak transport of 450 t/s-km to the north-northwest in October.

In 1975, the wind-driven transport for the first seven months was approximately the same magnitude as the 10-yr mean, but consistently in the ENE-ESE octant. It then increased in magnitude and turned toward the NNW-NNE octant for the remainder of the year, similar to the 10-yr mean. The estimated transport did reach a maximum in October, like the 10-yr mean, but its magnitude was only 300 t/s-km. The transport values for September and November 1975, however, were both higher than the mean value.

Gulf of Mexico

At 27N, 84W: The 10-yr mean values of the Ekman transport for this position show a general decrease from 610 t/s-km in January to a low of 128 t/s-km in July. The transport then increases to a yearly high in October of 870 t/s-km, and then decreases the rest of the year. The direction of the transport in the 10-yr mean is in the N-NE octant in all months except January, October, and November, when it is in the N-NW octant.

The fluctuations of the transport in 1975 were fairly similar in magnitude to the 10-yr mean values, but not in direction. Generally, the transport values were slightly smaller than the mean values, except in March and April, when they were close to the means. The transport maximum, 1300 t/s-km, was in November, a month later than the yearly maximum in the 10-yr mean data. Transport direction was generally more towards the east than the mean directions during the first seven months of the year, except in April, when it was close to the 10-yr mean. The July value was the most eastward, but this occurred during a period when the transport magnitude was at a minimum.

At 27N, 90W: The pattern of mean wind-driven transport at this position shows maximum values at two periods during the year, April and October. The April maximum transport (700 t/s-km) occurs just after a transition in direction from northwest to northeast. Thereafter, the transport changes back to the northwest by October, when the second peak in transport occurs (1,000 t/s-km).

The 1975 estimated transport values were larger in the spring (1,420 t/s-km) and fall (1,320 t/s-km) than the 10-yr mean values, but the fall peak occurred a month later, in November, as was the case at 27N, 84W. The directions of transport generally followed the mean values, but the shifts occurred about a month earlier than in the mean pattern and the directions for May through August were farther to the northeast.

At 27N, 96W: At this position, the 10-yr mean values of wind-driven transport exhibit sharp seasonal shifts in direction and magnitude. The magnitude of 600 t/s-km in January increases slowly through March, and then in April nearly doubles to the annual maximum, 1800 t/s-km. For the rest of the year, the magnitude decreases until the last quarter, when it levels off at 500-600 t/s-km. The direction of the mean transport moves from just east of north in January and February to northeast by April, remaining there until September when it swings to a more northerly direction for the balance of the year.

The wind-driven transport in 1975 followed the general pattern of fluctuations of the 10-yr mean, but the magnitude was consistently less and the direction more towards the north. The spring-summer magnitudes, however, were especially different from the 10-yr means, not reaching as high a peak in April, remaining distinctly lower in May and June, and diminishing to fall-winter levels some two months earlier, in July. Furthermore, the spring-summer wind directions in 1975 (Fig. 13.5) did not come fully around to typical southeasterlies except in June. Return tc the easterly wind condition of fall-winter occurred about one month earlier than the mean.

APPLICATION OF WIND DRIVEN TRANSPORT ESTIMATES TO ANALYSIS OF CIRCULATION ON THE TEXAS SHELF

rmstrong (see footnote 2) concluded that the Shelf Water irculation of the northwestern Gulf of Mexico is principally overned by wind-driven transport. Based on the methods of that tudy, the inference is that the wind-driven circulation during 975 induced longshore currents over the Texas shelf 1) toward he west and south from January into March and again from id-September through December; 2) toward the north and east, ccompanied by upwelling over the outer shelf, from April through uly; and 3) with transitional periods in March and August. omparison with 10-yr means indicates that the directions of flow n the Texas shelf were typical in 1975, except that the reversal rom summer to fall took place about a month earlier than the verage. In other words, the transition from the spring-summer low toward the north and east to fall and winter flow toward the est and south was in August rather than September. Based on nterpretations of monthly mean winds, the spring-summer flow was enerally weaker than average, and upwelling over the outer shelf ess pronounced, whereas the fall-winter flow was perhaps tronger than average in November and December.

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Table 13.1.--Monthly average Ekman transports for selecred points off the U.S. east coast and in the Gulf of Mexico, 1975, in t/s-km. Positive is eastward (zonal) and northward (meridional).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	De
<u>40°N, 70°W</u>												
Zonal	-10	-40	-90	-260	00	20	230	30	00	-30	00	-3
Meridional	-200	-180	-220	-330	-10	-40	-220	-80	-10	-30	-140	-1
<u>35°N, 75°W</u>												
Zonal	50	20	10	-130	20	20	150	10	10	-30	-20	-3
Meridional	-200	-70	-210	-290	-00	-10	-90	-60	60	30	-20	-3
<u>30°N, 80°W</u>												
Zonal	40	50	70	0	60	40	140	20	30	-100	-80	-5
Meridional	20	10	-40	-00	10	10	-10	30	260	290	270	9
<u>27°N, 84°W</u>												
Zonal	90	100	230	130	70	60	140	100	70	-160	-30	-3
Meridional	430	160	260	350	70	60	40	330	480	740	1300	65
<u>27°N, 90°W</u>												
Zonal	00	40	420	420	410	160	20	140	-390	-420	-260	-36
Meridional	560	270	730	1360	730	480	80	640	780	1000	1300	88
<u>27°N, 96°W</u>												
Zonal	100	30	350	820	560	790	370	240	-130	00	90	-1
Meridional	370	360	710	1410	850	740	480	620	590	570	540	41

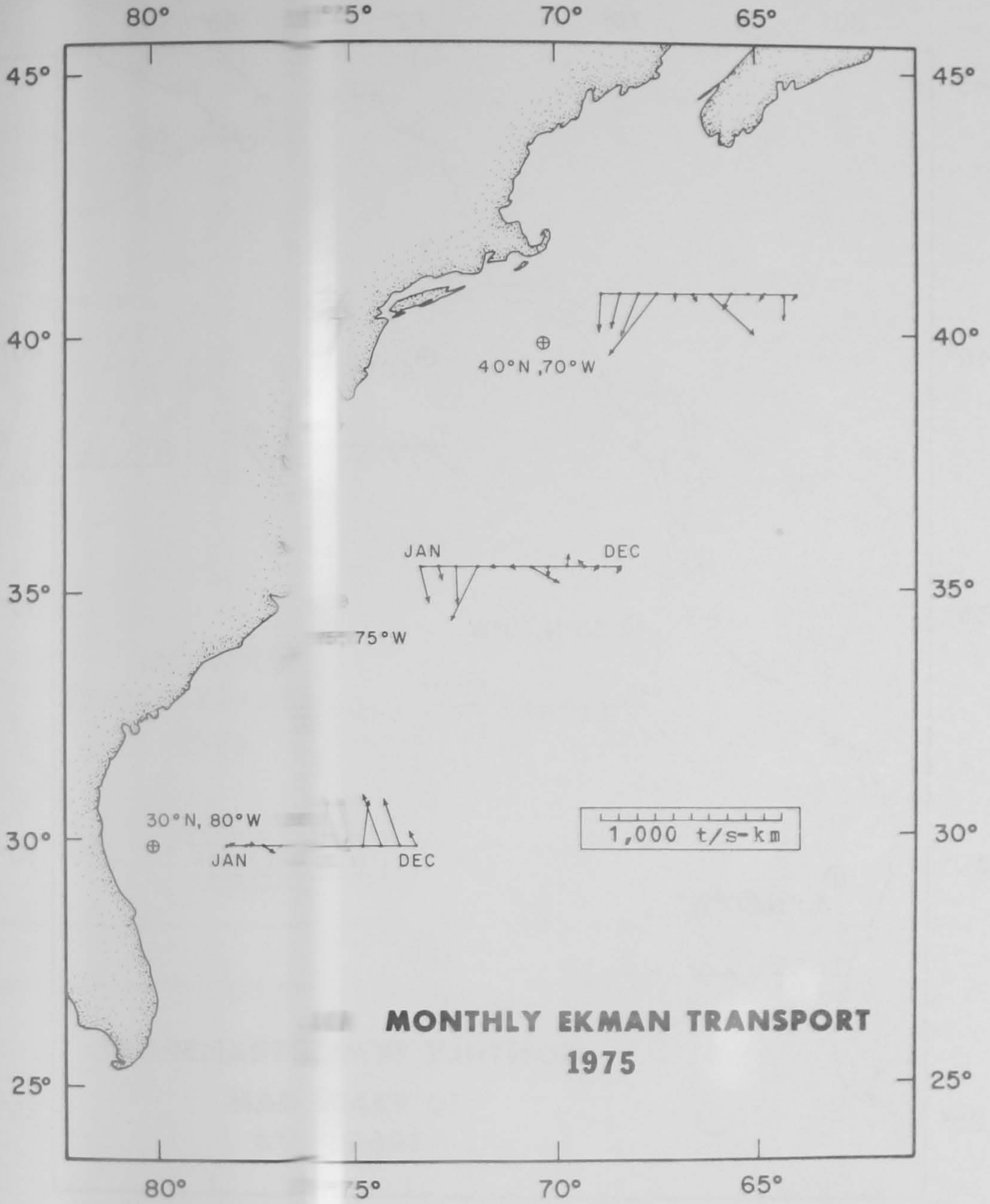

Figure 13.1.—Monthly Ekman (wind-driven) transports for three points off the Atlantic Coast for 1975.

Table 13.1.--Monthly average Ekman transports for selecred points off the U.S. east coast and in the Gulf of Mexico, 1975, in t/s-km. Positive is eastward (zonal) and northward (meridional).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	De
<u>40°N, 70°W</u>												
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<u>35°N, 75°W</u>												
Zonal	50	20	10	-130	20	20	150	10	10	-30	-20	-3
Meridional	-200	-70	-210	-290	-00	-10	-90	-60	60	30	-20	-3
<u>30°N, 80°W</u>												
Zonal	40	50	70	0	60	40	140	20	30	-100	-80	-5
Meridional	20	10	-40	-00	10	10	-10	30	260	290	270	9
<u>27°N, 84°W</u>												
Zonal	90	100	230	130	70	60	140	100	70	-160	-30	-3
Meridional	430	160	260	350	70	60	40	330	480	740	1300	65
<u>27°N, 90°W</u>												
Zonal	00	40	420	420	410	160	20	140	-390	-420	-260	-36
Meridional	560	270	730	1360	730	480	80	640	780	1000	1300	88
<u>27°N, 96°W</u>												
Zonal	100	30	350	820	560	790	370	240	-130	00	90	-1
Meridional	370	360	710	1410	850	740	480	620	590	570	540	41

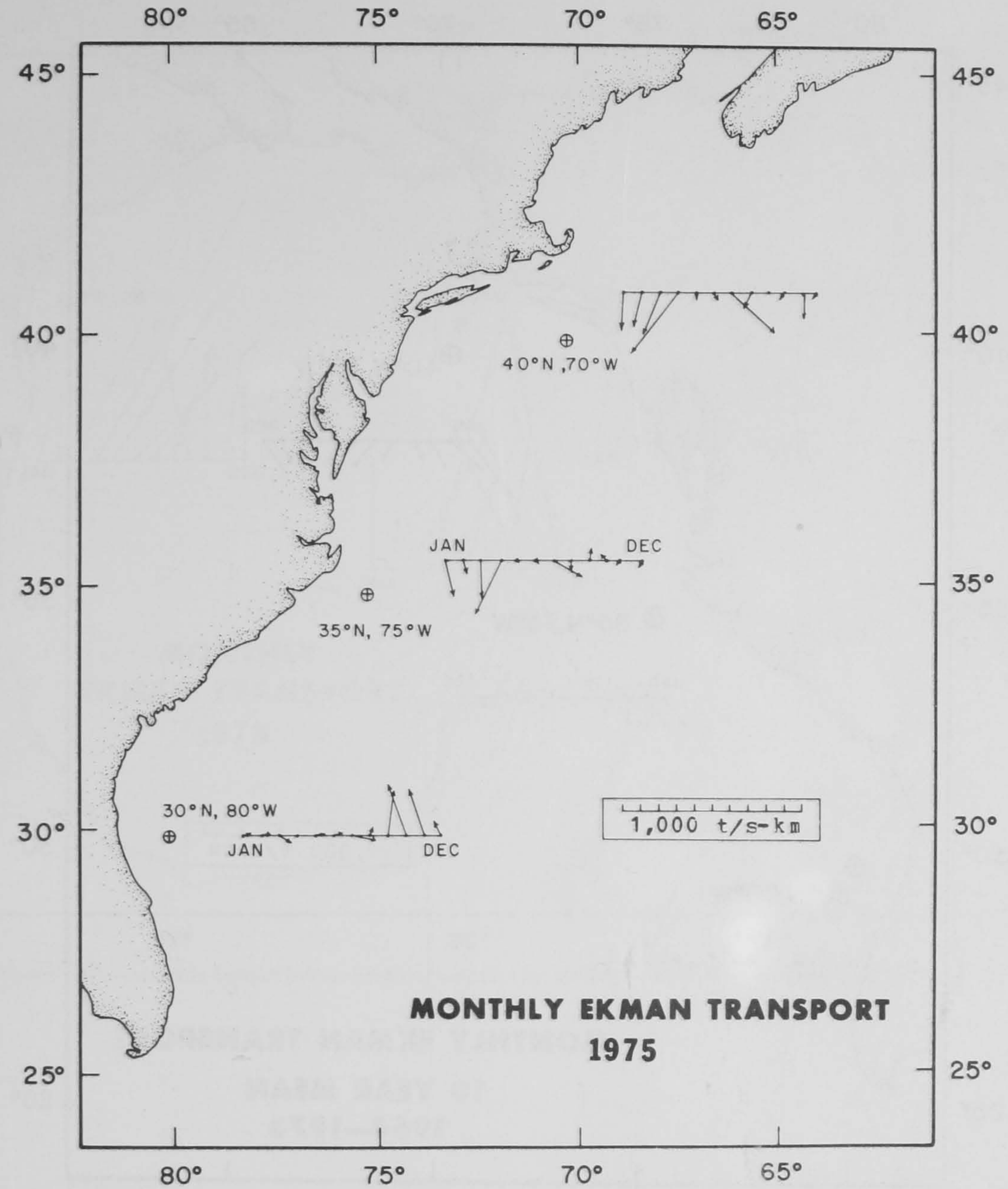

Figure 13.1.—Monthly Ekman (wind-driven) transports for three points off the Atlantic Coast for 1975.

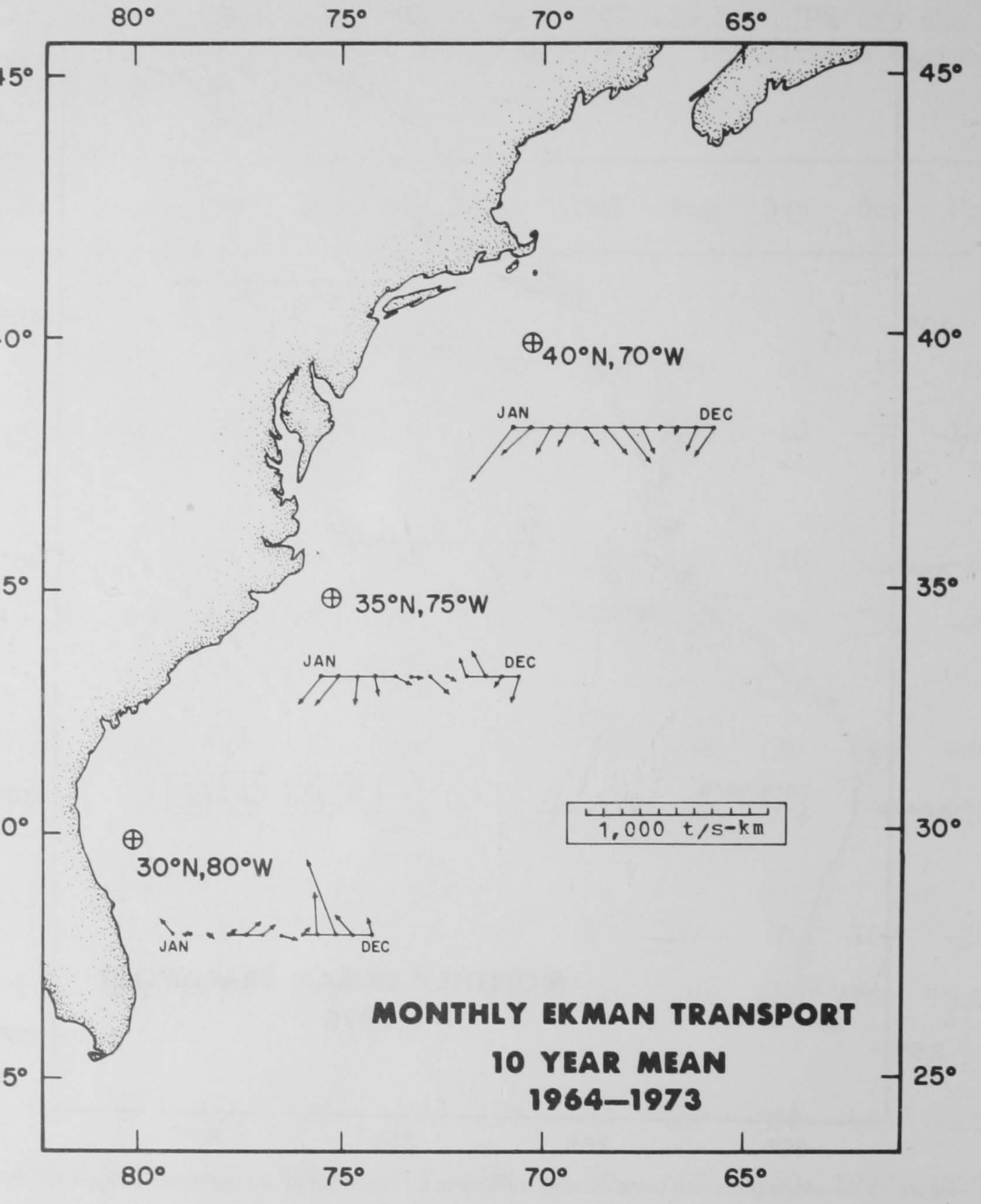

Figure 13.2.—Mean monthly Ekman (wind-driven) transports for three points off the Atlantic Coast for the 10-yr period, 1964-73.

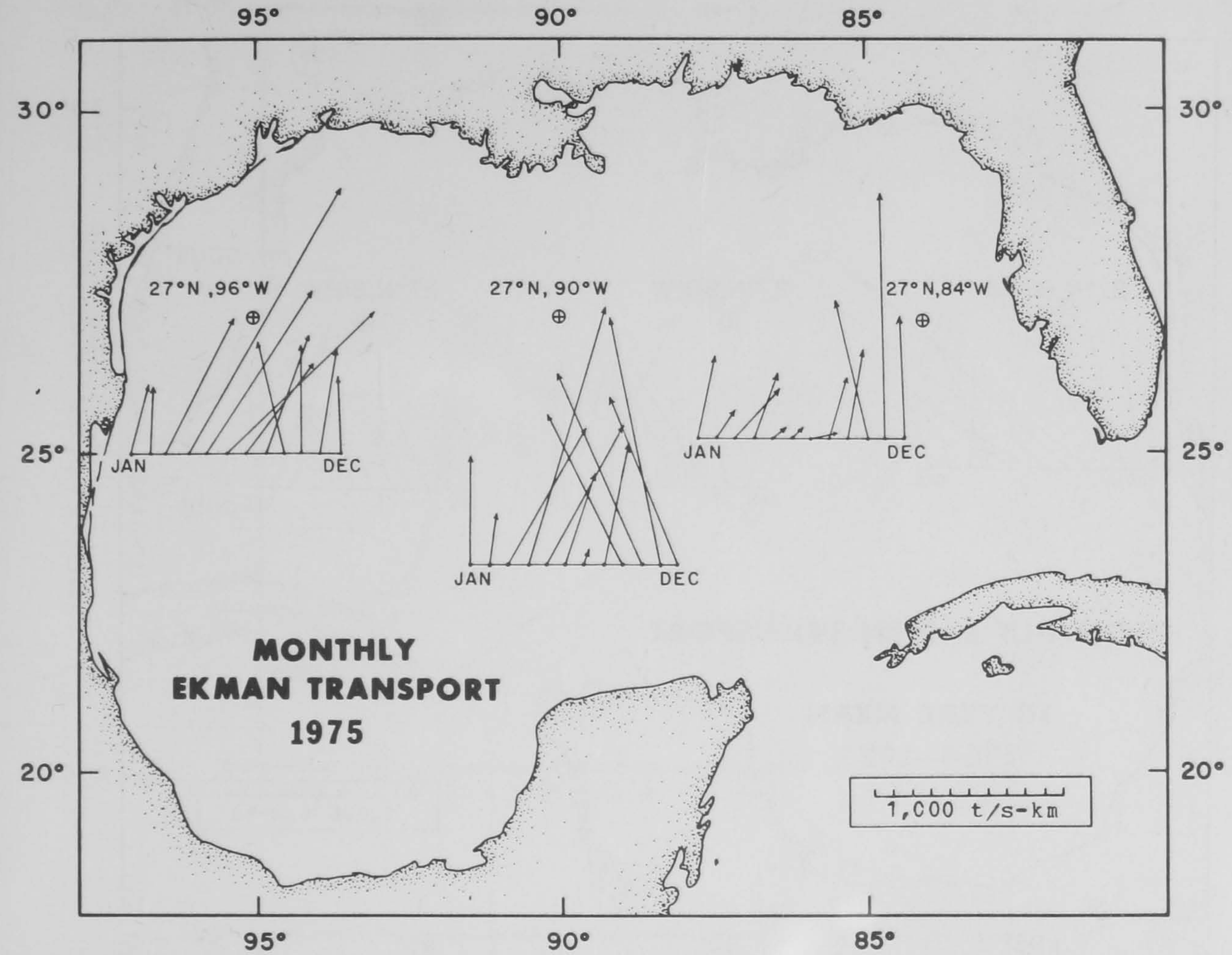

Figure 13.3.—Monthly Ekman (wind-driven) transports for three points in the northern Gulf of Mexico for 1975.

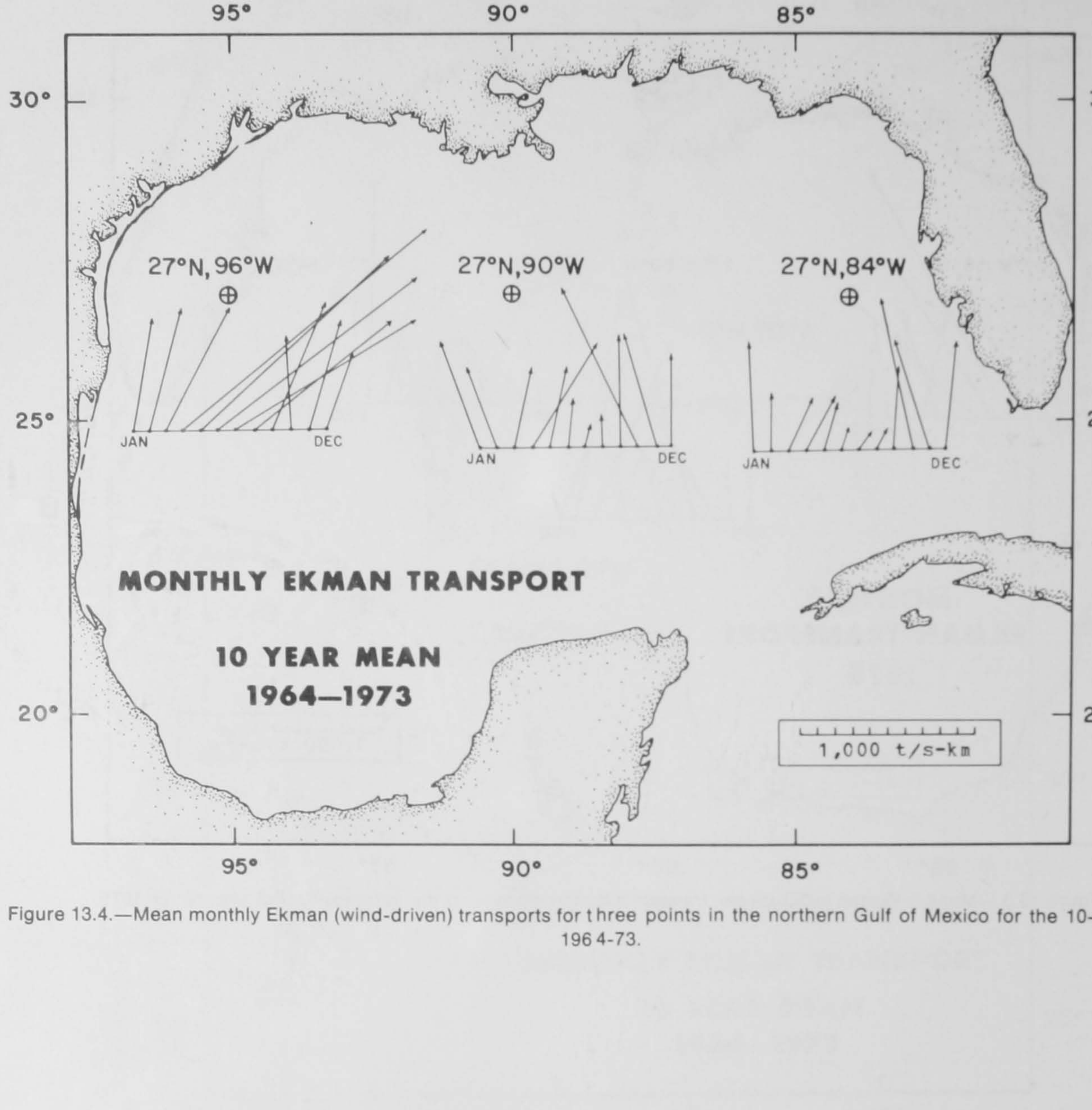

Figure 13.4.—Mean monthly Ekman (wind-driven) transports for three points in the northern Gulf of Mexico for the 10-yr period, 1964-73.

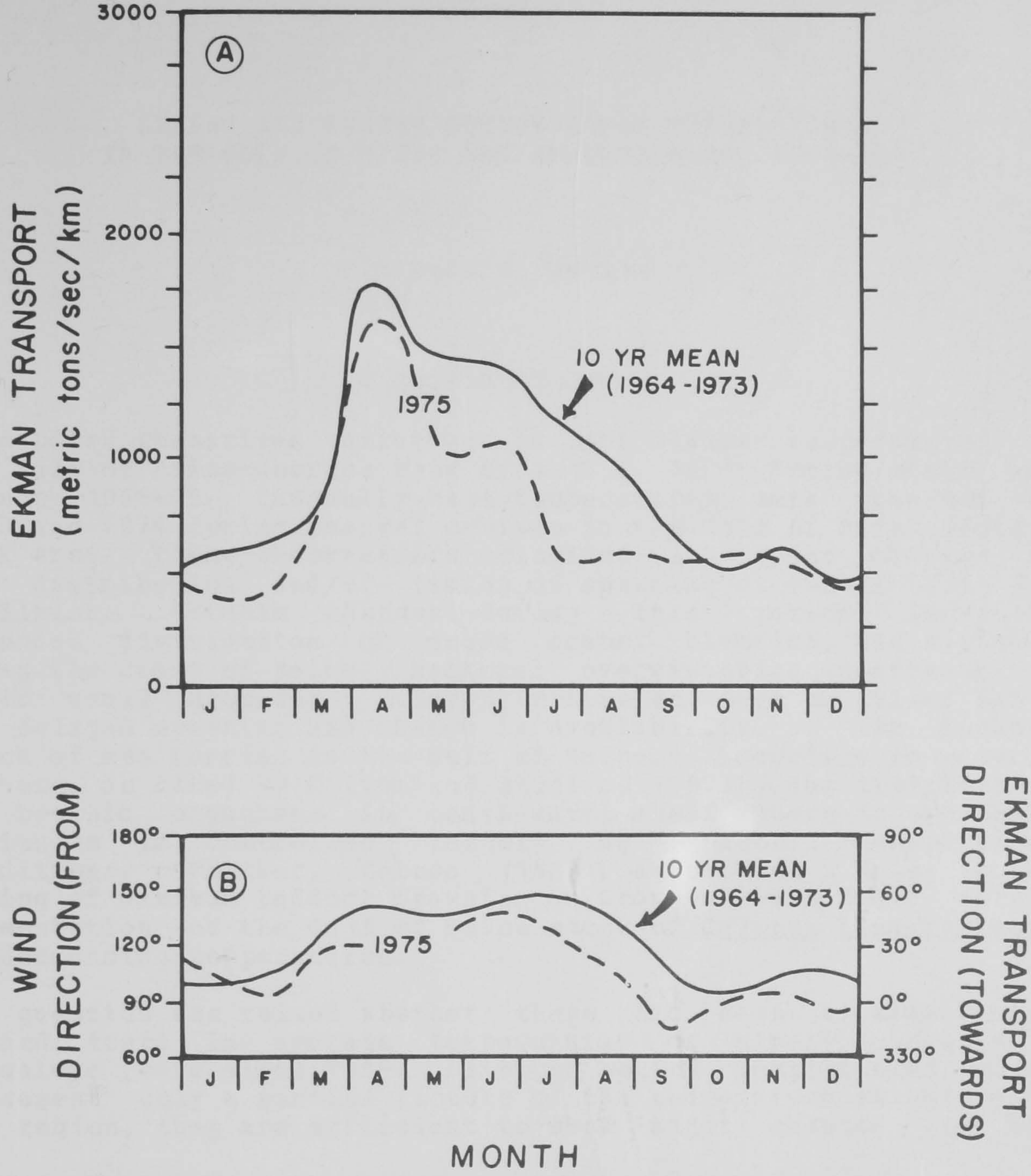

Figure 13.5.—Ekman transport and wind direction at 27N, 96W for 1975 and for 10-yr mean.

SPRING AND AUTUMN BOTTOM-WATER TEMPERATURES IN THE GULF OF MAINE AND GEORGES BANK, 1968-75[1]

Clarence W. Davis[2]

INTRODUCTION

This paper summarizes variations in bottom-water temperatures in the Gulf of Maine-Georges Bank area (Fig. 14.1) during spring and autumn 1968-75. Unusually high temperatures were observed in 1973 and 1974 during several cruises in the Gulf of Maine-Georges Bank area. These observations coincided with recent changes in the distribution and/or timing of spawning of certain fish and shellfish. Notable changes during this period included: extended distribution of green crabs, bluefish, and menhaden along the coast of Maine; mackerel overwintering northeast of their usual grounds; delayed inshore movement of silver hake; and delayed spawning and change in availability of the inshore stock of sea herring in the Gulf of Maine.[3] According to several authors, as cited by Colton and Stoddard (1973), the distribution of benthic organisms in continental shelf waters in temperate latitudes is controlled largely by seasonal temperature conditions. Further, Colton (1968a) attributed a delay in the timing of maximum haddock spawning on Georges Bank, and vernal augmentation of the Gulf of Maine stock of *Calanus finmarchicus*, to decreasing temperatures.

The question was raised whether there had been a significant upward trend in average temperatures or simply a couple of anomalous years since 1968. Although bottom temperatures alone represent only a partial picture of the temperature structure of the region, they are sufficient to show major changes and are

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[1]Summarized from ICNAF Res. Doc. 76/VI/85.
[2]Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.
[3]Anderson, E. D. 1975. The effects of a combined assessment for mackerel in ICNAF Subareas 3, 4, and 5, and Statistical Area 6. ICNAF Res. Doc. 75/14, 14 p. Also, personal communication from V. Anthony, Northeast Fisheries Center, NMFS, Woods Hole, MA 02543.

particularly relevant for the distribution of demersal species. The remainder of the temperature profile, from surface to near bottom, is not included in this study. Also salinity profiles are excluded from the study since subsurface data were not routinely obtained on these surveys. For these reasons, specific identification of subsurface water masses is not possible; however, it is known that the major source of subsurface inflow into the Gulf of Maine is relatively warm Slope Water through the Northeast Channel (Bigelow 1927; Colton 1968b). Therefore, major changes in the average bottom-water temperature in the Gulf should be preceded by changes in the volume and temperature of water entering the Gulf via the Northeast Channel.

Georges Bank water is derived largely from the Gulf of Maine but is also sporadically influenced, especially on the surface, by intrusions of Slope Water along the southern boundary.[4] Since the Bank is usually well mixed by tidal and wind forces throughout most of the year, subsurface temperatures there are influenced to a large degree by the deeper boundary waters.

RESULTS

Gulf of Maine - Spring

Spring bottom-water temperatures in the Gulf of Maine show a general warming trend since 1968, reaching a peak in 1973-74, with only slight decreases (-0.1C) from the previous year in 1972 and 1975 (Fig. 14.2). The largest increase (0.8C) from the previous year occurred in 1970 and accounted for over 50% of the total 8-yr range of 1.4C (5.2C-6.6C). The spring mean of 6.1C was about 1C colder than in 1955-56, but 1C warmer than in 1965-66 (Schopf 1967). Individual years from 1968 to 1972 corresponded with the 1962-72 long-term mean data of Karaulovsky and Sigaev[5] to within + or - 0.2C. The highest mean of 1974 corresponds with the highest positive sea surface temperature anomaly between 1970 and 1974 in the Gulf.[6]

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[4] Bumpus, D. F., 1975. Review of the physical oceanography of Georges Bank. ICNAF Res. Doc. 75/107, 32 p.
[5] Karaulovsky, V. P., and I. K. Sigaev. 1976. Long-term variations in heat content of the waters on the Northwest Atlantic Shelf. ICNAF Res. Doc. 76/VI/2, 9 pp.
[6] Personal communication from J. L. Chamberlin, Atlantic Environmental Group, NMFS, Narragansett, RI 02882.

Figure 14.3 illustrates the changes in percentage of temperature class intervals (TCI's) for the entire Gulf. The general warming trend is characterized by a rather progressive decrease in water <4C with a corresponding increase in water >8C (solid bars in histogram). Although some years had the same or nearly the same mean temperature, the TCI's were usually of quite different magnitude. For example, during the spring cruises of 1970 and 1972, the means varied by only 0.1C but the coldest and warmest TCI's varied by factors of about 2 and 13, respectively. The 6C-8C TCI dominated in all years, while the 4C-6C TCI remained the most consistent during the study period.

Figure 14.4 summarizes the annual mean spring temperatures for the Gulf by subareas of one degree longitude (Fig. 14.1). Subareas I and IV had the lowest and highest values respectively in each of the years investigated as expected, since I has the most shoal water and nearly all of IV is deeper than 200 m. The relative shoalness of I is also reflected in the large temperature variability between years, especially the increases between 1969 and 1970 (+1.5C) and between 1973 and 1974 (+1.0C), and the decreases between 1970 and 1971 (-0.6C) and between 1971 and 1972 (-0.7C). A temperature increase was noted between years in all subareas from 1968 to 1970 and from 1972 to 1973, but no year produced a decrease in every subarea. The 8-yr means and yearly anomalies are summarized in Table 14.1 and show that all subareas had negative values in 1968 and 1969 and positive values in 1974 and 1975, but a mixture of values in the intervening years.

Comparison of the Gulf by subarea again shows how years of similar mean temperatures can have vastly different TCI's (Fig. 14.5). In subarea I the means were all 5C in 1970, 1974, and 1975, but the TCI's in 1970 were about 20% each of 2C-4C and 6C-8C, and 60% of 4C-6C, while 1974 and 1975 were both nearly 100% of 4C-6C. Conversely, a deep, stable subarea like IV had very similar TCI percentages when the spring means were similar, and clearly showed the decrease of coldest and increase of warmest TCI's as the warming trend progressed.

<u>Gulf of Maine - Autumn</u>

Autumn bottom-water temperatures in the entire Gulf of Maine increased steadily from 1968 to 1974 and decreased quite abruptly in 1975 (Fig. 14.5). The total 7-yr increase was 1.3C (7.3C-8.6C), while the single decrease was 0.6C. The 8-yr mean of 7.9C was 0.9C warmer than observed by Karaulovsky and Sigaev (see footnote 5) for the years 1962-72, and about 2C warmer than the seasonal mean indicated for this area by Schopf (1967).

Temperature class intervals in the Gulf showed a consistent change annually even though the mean temperatures varied only slightly from year to year (Fig. 14.3). Generally, water <6C in colder years was "replaced" by >10C water, and dominance of the 6C-8C TCI shifted to the 8C-10C TCI as a result of the warming trend.

Temperatures fluctuated widely between years and generally did not show a consistent pattern between subareas. However, the easternmost subarea (V) was usually the warmest, and subarea II the coldest, and in 1975 all subareas decreased (Fig. 14.6). The largest fluctuations occurred in the coastal subareas I and V which had annual differences as much as 1.5C-1.8C. Although subarea I is the smallest of the Gulf divisions, its exceptionally large negative anomaly of 1.6C (Table 14.1) accounted for most of the 1975 decline in mean bottom water temperature for the entire Gulf (Fig. 14.2). Subarea II, which comprises most of the Western Basin of the Gulf of Maine, had the lowest mean bottom-water temperature (7.3C), whereas subarea V, influenced by its large area of shoal water and the inflow through the Northeast Channel, had the highest mean (9.1C).

The subarea TCI's are shown in Figure 14.7, and unlike the histogram for the entire Gulf, indicate that similar mean temperatures usually had similar TCI percentages. The best examples of this relationship occurred in 1969 between subareas I and V; in 1972 between IV and V; and in 1973 among I, II, and III. The relatively large amounts of 4C-6C water in subareas II and III in 1968 and in subarea I in 1975 were chiefly responsible for the lowest annual mean and single annual decrease. The absence of this TCI in 1974 coincided with the highest mean temperatures observed for the entire Gulf of Maine but not necessarily for the individual subareas.

Preliminary analysis of spring data for 1976 indicates record highs since 1968 for all subareas of the Gulf of Maine (observed mean 7.1C). A relatively large amount of 8C-10C water observed in the Gulf was probably of slope origin and entered through the Northeast Channel.

Georges Bank - Spring

Spring bottom-water temperatures on Georges Bank were characterized by a low in 1971 of 4C followed by rather large year to year increases to a peak of 6.5C in 1974, and then a sharp decline of 1.1C in 1975 (Fig. 14.8). The 8-yr mean of 5.2C is 1C lower than reported by Karaulovsky and Sigaev (see footnote 5) for 1962-72, but their coverage included waters deeper than 100 m. Schopf (1967) calculated a mean bottom-water temperature of approximately 4.8C for Georges Bank during this season in the periods 1955-56 and 1965-66.

Georges Bank is usually dominated by the 4C-6C TCI in the spring which in 1969 accounted for 90% of the area within the 100-m isobath (Fig. 14.9). The coldest (1971) and warmest (1974) years are marked by a displacement of this TCI with 2C-4C and 6C-8C water, respectively. Since the Bank waters are well mixed, these changes in TCI percentages reflect broad-scale habitat differences in 1971 and 1974 from average conditions.

Unlike the Gulf of Maine, year-to-year changes in spring temperatures were similar in all the subareas of Georges Bank, which again points out the homogeneity of these shoal waters (Fig. 14.10). Central Georges Bank was usually the coldest of the three subareas, and reached a minimum of 3.6C in 1971. Western and eastern Georges Bank had very similar mean temperatures except in 1968 when the latter subarea had an anomaly of -1.7C (Table 14.2).

Subarea TCI's for both spring and autumn are shown in Figure 14.11. It is interesting to note that the quite warm years of 1973 and 1975 were substantially influenced by water >8C in all three subareas, but that the warmest year, 1974, had none of this water. The rather low mean for the entire Bank in 1968 was mainly the result of a 2C-4C TCI of 75% in the eastern subarea.

Georges Bank - Autumn

Mean bottom-water temperatures on Georges bank in the autumn increased from a low of 10.6C to a high of 13.4C in 1973 (Fig. 14.12). The largest year-to-year variations were -1.5C (1968-69), -1.1C (1974-75), +1.3C (1970-71), and +1.2C (1972-73). The 8-yr mean of 12.1C was recorded in both 1968 and 1975; this value was about 1C warmer than that reported by Karaulovsky and Sigaev (see footnote 5) for 1962-72.

The two coldest years, 1969 and 1970, are characterized by relatively large amounts of water <10C and small amounts >14C, while the two warmest years, 1973 and 1974, had no water <8C (Fig. 14.9). Years of similar mean temperatures did not necessarily have similar TCI percentages; 1973 and 1974 were alike, but 1968 and 1975 were quite different.

Figure 14.13 and Table 14.2 summarize the mean temperatures and variations for the three subareas of the Bank. Especially notable are the consistently low temperatures on eastern Georges Bank during all years of the study. The warmest part of the Bank alternated nearly every year between the western and central subareas, and each had the same 8-yr mean (12.9C). Despite the large annual fluctuations, each subarea was in phase with the general trend depicted for the entire Bank.

The influence of the eastern subarea on autumn mean temperatures for the whole of Georges Bank is evident in the TCI distributions shown in Figure 14.11. Relatively large amounts of 6C-8C water and small amounts of 14C-16C water in the eastern subarea are prevalent in cold and warm years, respectively. The modal TCI percentages are consistently lower by one interval than those in the western and central subareas.

DISCUSSION

Year to year changes in spring and autumn bottom-water temperatures in the Gulf of Maine and Georges Bank are obviously related to the volume of unusually cold or warm water which denotes changes in composition of these waters. Bigelow (1927) and Colton (1968b) concluded that it is the volume and composition of offshore waters entering the Gulf of Maine via the Northeast Channel that principally determine these variations, at least in the deeper basins of the Gulf. Although salinity observations were not determined in this study, it can reasonably be assumed that Slope Water entering the Gulf through the Northeast Channel was mainly responsible for the general temperature trend observed in much of the Gulf, and ultimately effected changes in Georges Bank. Examination of the plotted isotherms (Figs. 14.14 and 14.15), especially for the spring cruises, clearly supports this assumption. Schlitz[7] suspected, from the above examination, that the high spring temperatures observed in 1972-74 were either the result of a repeated inflow through the Northeast Channel each year, as indicated by the 8C isotherm (Fig. 14.14), or that a single major pulse occurred in 1972, perhaps followed by lesser intrusions, and this warm water persisted in the deep basins until natural decay resulted in the observed 1975 decline in mean bottom temperature. Another hypothesis is that a similar sequence was initiated in the autumn of 1971 and that the warm spring conditions were the result of "overwintering" Slope Water. Regardless of the hypothesis, it seems clear that anomalous conditions occurred commencing in autumn 1971 and spring 1972 and persisted through 1974. In order to understand the dynamics of such changes, it will be necessary to carry out continuous monitoring of temperature, salinity, and currents in the very important Northeast Channel and contiguous waters. As stated by Bigelow (1927), this channel is the most striking feature of the Gulf of Maine affecting the hydrography of the region. Also, an examination of available data on the volume and temperature of adjacent Slope Waters in the past

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[7]Personal communication from R. Schlitz, Northeast Fisheries Center, NMFS, Woods Hole, MA 02543.

decade may provide a better understanding of the observed conditions in the Gulf of Maine and on Georges Bank during this period.

The trend of increasing temperatures since 1968 was much smoother in the Gulf of Maine than on Georges Bank when each area is analyzed as an entire unit (Figs. 14.2, 14.8), but on Georges Bank the subareas are much more alike within a given year (Figs. 14.4, 14.9). This is to be expected as the entire waters of Georges Bank are often well mixed by tides and winds as indicated by the homogeneity of TCI's in years of very comparable mean temperatures such as in spring 1969 and 1972 (Fig. 14.11). This phenomenon was not observable in the autumn because eastern Georges Bank was consistently two or more degrees colder than the rest of the area. This can be explained in part by the fact that eastern Georges Bank contains the smallest area of shoals of the three subareas, and the effect of the indraft through the Northeast Channel would tend to cool eastern Georges Bank in the autumn (Colton 1968b).

With respect to biological changes, it is perhaps more important to note the fluctuations in volumes of certain temperature intervals rather than variations in temperature means or extremes. For example, the TCI's might be considered estimates of suitable habitat area for any given species providing its temperature tolerances or preferences are known; if spawning and survival of species "X" on Georges Bank is most successful in 6C-8C water, then the 1974 year class might be stronger than the other seven year classes for which data are presented, as no other year had large quantities of this water in this area (Fig. 14.11). A close examination of such relationships with real species in the entire water column appears warranted as a follow-up to this report. It is perhaps unlikely that a simple linear relationship between year class success and temperature will be found for any species; however, temperature trends of the magnitude shown in this paper undoubtedly influence certain biological phenomena in significant ways, e.g., changes in time of spawning of sea herring and haddock, and distributional patterns of mackerel and silver hake. A more complete understanding of the net effects of temperature on spawning, hatching success, growth, predation, etc. is required, but nevertheless other gross effects such as those stated might be evident if available biological data for the last decade were closely scrutinized. Certainly there would be significant value in correlation analyses of time-series data, especially after we have better measures of the dynamics involved in temperature variations in the Gulf of Maine and on Georges Bank.

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Table 14.1.--Eight-year means and yearly anomalies for subareas of the Gulf of Maine, spring and autumn, 1968-75.

Subarea	$\bar{x}$	1968	1969	1970	1971	1972	1973	1974	1975
				SPRING					
I	4.2	-1.5	-0.7	+0.8	+0.2	-0.5	-0.2	+0.8	+0.8
II	5.9	-1.0	- .8	+ .6	+ .3	- .1	+ .1	+ .3	+ .4
III	6.2	-1.1	- .5	+ .5	+ .3	- .1	+ .2	+ .3	+ .3
IV	7.0	-0.7	- .5	- .1	- .2	+ .4	+ .6	+ .7	+ .2
V	6.0	-1.0	-1.0	- .3	0	0	+ .8	+ .5	+ .5
				AUTUMN					
I	8.1	+0.3	+0.2	+1.2	0	+0.3	-0.3	-0.1	-1.6
II	7.3	-1.2	- .5	0	+1.1	+ .1	+ .6	+ .1	-0.2
III	7.5	-1.2	- .4	-0.3	+0.1	+ .2	+ .2	+ .8	+ .5
IV	8.2	- .4	- .9	-1.0	- .5	+ .6	+ .4	+1.1	+ .5
V	9.1	- .2	- .7	-1.3	- .6	+ .3	+ .9	+1.7	- .1

Table 14.2.--Mean bottom-water temperatures and anomalies by subareas of Georges Bank, spring and autumn, 1968-75.

Subarea	$\bar{x}$	1968	1969	1970	1971	1972	1973	1974	1975
				SPRING					
Western	5.3	-0.7	-0.1	-0.3	-1.1	0	+0.9	+1.4	+0.2
Central	5.1	0	+ .1	-1.0	-1.5	+0.1	+ .7	+1.4	+ .4
Eastern	5.2	-1.7	0	- .4	-1.0	0	+1.0	+1.2	+ .6
				AUTUMN					
Western	12.9	0	-1.8	-1.1	+1.0	+0.4	+0.6	+1.3	-0.3
Central	12.9	-0.4	-1.2	-0.7	+0.3	- .2	+1.2	+1.1	- .1
Eastern	10.3	- .2	-1.6	-1.3	- .3	0	+1.5	+1.5	+ .4

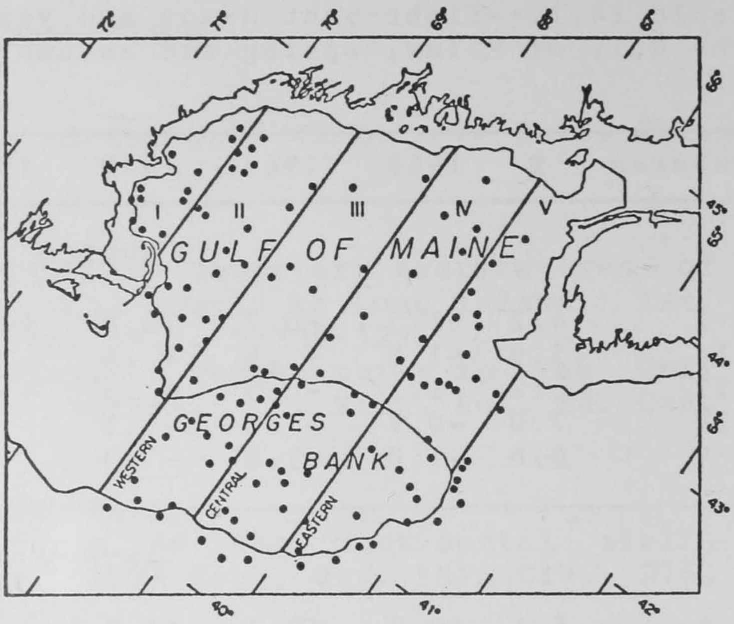


Figure 14.1.—Gulf of Maine-Georges Bank and sub-area boundaries used in data analysis (solid circles represent typical distribution of bathythermograph stations).

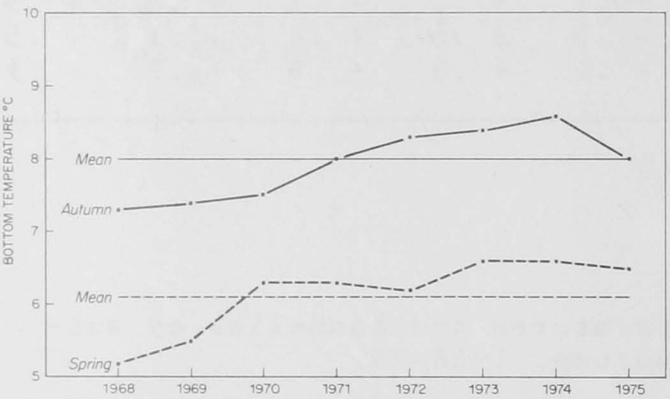


Figure 14.2.—Spring and autumn mean bottom-water temperatures in the Gulf of Maine, 1968-75.

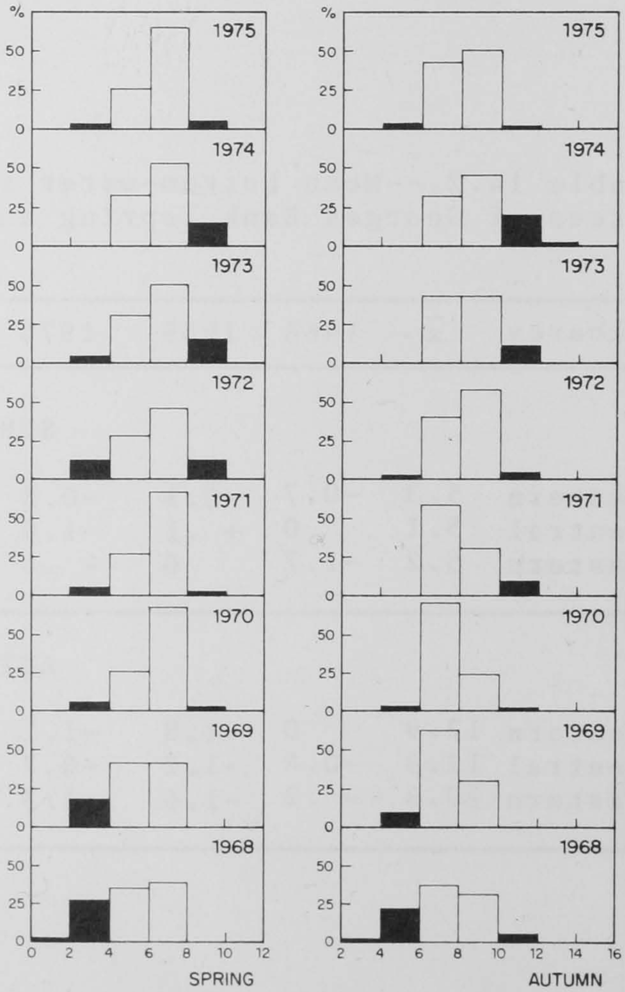


Figure 14.3.—Percentages of temperature class intervals (TCI's) in the Gulf of Maine, spring and autumn 1968-75.

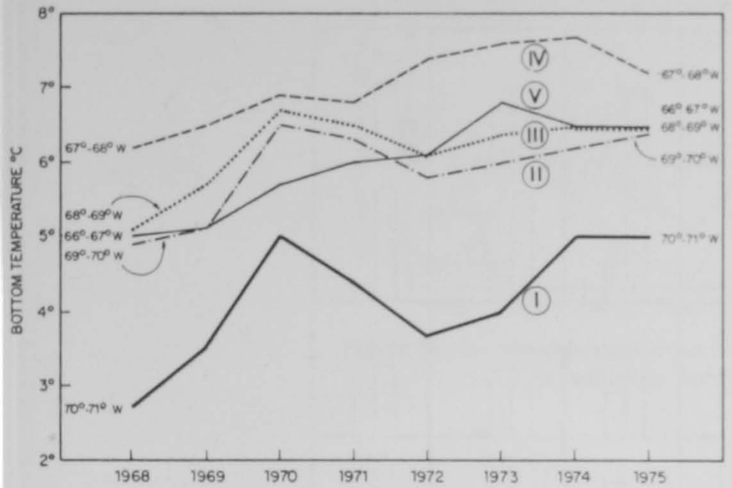


Figure 14.4.—Mean bottom-water temperatures in the Gulf of Maine by Subareas I-V, spring 1968-75.

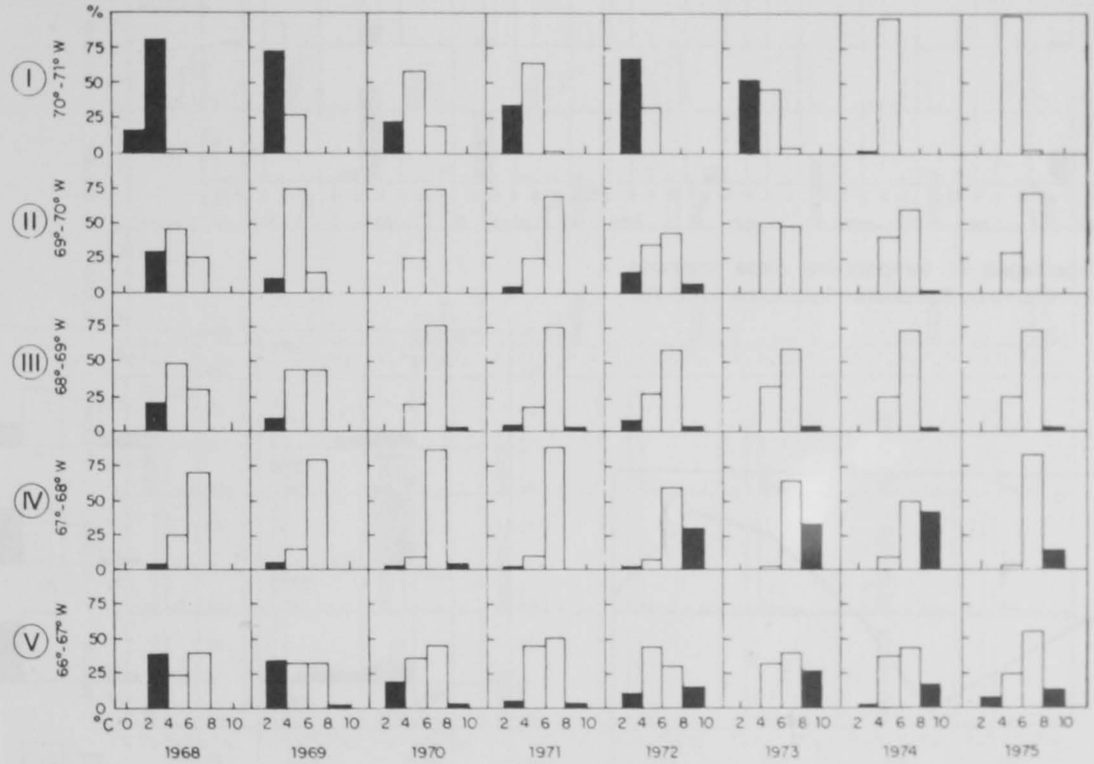
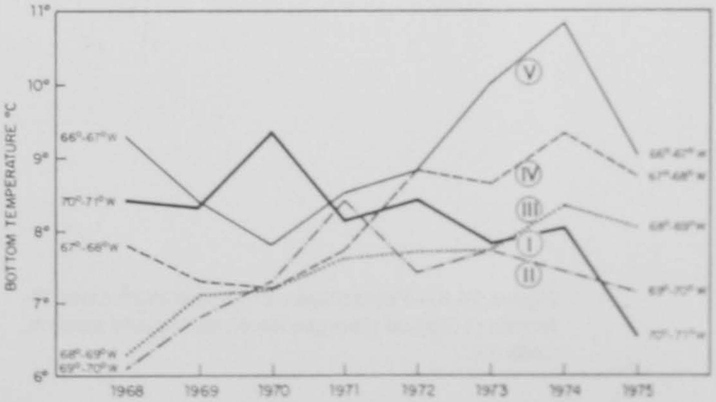


Figure 14.5.—Percentages of temperature class intervals (TCI's) in the Gulf of Maine by Subareas I-V, spring 1968-75.

Figure 14.6.—Mean bottom-water temperatures in the Gulf of Maine by Subareas I-V, autumn 1968-75.



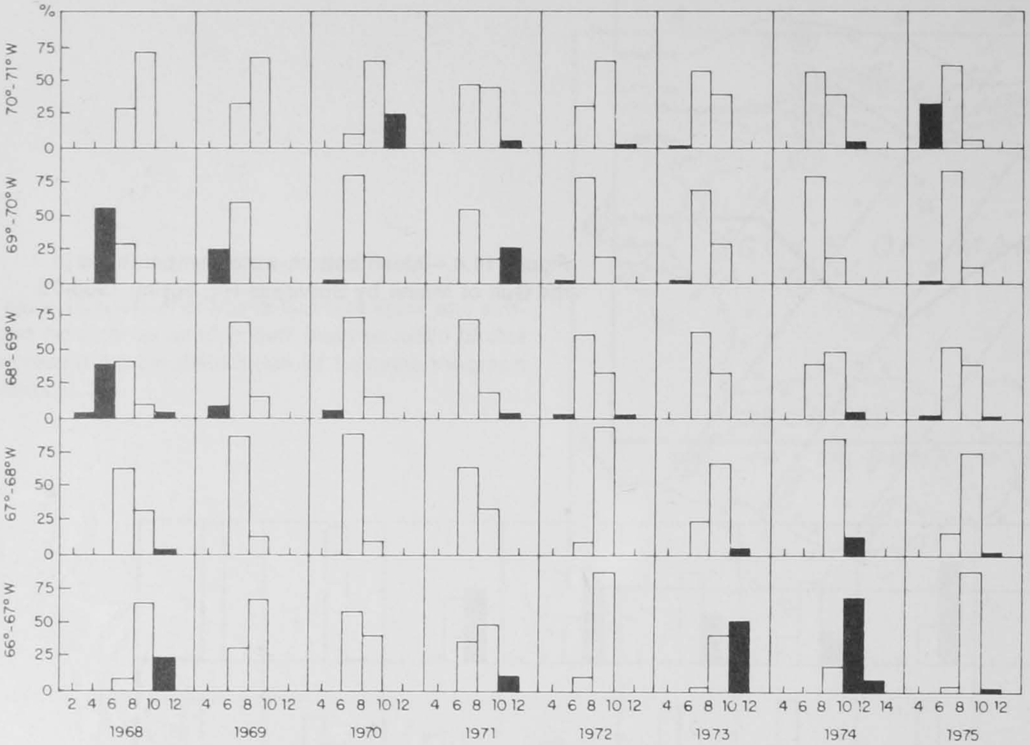


Figure 14.7.—Percentages of temperature class intervals (TCI's) in the Gulf of Maine by Subareas I-V, autumn 1968-75.

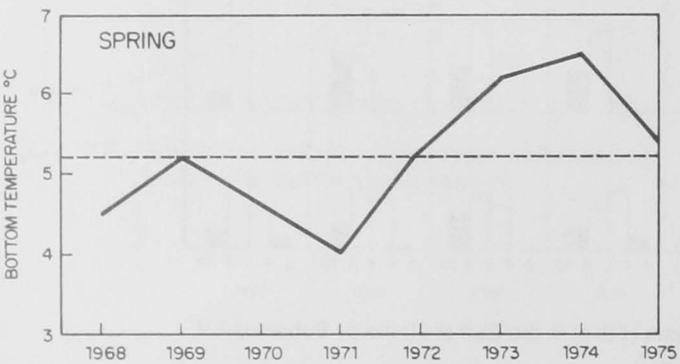


Figure 14.8.—Mean bottom-water temperatures on Georges Bank, spring 1968-75.

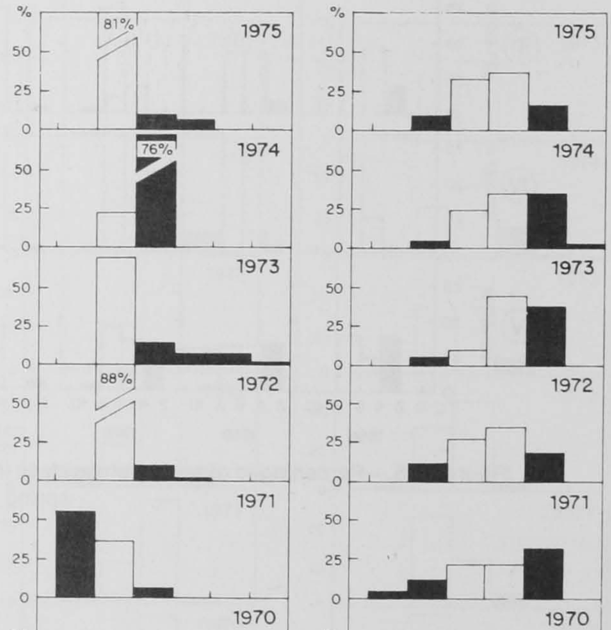


Figure 14.9.—Percentages of temperature class intervals (TCI's) on Georges Bank, spring and autumn, 1968-75.

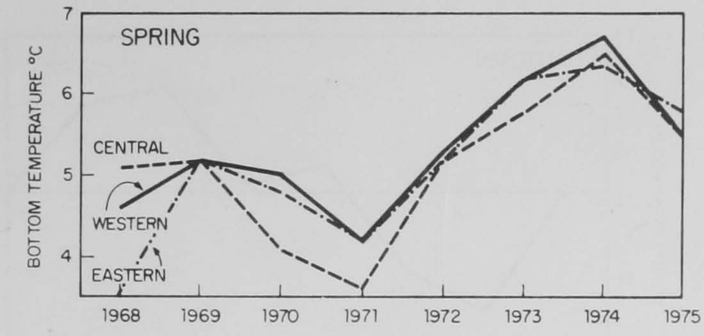


Figure 14.10.—Mean bottom-water temperatures on Georges Bank by subareas, spring 1968-75.

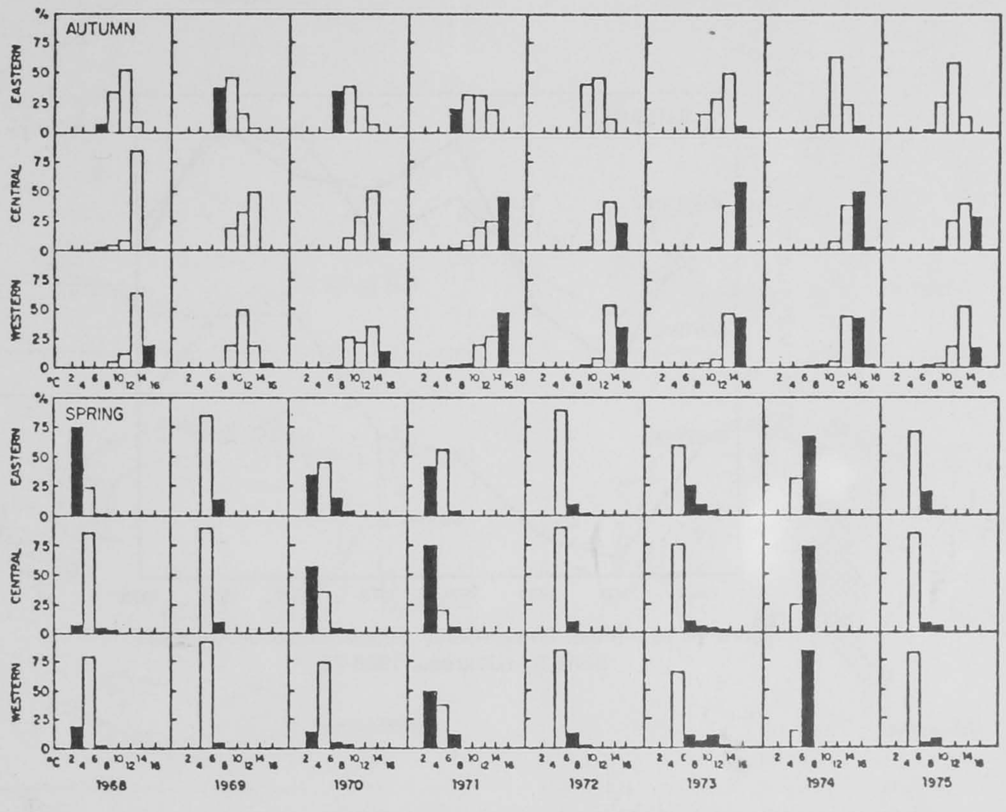


Figure 14.11.—Percentages oɪ temperature class intervals (TCI's) on Georges Bank by subareas, spring and autumn 1968-75.

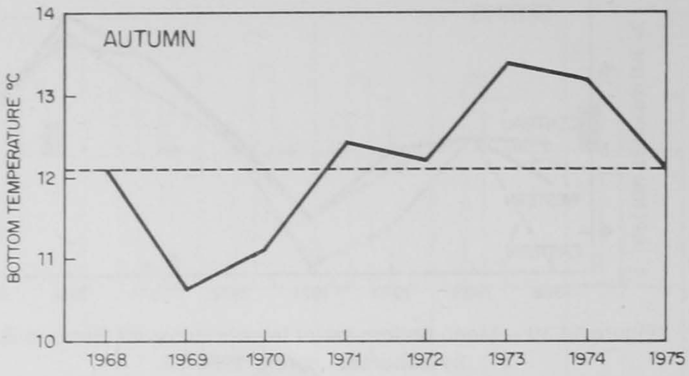


Figure 14.12.—Mean bottom-water temperatures on Georges Bank, autumn 1968-75.

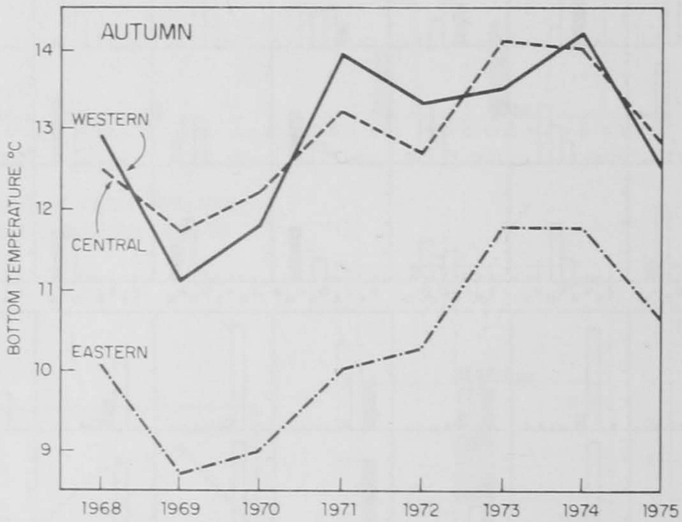


Figure 14.13.—Mean bottom-water temperatures on Georges Bank by subareas, 1968-75.

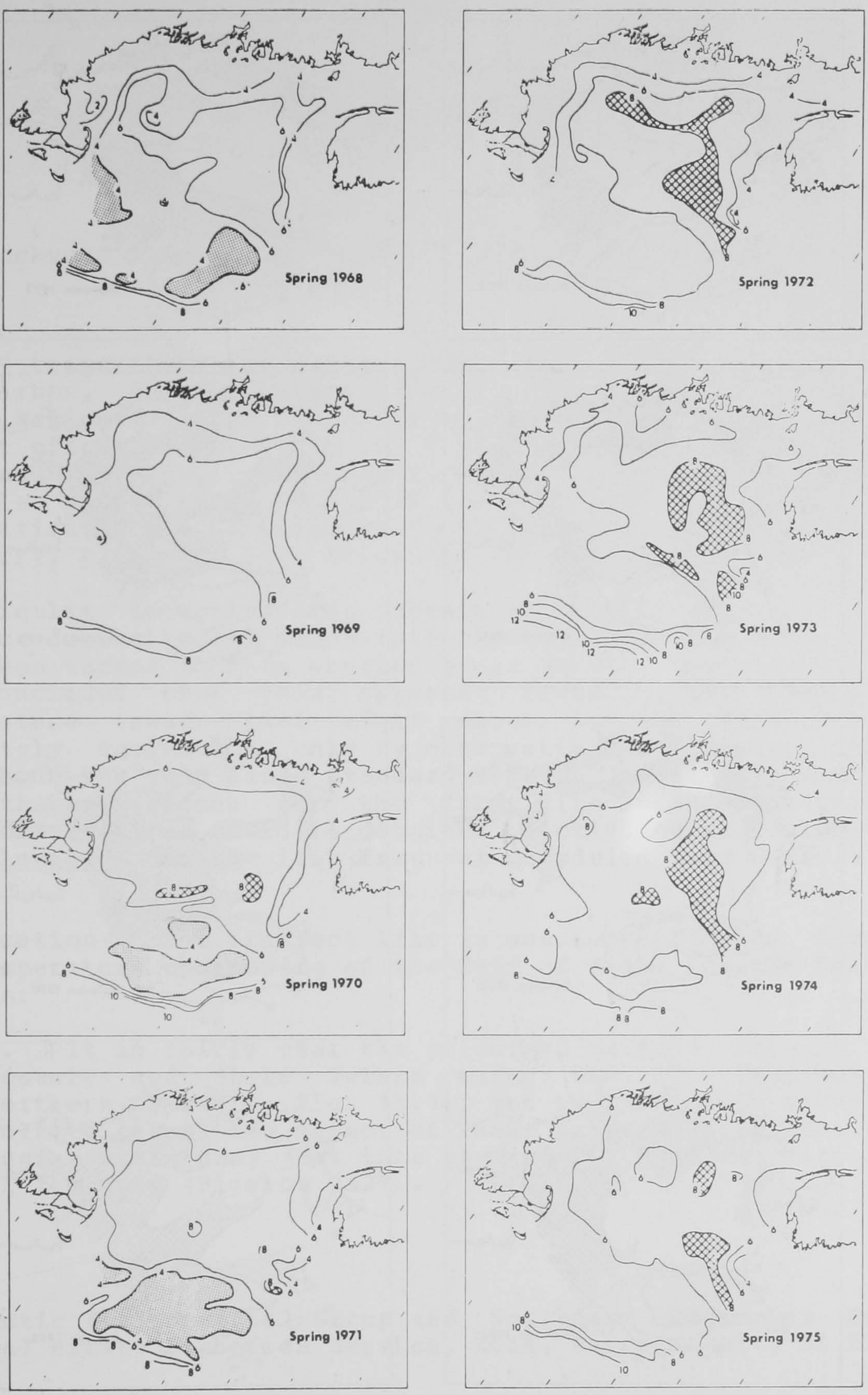


Figure 14.14.—Distribution of spring bottom-water temperatures, 1968-75. Dotted shading is<4C on Georges Bank. Gridded shading is>8C in Gulf of Maine.

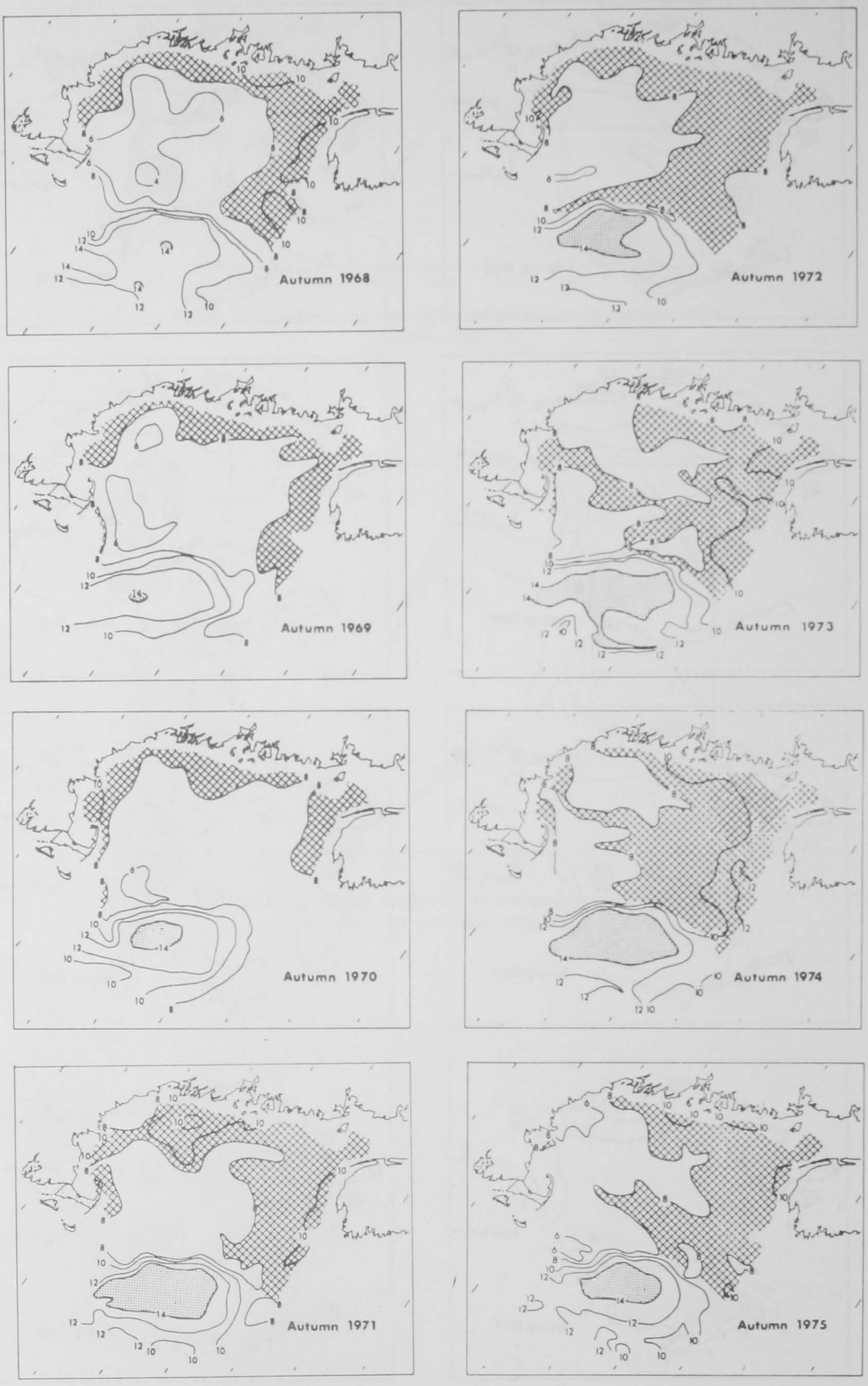


Figure 14.15.—Distribution of autumn bottom-water temperatures, 1968-75. Dotted shading is>14C on Georges Bank. Gridded shading is>8C in Gulf of Maine.

Section 15

INITIATION OF MONTHLY TEMPERATURE TRANSECTS ACROSS THE NORTHERN GULF OF MAINE

J. Lockwood Chamberlin, John J. Kosmark, and Steven K. Cook[1]

Monthly temperature transects across the Gulf of Maine, between Bar Harbor, ME, and Yarmouth, N.S. (Fig. 15.1), were initiated by the National Marine Fisheries Service (NMFS) in June 1975, as a joint effort of the Northeast Fisheries Center and the Atlantic Environmental Group. Obtaining these sections on a regular schedule and at reasonable cost has been possible because of the cooperation of the Canadian National Railways, which operates the car ferry, Bluenose, from which the observations have been made.

A particular incentive for obtaining the sections has been evidence during recent years that the waters of the Gulf of Maine have been warmer than in earlier years (Davis, Section 14). It was concluded that this apparent trend or any other overall temperature trends that might occur in the Gulf could be adequately documented only by observations at regular intervals throughout the year along standard section lines. Bar Harbor to Yarmouth was chosen for the first line because the necessary field observations could be obtained quickly and at low cost from the Bluenose during its frequent scheduled runs between these ports.

The location of the transect line is oceanographically favorable for temperature monitoring of the Gulf of Maine for the following reasons:

1. It is fairly near the principal portals through which oceanic and Shelf Waters enter the Gulf (Northeast and Northern Channels, Fig. 15.1), yet is far enough within the Gulf to reveal the effect of these waters on the temperature regime where they join into the general cyclonic circulation of the Gulf (Bigelow 1927).

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[1]Atlantic Environmental Group and Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.

2. Water in the vicinity of the transect can be expected to move more or less southwestward along the western side of the Gulf off the coasts of Maine, New Hampshire, and Massachusetts. Monitoring variations in temperature along the transect should, therefore, provide some of the necessary basis for forecasting water temperatures in the western Gulf.

3. Previous oceanographic studies (summarized by Bumpus 1973) have shown that in the spring and summer there is a "U turn" type of surface circulation in the Bay of Fundy, with water from the Scotian Shelf and eastern Gulf of Maine entering the Bay off the coast of western Nova Scotia and leaving off the coast of northern Maine. Because the Bar Harbor-Yarmouth transect crosses the mouth of the Bay, the temperature sections should reveal both the inflow and outflow, and provide information on whether or not the "U turn" circulation also occurs in the subsurface waters.

SOURCE OF DATA

Half-hourly temperature data were obtained with expendable bathythermographs (XBT's) during the six-hour crossing of the Bluenose. Because of the depth limit of the T-10 XBT probes (200 m at 10 knots) and the speed of the vessel (19 knots), temperatures usually were not recorded deeper than about 180 m, thus not reaching all the way to the bottom in the deepest parts of the section.

At each XBT station, surface bucket temperatures were recorded and surface water samples were obtained for later determinations of salinity with a Beckman inductive salinometer calibrated with standard (Copenhagen) seawater at least once every 30 samples. The position of each station is based on radio navigation.

Preparation of Temperature Sections from the Bluenose in 1975

In preparing the temperature sections from the Bluenose (Figs. 15.2-15.4), digitizations of the XBT traces, as well as plotting and contouring of the data, have been by hand. A preliminary version of each section, starting with August, has been mailed to interested parties at New England and Canadian fishing ports.

A standard bottom profile has been used in all the sections for production purposes. This profile, based on bathymetric chart data and echo sounder traces from two transects, follows the regular path of the Bluenose. The relief has been moderately simplified, appropriate to the scale of the sections, and is completely smoothed at the extreme shoreward ends. Isolated prominences and depressions are drawn with subdued relief. Minor discrepancies have been found between the depths recorded at the XBT stations and the depths of the standard bottom profile.

Average Temperature Sections

To provide a basis for comparison with the temperature sections from the Bluenose (Figs. 15.1-15.4), similar sections were prepared based on long-term average monthly temperatures. The data for these sections have been derived from manuscript charts.[2] These charts were originally compiled for two atlases of average monthly seawater temperatures, each of which includes the Gulf of Maine region (Colton and Stoddard 1972, 1973). The charts for the first atlas include contours of average monthly temperatures by 1/4 degree quadrangles of latitude and longitude for the period 1940-59. For each month there are maps for the surface and for depths of 10, 20, 30, 40, 50, 75, and 100 m. On each of these charts a transect line was drawn, corresponding to the course taken by the Bluenose. The positions of isopleth intercepts along this line were recorded for each depth and each month of the year. These intercept values were plotted on graphs (one graph for each depth) using a time scale of one year as one axis and the length of the transect as the other axis. All intercept values were plotted along midmonth lines. The plotted values were then contoured in 1/2C intervals. By folding the plots so that December was brought adjacent to January, the contouring was completed as a continuous loop.

Incoherence in the data in these diagrams led to numerous modifications of the contouring on the manuscript charts and concommitant changes in the isopleth positions plotted on the diagrams. Because some incoherencies persisted in the diagrams, subjective liberties were taken in the final contouring to eliminate small irregularities.

To produce a long-term average vertical temperature section for any day when a Bluenose section was made, isopleth positions along the transect for that day were read from each contoured diagram and plotted in the standard temperature section format.

Additional long-term average monthly temperature values, especially for depths greater than 100 m, were derived from the manuscript maps for Colton and Stoddard (1973), a bottom temperature atlas. The average monthly values on these maps are by 1/4

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[2]Personal communication from J. B. Colton, Jr., Northeast Fisheries Center, NMFS, Narragansett, RI 02882.

degree quadrangles of latitude and longitude, further subdivided into 20-m depth bands for depths less than 100 m, and 50-m bands for depths of 100-250 m. All such values as were found on the maps in the immediate vicinity of the transect line were plotted in the standard section format.

Contouring of the average vertical temperature sections themselves required considerable subjectivity to deal with data incoherencies, especially between data derived from the two different atlas compilations. Part of the reason for these incoherencies is the difference in the years of data that were averaged for the two atlases: 1940-59 for the first and 1940-66 for the second. A warming trend during this century, found in surface temperature records from shore stations in the Gulf of Maine (Stearns 1965; Chamberlin and Kosmark 1976) could contribute to discrepancies between averages based on data from these two sets of years.

Undoubtedly, however, the main cause of the incoherencies in the data used in the average sections is the paucity of historical data available for the vicinity of the Bluenose sections. In the bottom temperature atlas (Colton and Stoddard 1973), based on 27 years of data, the majority of the averages for any month are based on data from only one year. Lack of coherence of data within any section, as well as between sections for adjacent months, is, therefore, to be expected. Nevertheless, it should be mentioned that Colton and Stoddard, in each of their atlases, reduced much of the data bias by using "corrected values" of monthly mean temperatures. These "corrected values" were read from smoothed seasonal temperature curves drawn on the data, or determined from 3-mo moving averages.

We conclude that the average sections are a basis for only very general comparison with the Bluenose sections for 1975.

Bottom Temperature Diagrams

The average bottom temperature diagrams and those for 1975 (Figs. 15.5, 15.6) were prepared in the same way. Smoothed bottom profiles, which eliminate depth inversions, were superimposed on each section, from the shore to deep water, at both the Bar Harbor and Yarmouth ends. Each of these smoothed profiles stops short of the high ridges in the center of the sections. The values of the isotherms were then plotted against 1) their depths of intersect with the smoothed bottom profiles and 2) time of year, and then contoured in 1C intervals.

TEMPERATURE TRENDS IN 1975

Until monthly temperature sections from Bar Harbor to Yarmouth have been obtained for at least two years, detailed analysis of temperature trends will be premature. For the present, some of the principal trends during the seven months of record in 1975 (June-December) can be briefly summarized:

1. During the summer, three principal processes appear to have influenced the section:

   a. Local solar heating produced a well-developed warm surface layer in the center of the section and near the coast of Maine, as well as progressive warming to depths of about 100 m off the coasts of both Maine and Nova Scotia. The lack of development of a warm surface layer off Nova Scotia was accompanied by more rapid warming at depth than off Maine. Presumably this resulted from stronger vertical mixing by tidal currents in the former area. Weak development of a warm surface layer about 25-40 nm (45-75 km) from Bar Harbor was also, presumably, the result of strong tidal currents. The highest surface temperatures from the Maine coast to the center of the section occurred in August, but they occurred in September off Nova Scotia.

   b. There were cores of relatively cold water at middepth off both coasts. These cold cores may be analogous to the summer occurrence of cold core bottom water on the Middle Atlantic continental shelf, which Ketchum and Corwin (1946) described as persistent "winter" water. Alternatively, if the mid depth circulation parallels the surface circulation, as described by Bumpus and Lauzier (1965), the cold cores may represent flow into the Bay of Fundy off Nova Scotia and outflow off the Maine coast. These cold cores shifted: 1) to greater depths from June to July, 2) closer to the center of the section in August, and 3) to the westward in September. During this time the minimum temperature in these cores rose 2C off the Maine coast and 3C off the Nova Scotia coast. The cold core off Nova Scotia was about 1C warmer than off Maine in June, remained colder in July, but became about 1C warmer during August and September.

   c. Temperature inversions near bottom in the deepest parts of the section suggest inflow of modified Slope Water during some months.

2. During the autumn the principal processes influencing the section were:

a. Surface cooling was accompanied by increased vertical mixing as the water column lost stability. At depths around 100 m, off both coasts, the vertical mixing produced the maximum temperatures of the year (10C off Maine and 9.5C off Nova Scotia). The middepth cores of cold water disappeared in October, and by mid-December, the water column was completely mixed near Yarmouth and nearly so near Bar Harbor.

b. Warm water with a maximum temperature above 9C flowed in along the bottom in the deep channel 60 nm (110 km) off Yarmouth in December.

Comparison of the temperatures in 1975 with the long-term averages from June to December reveals that:

1. The surface temperatures are quite similar with maximum differences of no more than about 1C.

2. The cold cores in the summer sections for 1975 are not in evidence in the average sections.

3. The subsurface temperatures during the summer months are about 1C warmer than the averages, with the exception of the cold cores.

4. The subsurface temperature differences during the autumn are somewhat greater (1C-2C) than in the summer.

5. The temperature inversion in the December 1975 section is absent in the December average section.

ACKNOWLEDGMENTS

John B. Colton, Jr. and Reed S. Armstrong, National Marine Fisheries Service, provided helpful advice and criticism.

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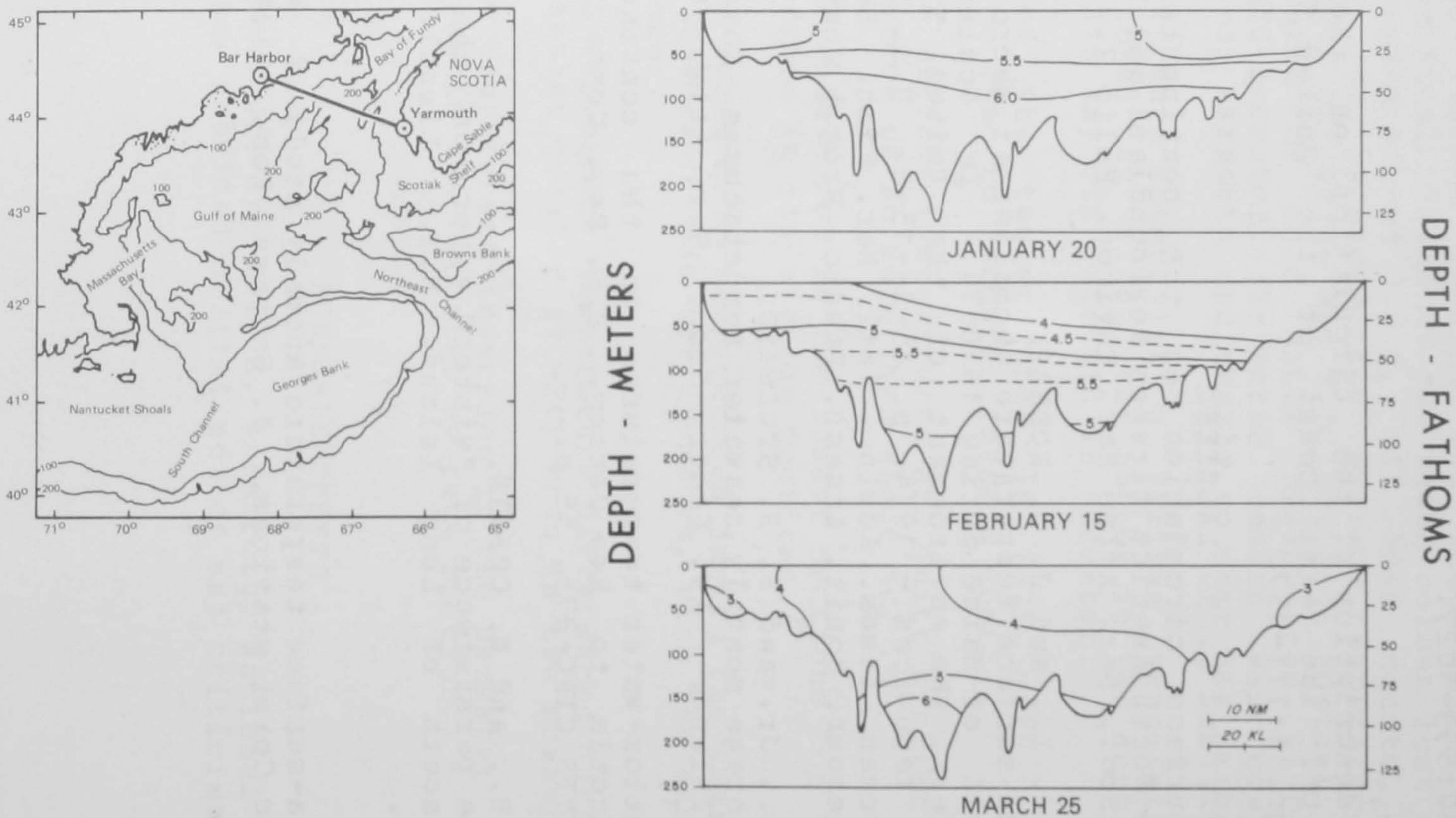

Figure 15.1.—Location of transects across northern Gulf of Maine (left). Long-term average temperature sections (right).

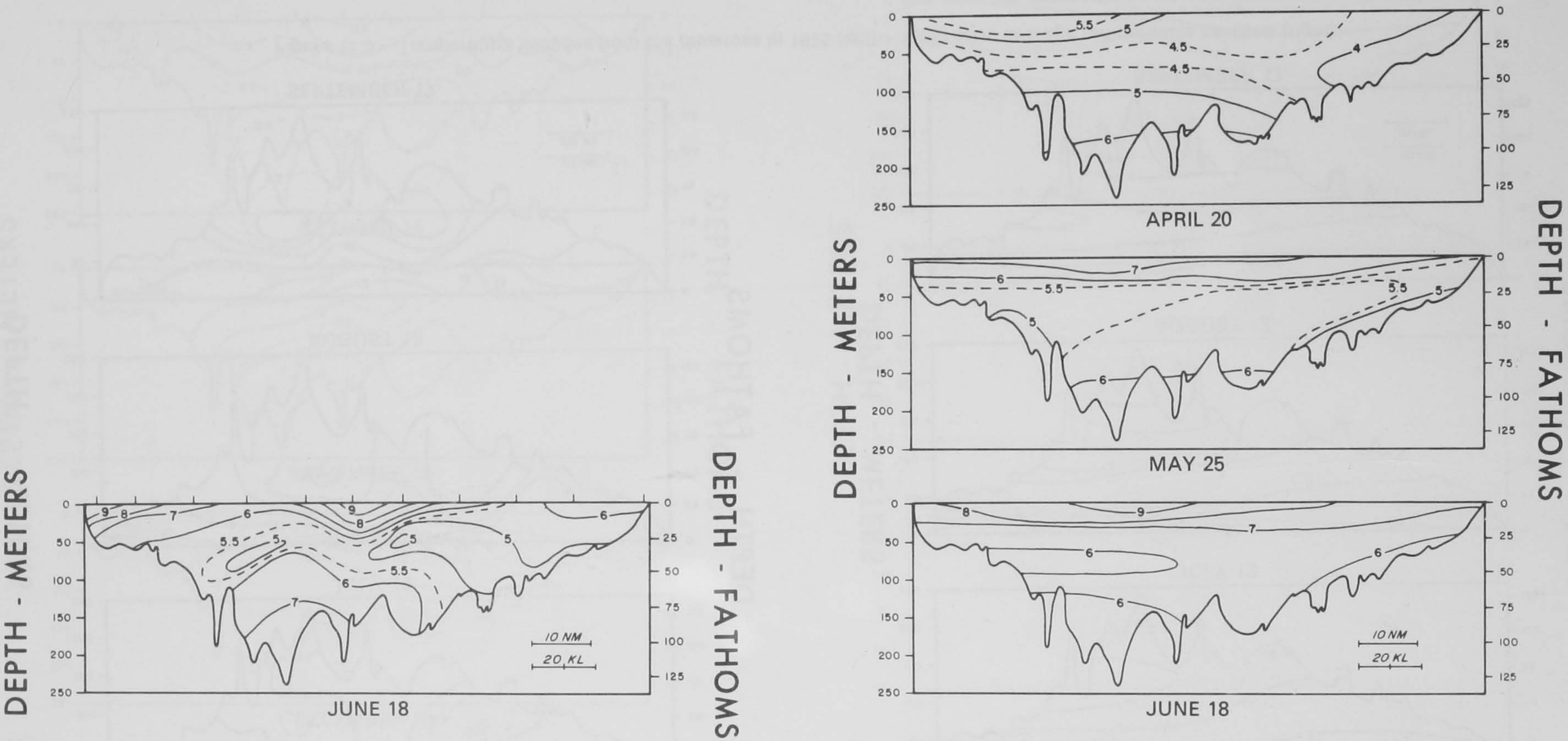

Figure 15.2—Temperature sections from the *Bluenose* in 1975 (left). Long-term average temperature sections (right).

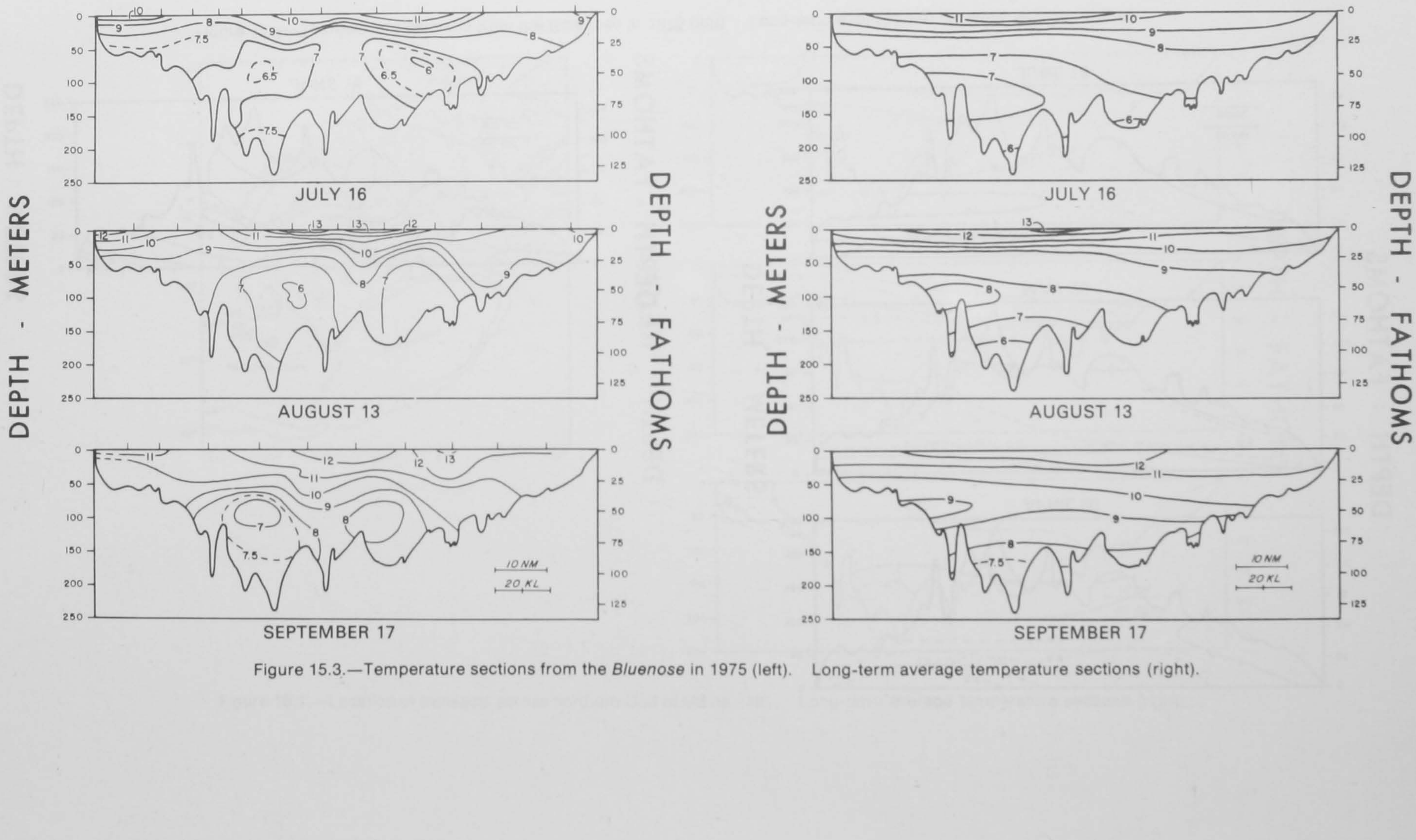

Figure 15.3.—Temperature sections from the *Bluenose* in 1975 (left). Long-term average temperature sections (right).

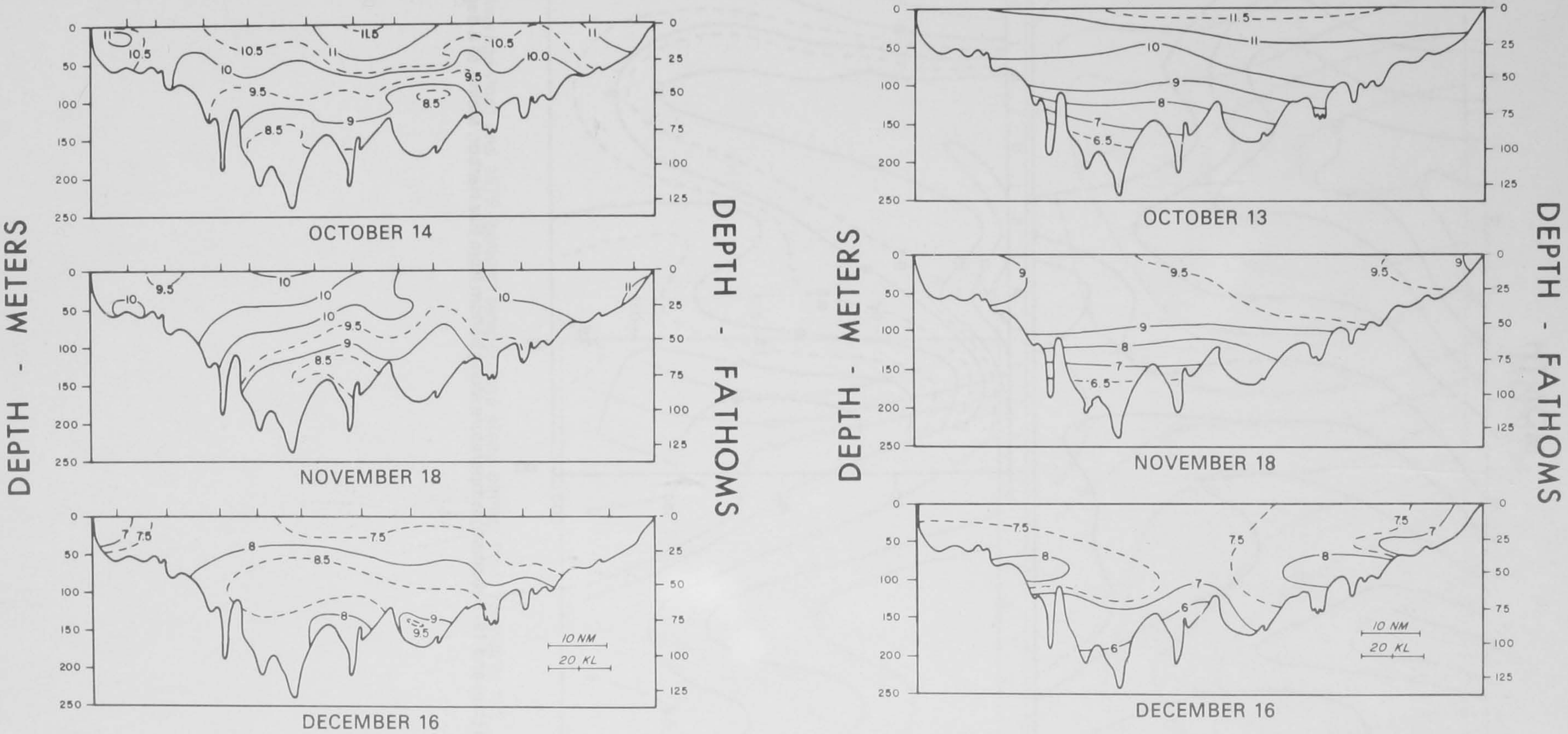

Figure 15.4.—Temperature sections from the *Bluenose* in 1975 (left). Long-term average temperature sections (right).

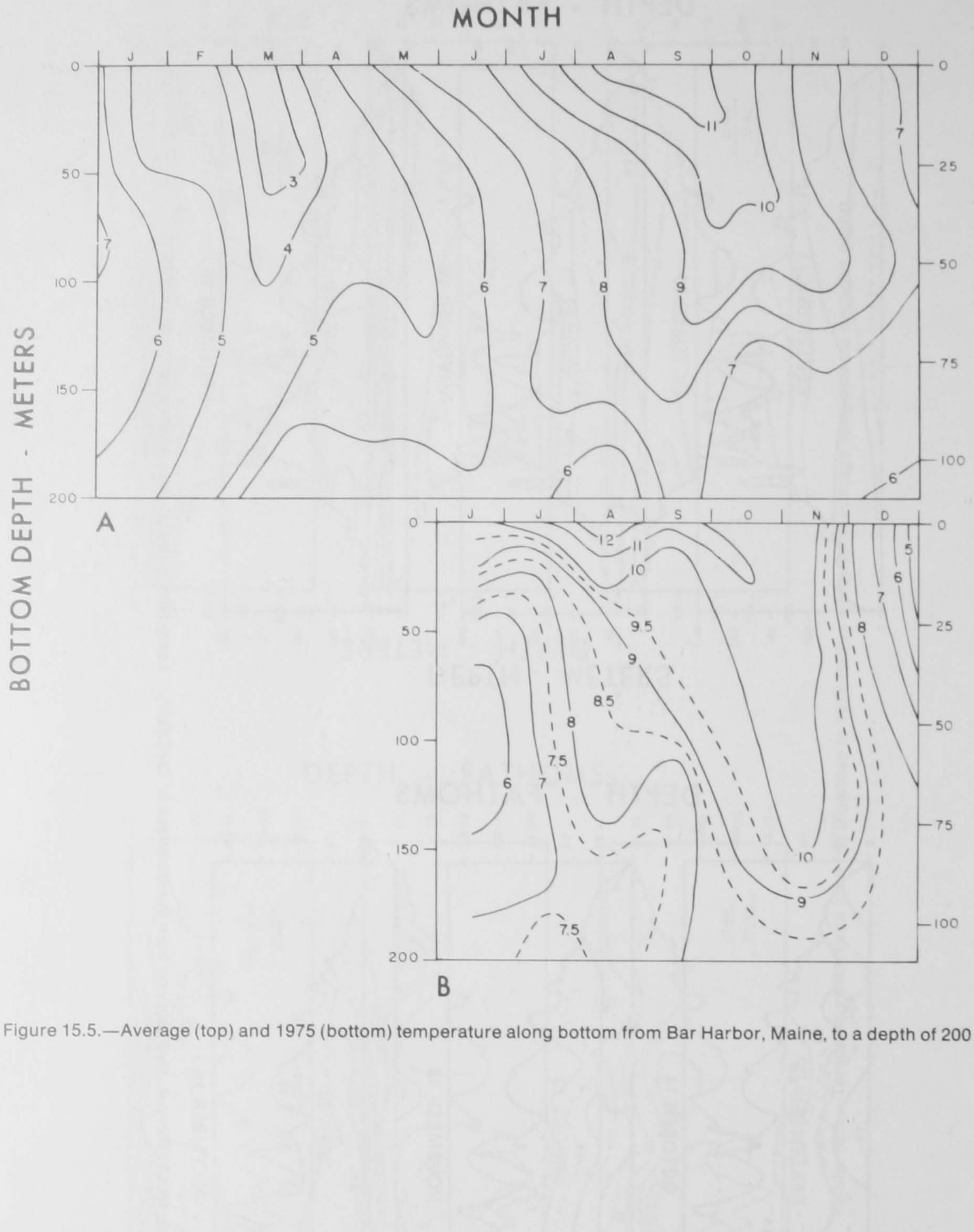

Figure 15.5.—Average (top) and 1975 (bottom) temperature along bottom from Bar Harbor, Maine, to a depth of 200 m.

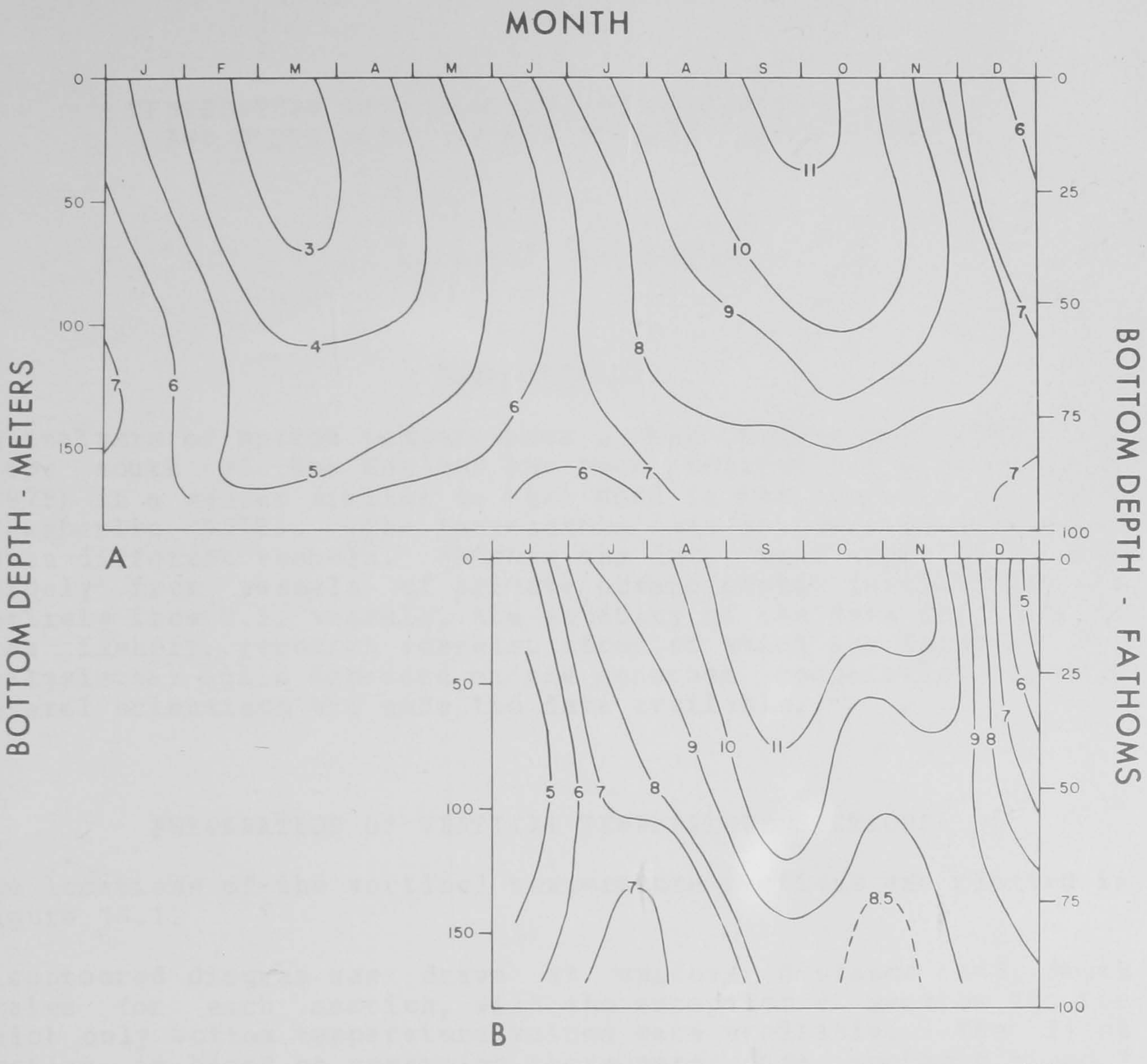

Figure 15.6.—Average (top) and 1975 (bottom) temperature along bottom from Yarmouth, N.S., to a depth of 200 m.

Section 16

TEMPERATURE STRUCTURE ON THE CONTINENTAL SHELF AND SLOPE SOUTH OF NEW ENGLAND DURING 1975

J. Lockwood Chamberlin[1]

INTRODUCTION

An analysis of bottom temperatures on the continental shelf and slope south of New England has been prepared for a second year (1975) in a manner similar to that used in the analysis for 1974 (Chamberlin 1976). The temperature data are from 18 cruises of seven different vessels. Whereas the data used for 1974 were largely from vessels of private oceanographic institutions and entirely from U.S. vessels, the majority of the data for 1975 is from fishery research vessels, three of which are foreign. The analysis has again depended on the generous cooperation of the several scientists who made the data available.

PREPARATION OF VERTICAL TEMPERATURE SECTIONS

The locations of the vertical temperature sections are plotted in Figure 16.1.

A contoured diagram was drawn at uniform distance and depth scales for each section, with the exception of section 12, for which only bottom temperature values were available. The first section is based on reversing thermometer data, sections 5 and 7 on data supplied from mechanical bathythermographs, and the remainder on expendable bathythermograph (XBT) data plotted directly from the traces.

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[1]Atlantic Environmental Group, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.

CONSTRUCTION OF BOTTOM TEMPERATURE DIAGRAM FOR 1975

A contoured diagram of bottom temperatures (Fig. 16.2) was prepared in three steps, similar to the method used in Chamberlin (1976):

1. The values of the isotherms on vertical temperature sections and the depths where these intersect the bottom were tabulated. In parts of sections where localized ridges and depressions in the bottom profile produced inversions in the bottom temperatures, a smooth profile was drawn through the irregularities and the temperatures recorded at the depths of isotherm intersects with the smoothed profile.

2. The tabuled values were plotted at the depths of the bottom and at the times of year when the observations were made. Bottom temperature values from section 12, which were the only data available, were plotted in the same way. To avoid excessive crowding of the contours in two cases where sections were made within a few days of one another, the data were combined before plotting (section 3 with section 4, and the offshore portion of section 5 with section 6) by averaging the bottom depths of each temperature value. As can be seen in Appendix 16.1, the sections for which data were combined are similar, except that in sections 3 and 4 the depth ranges of 12C bottom temperatures are distinct.

3. The plotted values were contoured at 1C intervals. The process of the contouring itself led to minor re-interpretations of some vertical sections and the concomitant changes in the depths at which bottom temperature values were plotted, as well as the addition of a few values.

Although the diagram is designed to show only the gross pattern of bottom temperature change in the region south of New England (exclusive of the Nantucket Shoals area), it has, because of the manner of its construction, a characteristic that could be misleading unless explained. The temperature sections used for the diagram all run in a more or less north-south direction across the shelf and slope, but are from various longitudes between 70W13' and 71W46', a width of about 100 km (Fig. 16.1). In the diagram, however, they are treated essentially as though all were from a single line or narrow band. An adverse result of this treatment is possible ambiguity in the timing of the "temperature events" as displayed, because the apparent timing, although largely a product of the actual timing of temperature changes, is partly a product of the different locations of the successive sections. Because the shelf and slope region south of New England extends generally east-west and the main direction of the circulation is westward (Bumpus 1973), the diagram has been drawn on the assumption that the temperature regime in the region covered is reasonably homogeneous. This assumption is also supported by the previous studies of this region, such as those of Bigelow (1933), Walford and Wicklund (1968), and Colton and Stoddard (1973).

The bottom temperature diagram for 1974 (Fig. 16.3) was prepared by the same method as used for 1975, except that the vertical temperature sections on which it is based were not all drawn to the same scale, several of them having been provided by cooperating oceanographers (see Chamberlin 1976).

CONSTRUCTION OF A LONG-TERM MONTHLY MEAN BOTTOM TEMPERATURE DIAGRAM - 1940-66

The long-term monthly mean bottom temperature diagram (Fig. 16.4) is based on values computed by Colton and Stoddard[2] for preparation of an atlas of bottom temperatures on the continental shelf from Nova Scotia to New Jersey (Colton and Stoddard 1973). These mean values were computed for the period 1940-66 from data extracted from the bathythermograph file of the Woods Hole Oceanographic Institution. The particular mean values used in preparing Figure 16.4 are those for the 1/4 degree squares between 70W30' and 71W00'.

OCCURRENCE OF WARM CORE GULF STREAM EDDIES SOUTH OF NEW ENGLAND

Because of the possible influence of anticyclonic warm core Gulf Stream eddies ("rings") on the shelf and slope bottom temperatures (Chamberlin 1976), the times of occurrence of these features in the Slope Water south of New England are shown as duration lines at the bottom of the bottom temperature diagrams for 1975 (Fig. 16.2) and 1974 (Fig. 16.3). During 1975, four anticyclonic eddies (ACE) passed westward through the Slope Water region south of New England.[3] In Figure 16.2 these eddies are labeled ACE 5, 6, 8, and 10, the numbers applied to them by Bisagni. Four eddies also passed south of New England in 1974, and are labeled ACE 1, 2, 3, and 5 in Figure 16.3.

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[2]Personal communication from J. B. Colton, Jr., Northeast Fisheries Center, NMFS, Narragansett, RI 02882.

[3]Bisagni, J. J., 1976. Passage of anticyclonic Gulf Stream eddies through Deepwater Dumpsite 106 during 1974 and 1975. NOAA Dumpsite Evaluation Report, 76-1, 39 p.

The eddy duration lines in Figures 16.2 and 16.3 are derived from the weekly Experimental Ocean Frontal Analysis distributed by the U.S. Naval Oceanographic Office. Because the eddies move more or less westward into the Southern New England area, but pass out of the region in a more southwestward direction, the following criteria were used to develop the duration lines. The beginning of each line is on the approximate day when the western surface boundary of the eddy reached 70W15' and the end of each line is when the entire eddy at the surface had passed south of 30N30'.

The 1975 ACE's 5, 6, and 10 each extended about the same distance northward while in southern New England waters, but ACE 6 was by far the largest (Cheney 1975). ACE 8, on the other hand, was only moderate in size and passed too far to the south to have had effects on the shelf and slope bottom temperatures comparable to those of the other eddies. None of the 1975 eddies, however, appears to have come in as close contact with the continental slope, or remained in southern New England waters nearly as long, as ACE 2 in 1974 (Fig. 16.3; Chamberlin 1976), whereas none of the four eddies that passed south of New England during 1974 was of such great size as ACE 6 in 1975.

HIGHLIGHTS OF THE TEMPERATURE SECTIONS

The following sections are illustrated in Appendix 16.1.

Section 1. USCGC Evergreen SAR 75-1, 22 January.
The margin of Eddy 5 is apparent at the offshore XBT station. Slope Water invading the outer shelf contains an isolated body of 14C water, probably derived from this eddy. Mixed Shelf Water occupying the inshore end of the section has cooled below 5C where the bottom depth is less than about 40 m.

Section 2. NOAA RV Albatross IV 75-2, 27 February.
The Slope Water invading the outer shelf contains an isolated core of 15C-17C water which was presumably injected from Eddy 5 when it passed through the area of the section during the first three weeks of February. Bottom water with a temperature of 17C on the outer shelf is warmer than seen in any previous section in this region. This anomaly, which is evident in only one XBT, may therefore be the product of a faulty XBT probe. Isothermal shelf water colder than 5C has extended offshore to about the 65 m isobath, but contains an isolated body of 5C water that presumably originated from a Slope Water incursion.

Section 3. NOAA RV Albatross IV 75-3-I, 4-6 March.
Slope Water is invading the outer continental shelf in a similar pattern to that of section 2, but contains a more usual maximum temperature of 12C. Nearly isolated 6C water, presumably

derived from the Slope Water incursion, occupies the bottom toward the shoreward end of the section where a major part of the surrounding shelf has warmed to above 5C.

Section 4. WHOI RV Knorr 48, 9 March.

Slope Water with a maximum temperature of 12C is contacting bottom on the outer shelf and upper slope over a depth range of about 70 m. Toward the shoreward end of the section, a "bubble" of 6C water, presumably derived from a Slope Water intrusion, lies near the bottom, surrounded by isothermal 5C shelf water.

Section 5. Polish RV Wieczno 75-1, 10-11, 16, 19 March.

This section, constructed from mechanical bathythermograms obtained during a 10-day period, resembles the previous one made 2-10 days earlier; although the maximum bottom temperature produced by contact of warm Slope Water is apparently 11C rather than 12C, the Slope Water front is farther offshore, and the Shelf Water shoreward of the 70-m isobath is about 1C colder, having reached the annual minimum.

Section 6. NOAA RV Albatross IV 75-3-II, 22 and 26 March.

The warmest Slope Water contacting the bottom on the outer shelf remains, as in the previous section, at the observed annual minimum of 11C. This 11C water, however, extends farther onto the shelf at the bottom, as an isolated or nearly isolated injection. The isothermal Shelf Water occupying the shoreward half of the section is essentially unchanged.

Section 7. Polish RV Wieczno 75-2, 20-21 April.

This short section which occupies only the outer shelf is based on mechanical bathythermograph data. Although 12C Slope Water is again contacting the bottom on the outer shelf, the Slope Water front is farther offshore than in the previous sections, and the 5C Shelf Water apparently contacts the bottom to a depth of over 100 m.

Section 8. NOAA RV Albatross IV 75-5, 2 May.

In this short section confined to shelf depths, spring stratification appears and the bottom water is 1C-4C warmer than in the previous section.

Section 9. University of Rhode Island RV Trident 168, 10 June.

Only the shoreward end of a much longer XBT section is presented here. "One of the most pronounced warm rings ever observed" appears in the full section (Cheney 1975), whereas only its northern margin is seen in the portion presented here. The isolated body of 13C water which contacts the bottom in depths of about 115-140 m is likely derived from this eddy. On the shelf stratification is pronounced and the cold core bottom water, with minimum temperatures below 6.5C, occupies most of the water column but is strangely divided into two parts by 8C water.

Section 10. University of Rhode Island RV Trident Cruise 169, 11 July.

In this short section, confined to the shelf depths, stratification remains strong, but the shallow position of the cold core bottom water, its diminution in cross sectional area, and its rise in temperature (compare with section 7) indicate a strong invasion of Slope Water onto the shelf. This apparent invasion may have been associated with the presence of an unusually prominent warm core eddy in the Slope Water area to the south (Fig. 16.2). When this section is further compared to the following one, section 11, in which the cross sectional area of the cold core bottom water is three times greater and the minimum temperature about 1C lower, it may be concluded that the cold core was temporarily divided into eastern and western segments during July.

Section 11. NOAA RV Albatross IV 5-8, August 7.

The maximum temperature of Slope Water contacting the bottom is below 12C, and cross frontal exchange of Slope and Shelf Waters is apparent at middepths. The incursion of Slope Water as well as the shoaling and partial interruption of the cold core bottom water that are apparent in the previous section have abated in the present section. Stratification of the Shelf Water is at maximum development.

Section 12. Soviet RV Belogorsk 75-1, 23 August.

No diagram of this section has been prepared because only bottom temperature values have been obtained. These few values which have been used in the bottom temperature diagram (Fig. 16.2) indicate offshore displacement and warming of the cold core bottom water relative to the previous section.

Section 13. Soviet RV Belogorsk 75-2, September 25-26.

The maximum temperature of slope water contacting the bottom is apparently warmer than 12C. The surface layer on the shelf is 5C-6C cooler than in early August (section 11). In contrast, the minimum temperature of the cold core bottom water has warmed to above 10C, resulting in a weak temperature front with the Slope Water (Wright 1976). The main body of the cold core water is off the bottom.

Section 14. NOAA RV Albatross IV 75-12, 7-8 October.

The maximum temperature Slope Water contacting the bottom is warmer than 12C. Cross frontal exchange of Shelf and Slope Waters is apparent in the 60-100 m depth range. Temperatures at the surface over the shelf and in the cold core bottom water are little changed from the end of September (section 13), although an advance in vertical mixing is shown by the 1C rise in bottom temperatures at the inshore end of the section.

Section 15. Soviet RV Belogorsk 75-3, 29-30 October.

Slope Water warmer than 12C contacts bottom on the outer shelf. A final remnant of the cold core water, with its minimum temperature elevated to nearly 12C, contacts the bottom in the vicinity of 80-m depth. Nearly complete vertical mixing on the shelf has produced maximum annual bottom temperatures: above 13C shoreward of the 60-m isobath and above 14C shoreward of the 40 m isobath.

Section 16. Federal Republic of Germany RV Anton Dohrn 75-1, 15 November.

Slope Water warmer than 12C contacts bottom on the outer shelf, and the remnant of cold core water in the previous section is no longer evident. Penetration of the Shelf Water at middepth by warm Slope Water (>14C) may be associated with the presence of a Gulf Stream warm core eddy (ACE 10, in Fig. 16.2) off the seaward end of the section. The 14C water contacting the bottom at depths of 60-70 m appears to be either a product of the Slope Water penetration or a remnant of the 14C Shelf Water that occupied the whole water column in late October in depths between 40 and 65 m (section 15). In the shoreward portion of the section, the isothermal Shelf Water is about 1C colder than in the previous section when it was at the annual maximum.

Section 17. University of Rhode Island RV Trident 175, 10 December.

A Gulf Stream warm core eddy (ACE 10, Fig. 16.2), passing south of New England when this section was made, provides a reasonable explanation for the isolated body of 16C water that lies at middepth over the outer shelf. The 15C bottom temperatures associated with this warm intrusion on the outer shelf were the maximum temperatures during the year, except for the questionable 17C in section 2. At the shoreward end of the section, the essentially isothermal Shelf Water is 2C colder than in the previous section (Section 16), made almost a month earlier.

Section 18. NOAA RV Albatross IV 74-14, 16-17 December.

The northern edge of a Gulf Stream warm core eddy (ACE 10, Fig. 16.2) appears in this section, and intrusion of water from this eddy onto the shelf is further advanced than in the previous section made a week earlier. (These two sections cross each other at a bottom depth of about 72 m). Toward the shoreward end of the section, the shelf water temperatures are about 1C colder than in the previous section.

BOTTOM TEMPERATURES IN 1975

Warmer than Long-Term Averages but Cooler than 1974

Comparison of Figures 16.3, 16.4, and 16.5 reveals that bottom temperatures on the continental shelf and upper slope south of New England in 1975 were, as in 1974, 1C-3C warmer than the averages for 1940-66, and yet tended to be cooler than in 1974. On the outer shelf, so far as the data show, warm Slope Water contacted the bottom continuously over varying depth ranges, maintaining maximum temperatures above 11C, and for most of the year, above 12C.

In some earlier years, as shown, for example, in 1965 and 1966 by Colton et al. (1968) and Colton (1968), westward penetration of Labrador Coastal Water along the southern edge of Georges Bank and outer shelf off southern New England completely displaced the warm Slope Water from the bottom and depressed the maximum bottom temperature, at depths greater than 100 m, to as low as 4C. No sign of this cold water off southern New England appears in the data for 1974 or 1975. Nevertheless, the bottom temperatures in 1975 were moderately cooler than in 1974.

In the zone of warm Slope Water contact on the outer shelf, the cooler conditions are shown by the lesser depth range of water warmer than 12C. Furthermore, the maximum temperature in this zone fell below 12C in March and August 1975, whereas during all of 1974 the temperature seems to have remained above 12C. The March 1975 temperature depression, however, would appear to have been a normal phenomenon, March being the time when temperatures on the outer shelf generally reach their annual minimum (Fig. 16.4). The anomalous event was, in fact, the absence of a temperature depression in March 1974 when a Gulf Stream warm core eddy was in prolonged proximity to the continental slope south of New England (Chamberlin 1976).

An anomalously warm body of water (>16C) (Figure 16.2), at 100 m in February, can only be explained as an injection of warm eddy water (ACE 5) or as erroneous XBT data (see discussion of section 2 in the previous part of this report).

In the cold core bottom water on the shoreward side of the Slope Water zone, the minimum temperature in 1975 was about 1C colder than in 1974 during each month from March, when the cold core formed, until late October, when it was dissipated by vertical mixing.

Inshore-Offshore Fluctuations of the Cold Core Water

Fluctuation in the depth of the cold core water at the bottom over a range of about 60 m is apparent in the bottom temperature diagrams for both 1974, 1975 (Figs. 16.2 and 16.3). These fluctuations, which, of course, represent inshore-offshore excursions of the cold core, are associated with, and perhaps partly driven by, near bottom intrusions and withdrawals of Slope Water on the outer shelf. An apparent breaking of the cold core by a strong Slope Water intrusion in July 1975 can be seen in Figure 16.2 where the minimum temperature of the core rises above and then falls below 8C. Synoptic water temperature surveys of the shelf off southern New England and the Middle Atlantic States have characteristically shown the cold core water to be a continuous band from south of Cape Cod to the offing of Chesapeake Bay (see fig. 87 in Whitcomb 1970). The rise and fall of temperatures in the cold core during July 1975 south of New England can, therefore, be interpreted as a temporary division of the core into eastern and western segments which, presumably, rejoined as the Slope Water intrusion abated. It is also reasonable to infer from the interruption and "recovery" of the cold core that the associated Slope Water intrusion was localized.

Boicourt and Hacker (1976), from studies on the shelf in the southern part of the Middle Atlantic Bight, described how southerly winds "can drive offshore motion in the upper Ekman layer, requiring subsurface return flow . . . of high salinity Slope Water . . . ." Westerly winds would create the analagous effect off southern New England. Chase (1959), using serial data from Atlantic Coast lightships, demonstrated that the cold core water at some stations could be driven offshore by the inshore accumulation of warm surface layer water, during periods of onshore wind. Beardsley and Flagg (1976) reviewed wind stress as well as other possible oceanographic mechanisms that may force subsurface flow of Slope Water onto the shelf. An additional mechanism not considered by them, but consistent with data presented here, is that subsurface inshore flow of Slope Water may occur in the wake of warm core eddies as a compensation for offshore surface entrainment of Shelf Water by these eddies.

ACKNOWLEDGMENTS

For supplying the data for the temperature sections, we thank: Marianna Pastuschak, Morski Instytut, Rybacki, Poland, for the sections from the _Wieczno_; I. V. Worthington, Woods Hole Oceanographic Institution, for the section from the _Knorr_; Charles W. Morgan, U.S. Coast Guard Oceanographic Unit, for the section from the _Evergreen_; S. R. Nickerson, Henry Jensen, and Ronald Schlitz, Northeast Fisheries Center, NMFS, for the eleven sections from the Anton Dohrn, Belogorsk, and Albatross IV; and S. K. Cook, Atlantic Environmental Group, NMFS, for the three sections from the Trident. Henry Jensen designed a southern New England XBT section, with closely spaced XBT's, for some of the Albatross IV cruises. In the Atlantic Environmental Group, J. J. Kosmark and R. W. Crist helped prepare the figures, and R. S. Armstrong gave valuable advice.

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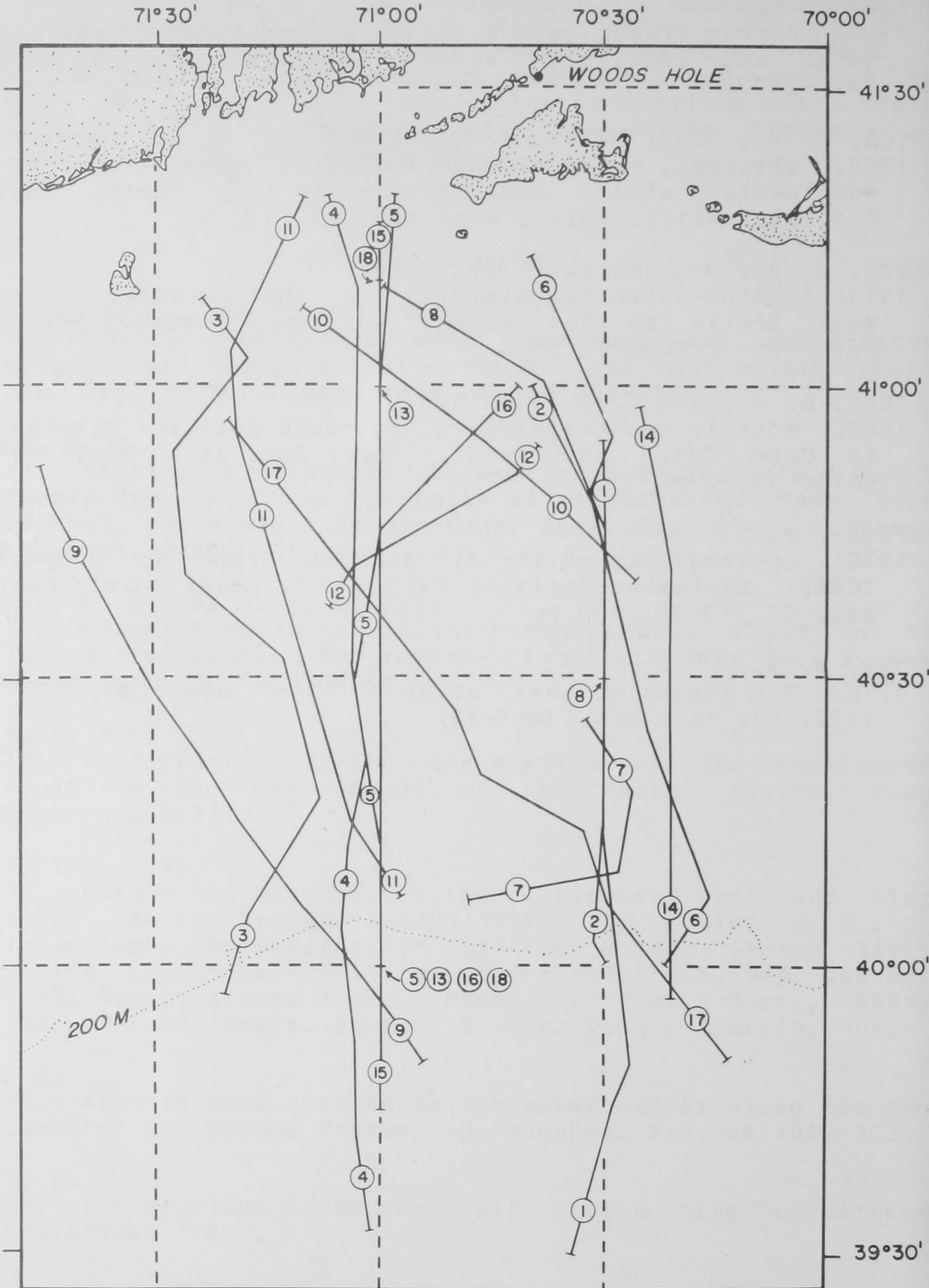


Figure 16.1.—Locations of vertical temperature sections included in this report. Sections numbered chronologically. See Appendix 16.1 for identification of sections.

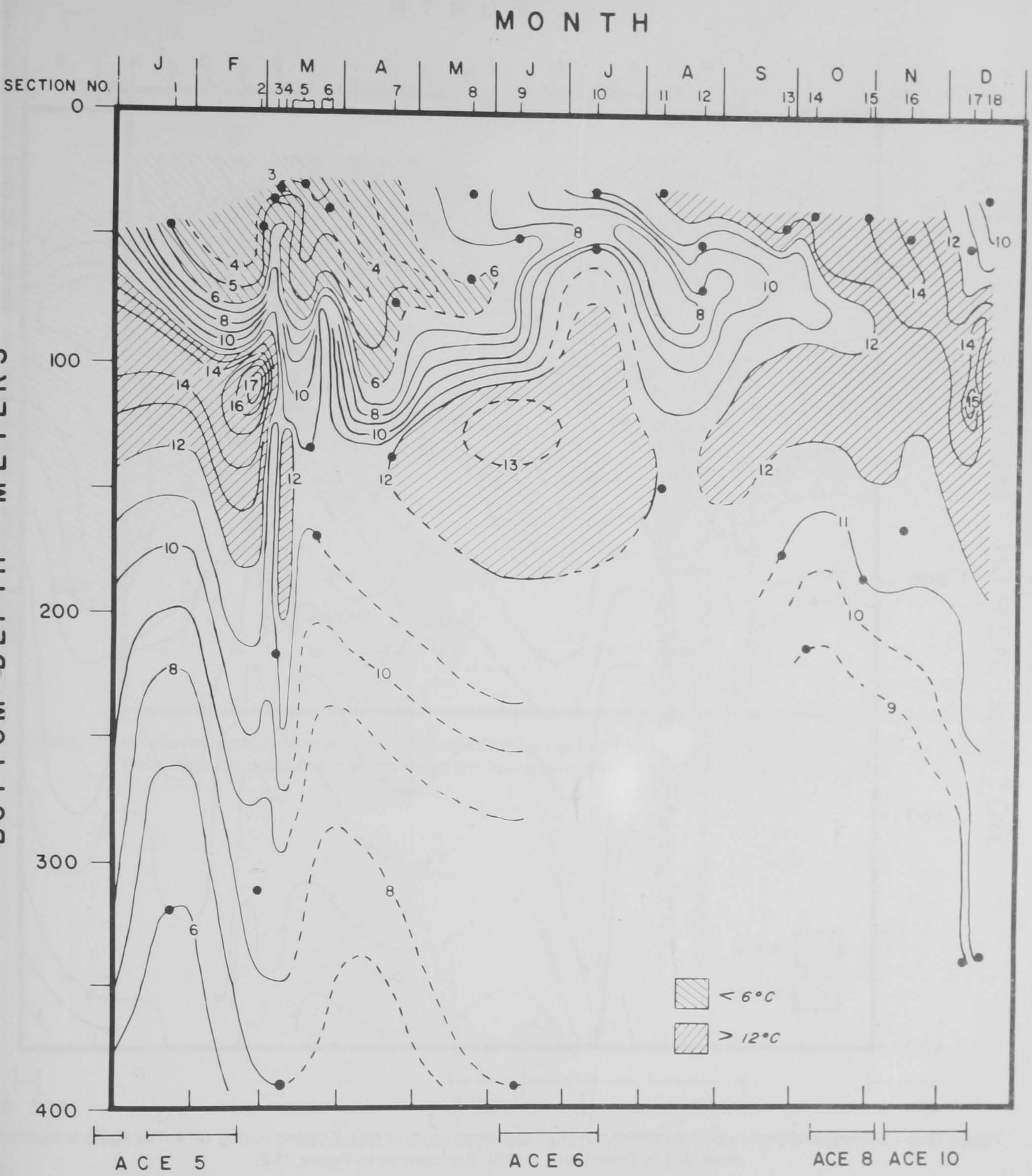


Figure 16.2.—Bottom temperatures on the continental shelf and slope south of New England during 1975. Temperature sections numbered along the top margin (see Appendix 16.1). Dots mark the depth limits of bottom data from each section. Horizontal lines at the bottom of the diagram indicate the times of Gulf Stream anticyclonic eddy (ACE) passages south of New England and are numbered after Bisagni (see text footnote 3).

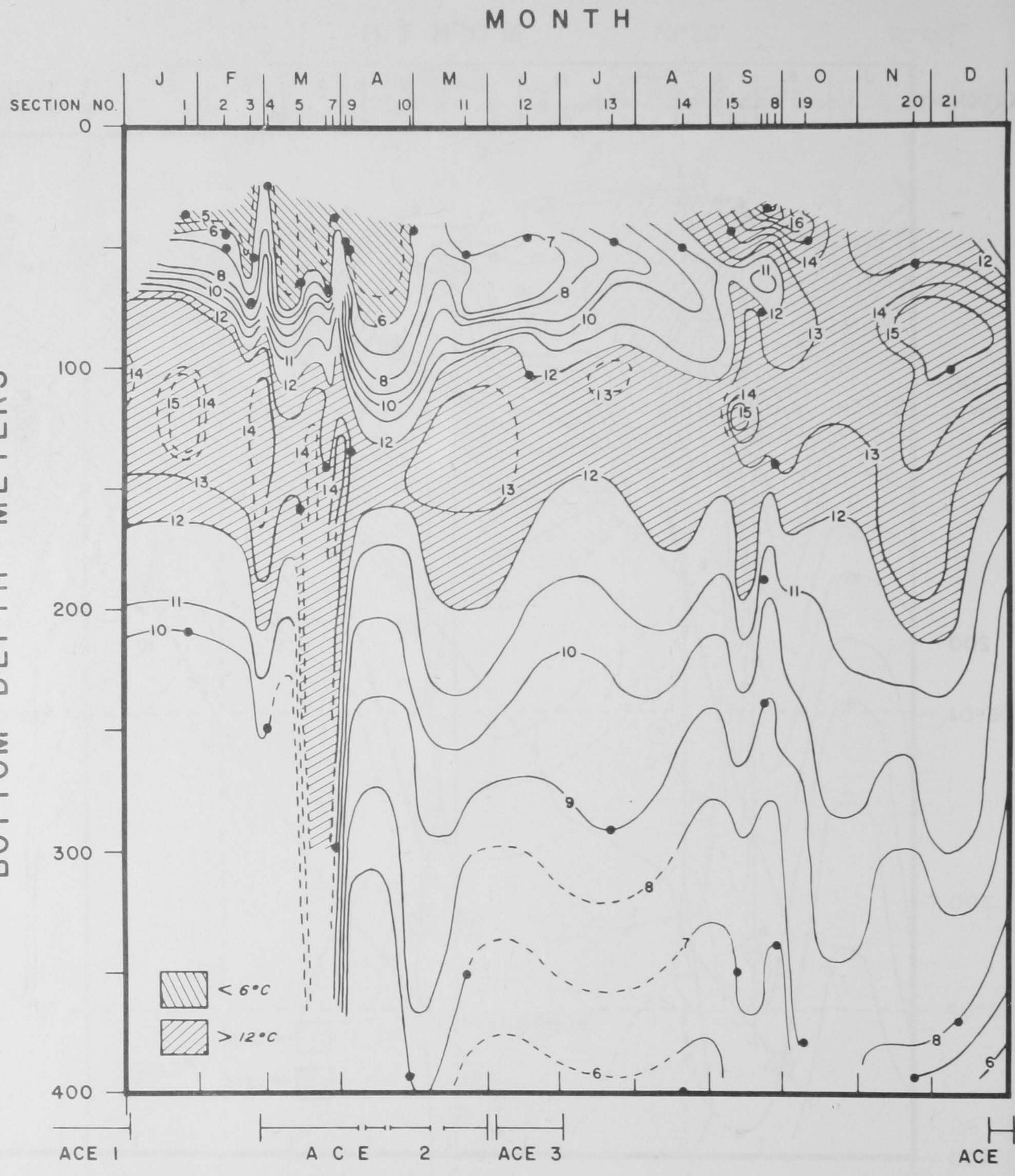


Figure 16.3.—Bottom temperature on the continental shelf and slope south of New England during 1974. The figure is modified from that in Chamberlin (1976). See caption to Figure 16.2.

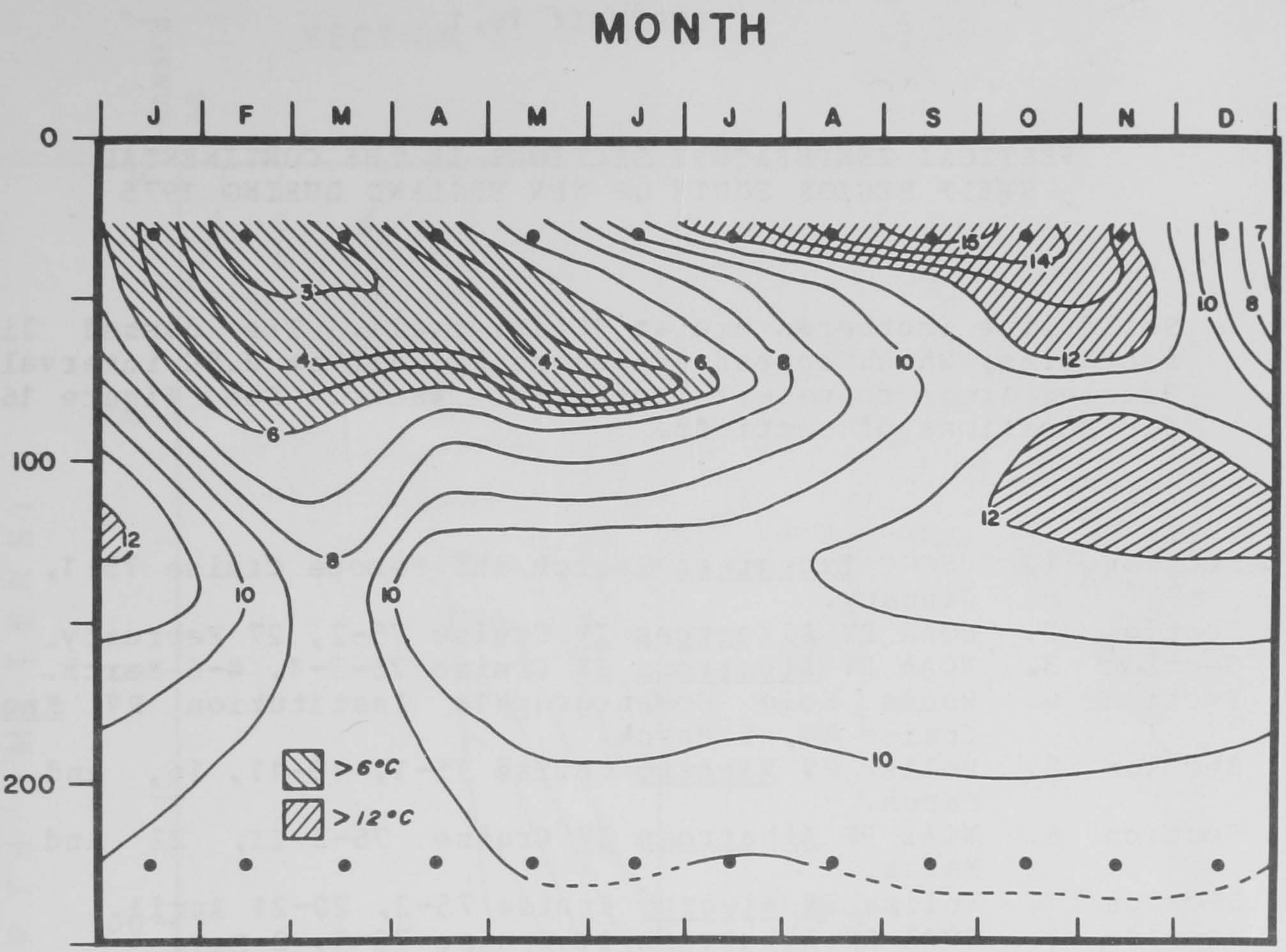


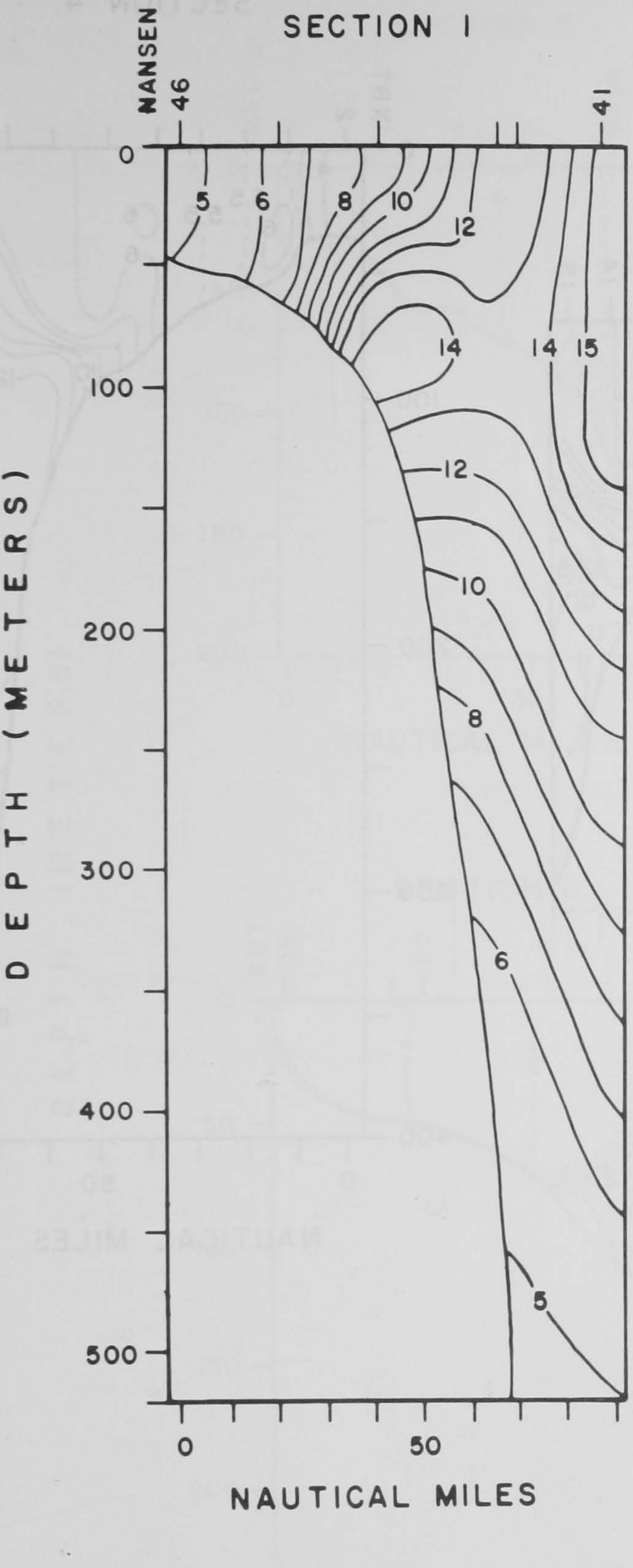
Figure 16.4.—Mean monthly bottom temperatures on the continental shelf and slope south of New England for the years 1940-66. Dots mark the depth limits of the data. The figure is modified from that in Chamberlin (1976).

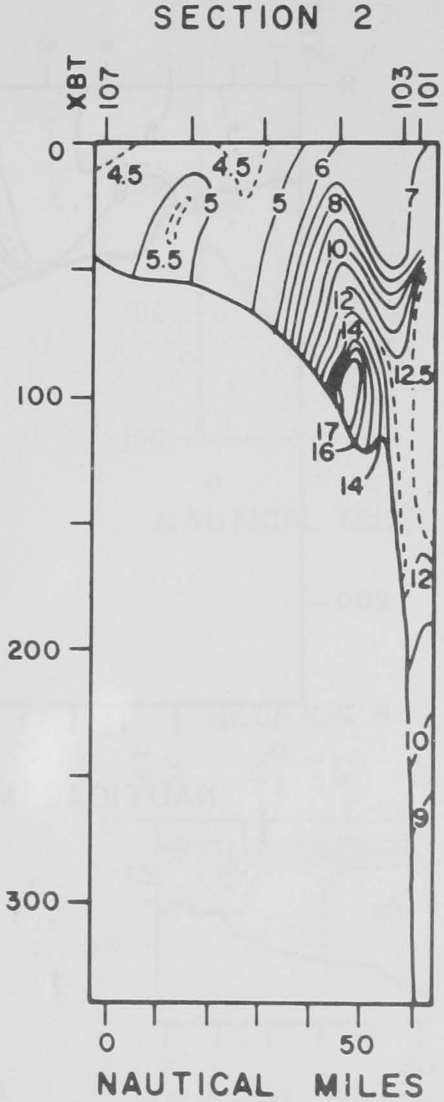
APPENDIX 16.1

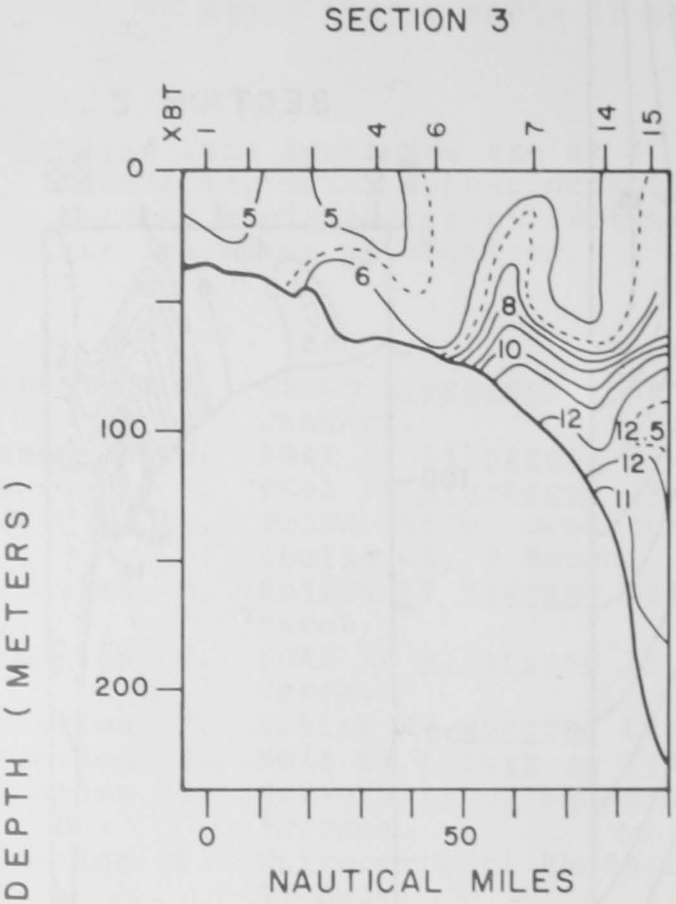
VERTICAL TEMPERATURE SECTIONS IN THE CONTINENTAL SHELF REGION SOUTH OF NEW ENGLAND DURING 1975

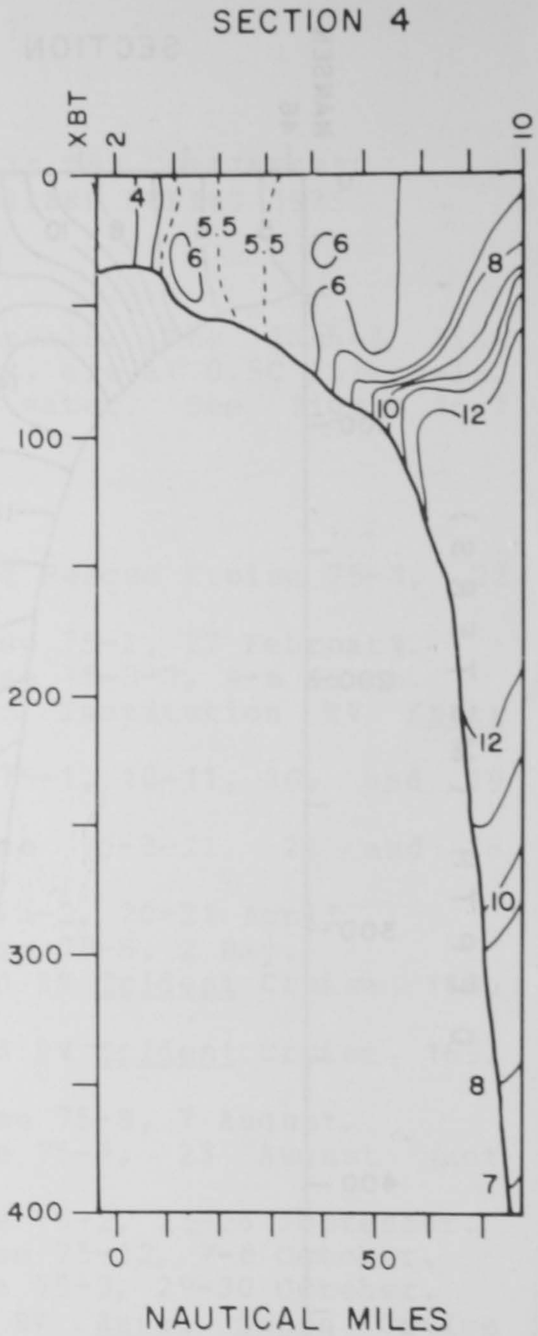
Solid line isotherms are at 1C intervals. The dashed line isotherms, which appear occasionally, are at 0.5C intervals. Hatched areas represent isothermal water. See Figure 16.1 for locations of sections.

Section 1. USCGC _Evergreen_ Search and Rescue Cruise 75-1, 22 January.
Section 2. NOAA RV _Albatross IV_ Cruise 75-2, 27 February.
Section 3. NOAA RV _Albatross IV_ Cruise 75-3-1, 4-6 March.
Section 4. Woods Hole Oceanographic Institution RV _Knorr_ Cruise 48, 9 March.
Section 5. Polish RV _Wieczno_ Cruise 75-1, 10-11, 16, and 19 March.
Section 6. NOAA RV _Albatross IV_ Cruise 75-3-II, 22 and 26 March.
Section 7. Polish RV _Wieczno_ Cruise 75-2, 20-21 April.
Section 8. NOAA RV _Albatross IV_ Cruise 75-5, 2 May.
Section 9. University of Rhode Island RV _Trident_ Cruise 168, 10 June.
Section 10. University of Rhode Island RV _Trident_ Cruise 169, 11 July.
Section 11. NOAA RV _Albatross IV_ Cruise 75-8, 7 August.
Section 12. Soviet RV _Belogorsk_ Cruise 75-1, 23 August (not drawn, see text).
Section 13. Soviet RV _Belogorsk_ Cruise 75-2, 25-26 September.
Section 14. NOAA RV _Albatross IV_ Cruise 75-12, 7-8 October.
Section 15. Soviet RV _Belogorsk_ Cruise 75-3, 29-30 October.
Section 16. German Federal Republic RV _Anton Dohrn_ Cruise 75-1, 15 November.
Section 17. University of Rhode Island RV _Trident_ Cruise 175, 10 December.
Section 18. NOAA RV _Albatross IV_ Cruise 75-14, 16-17 December.


SECTION 1
NANSEN
46
41
0
100
200
300
400
500
DEPTH (METERS)
5
6
8
10
12
14
14
15
12
10
8
6
5
0
50
NAUTICAL MILES


SECTION 2
XBT
107
103
101
0
100
200
300
4.5
4.5
5
5
5.5
6
8
10
12
14
7
12.5
17
16
14
12
10
9
0
50
NAUTICAL MILES


SECTION 3
XBT
1
4
6
7
14
15
DEPTH (METERS)
0
100
200
5
5
6
8
10
12
12.5
12
11
0
50
NAUTICAL MILES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XBT
2
10
0
100
200
300
400
4
5.5
5.5
6
6
6
8
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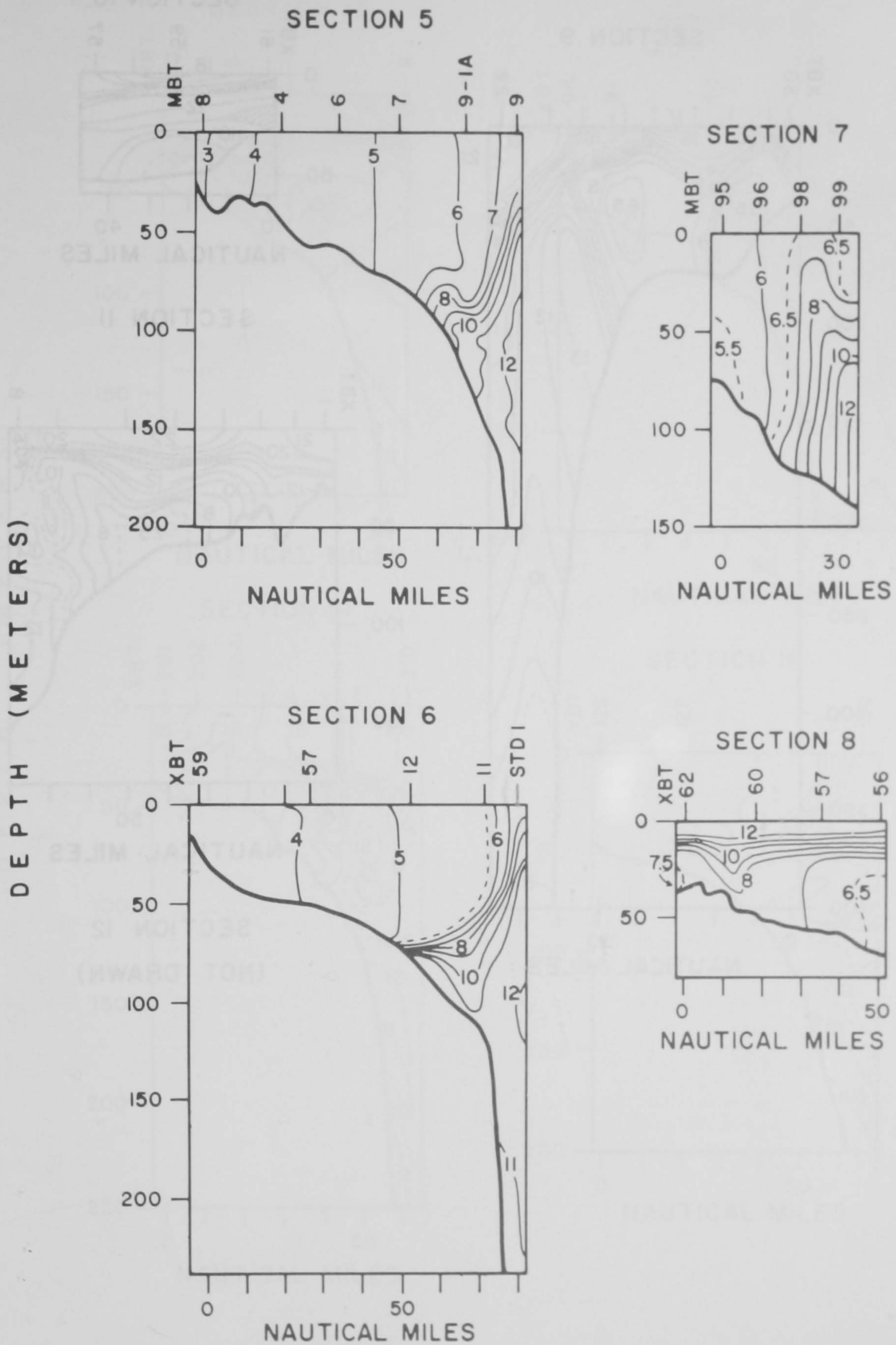
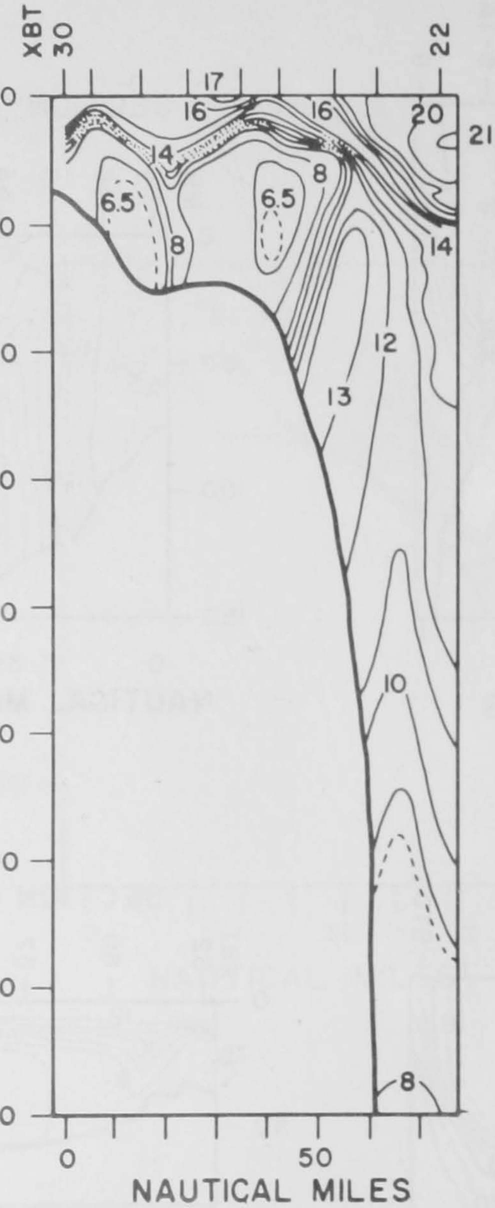
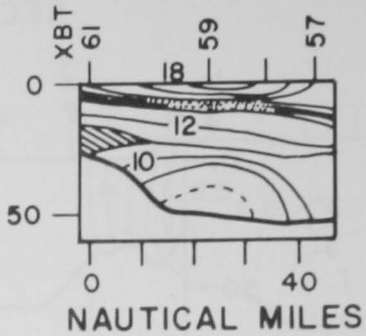
12
12
10
8
7
0
50
NAUTICAL MILES


SECTION 5
MBT
8
4
6
7
9-1A
9
0
50
100
150
200
3
4
5
6
7
8
10
12
0
50
NAUTICAL MILES
SECTION 7
MBT
95
96
98
99
0
50
100
150
6.5
6
8
6.5
5.5
10
12
0
30
NAUTICAL MILES
DEPTH (METERS)
SECTION 6
XBT
59
57
12
11
STD1
0
50
100
150
200
4
5
6
8
10
12
11
0
50
NAUTICAL MILES
SECTION 8
XBT
62
60
57
56
0
50
12
10
7.5
8
6.5
0
50
NAUTICAL MILES

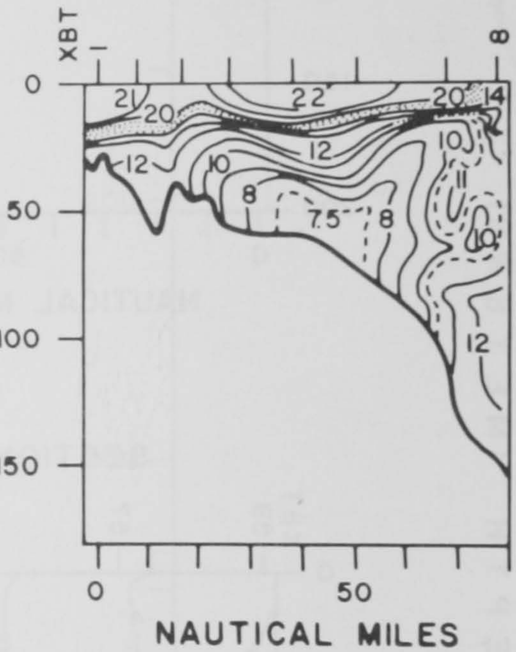
SECTION 9



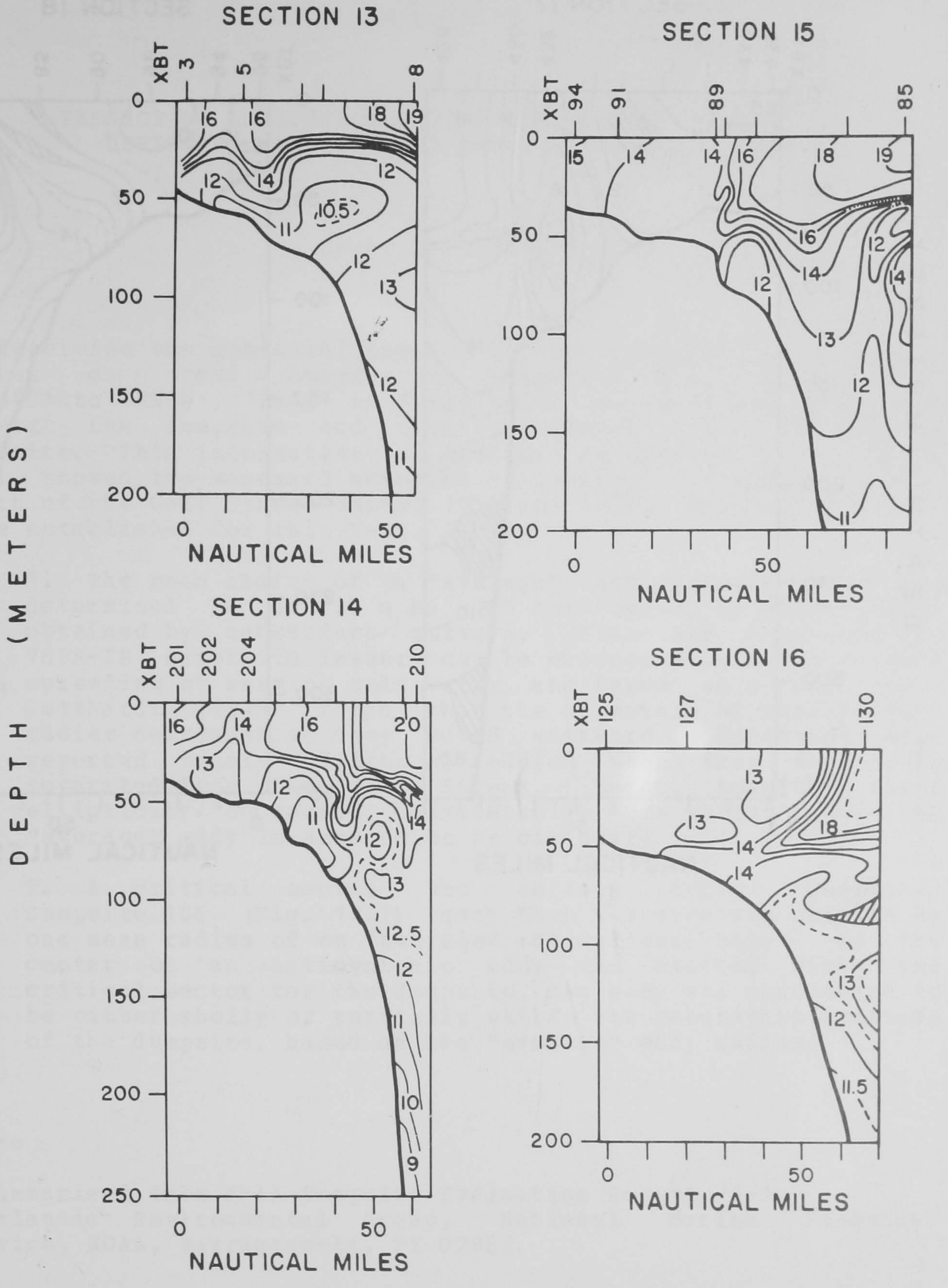
SECTION 10



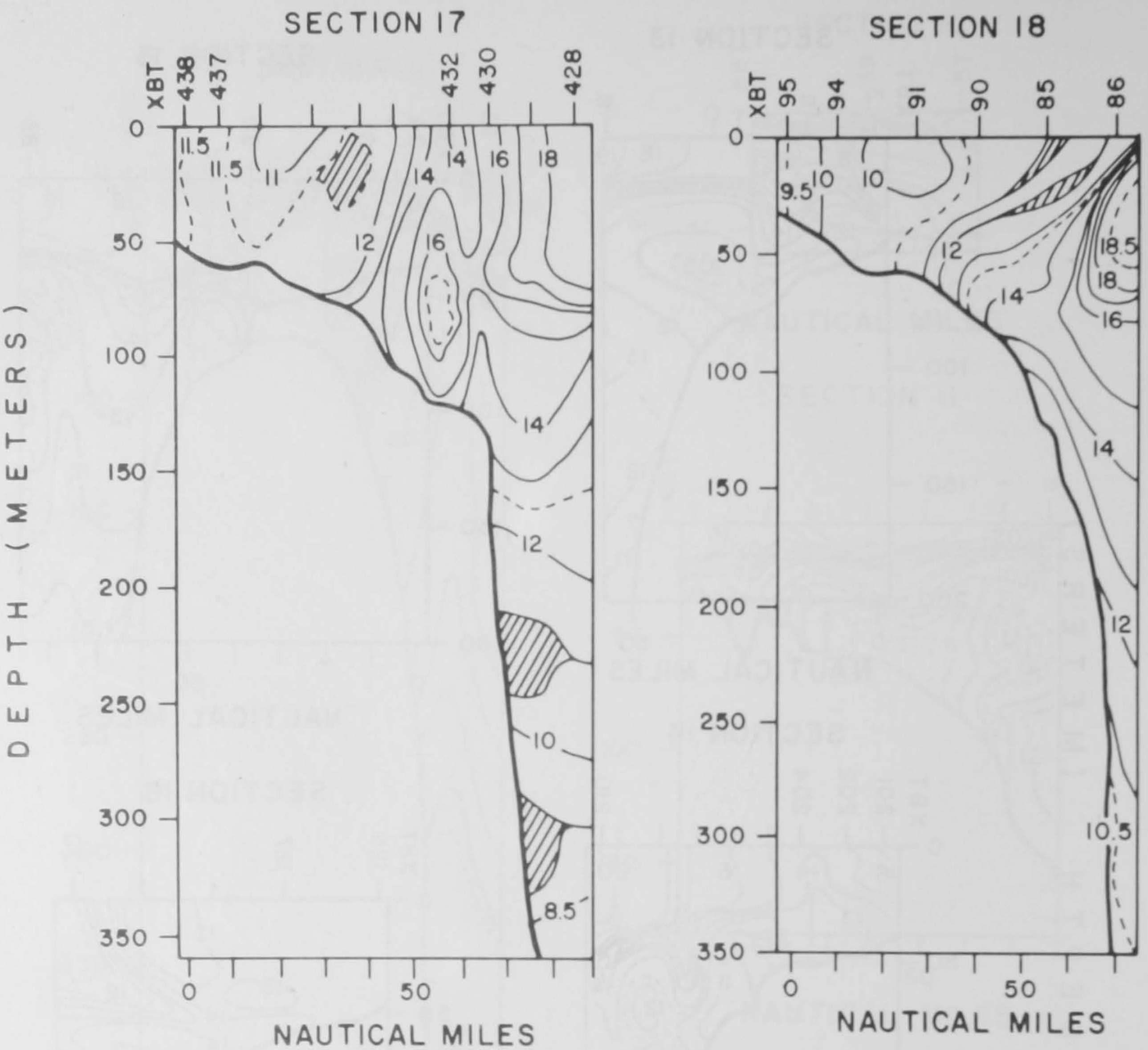
SECTION 11



SECTION 12
(NOT DRAWN)



SECTION 13
XBT
3
5
8
NAUTICAL MILES
SECTION 15
XBT
94
91
89
85
NAUTICAL MILES
SECTION 14
XBT
201
202
204
210
NAUTICAL MILES
SECTION 16
XBT
125
127
130
NAUTICAL MILES
DEPTH (METERS)



SECTION 17
XBT
438
437
432
430
428
DEPTH (METERS)
0
50
100
150
200
250
300
350
11.5
11.5
11
12
14
14
16
16
18
14
12
10
8.5
0
50
NAUTICAL MILES
SECTION 18
XBT
95
94
91
90
85
86
9.5
10
10
12
14
18.5
18
16
14
12
10.5
NAUTICAL MILES

Section 17

PASSAGE OF ANTICYCLONIC GULF STREAM EDDIES THROUGH DEEPWATER DUMPSITE 106 DURING 1974 AND 1975[1]

James J. Bisagni[2]

To determine the potential impact of anticyclonic Gulf Stream eddies on ocean dumping at Deepwater Dumpsite (DWD) 106 (38N40' to 39N00', 72W00' to 72W30'), we must know how often they affect the dumpsite and their residence times within the dumpsite. This information was obtained by plotting trajectories that showed the westward movement of anticyclonic eddies located north of the Gulf Stream during 1974 and 1975. Several criteria were established for this task.

1. The mean radius of an "average" anticyclonic eddy was determined to be 30 n mi (55 km) based on observations obtained by subsurface surveys. Diameters described by VHRR-IR satellite imagery can be erroneous owing to surface spreading of warm or cold water, and hence were not used. Gotthardt (1973) found that the diameters of anticyclonic eddies decreased as they moved westward. Gotthardt also reported highly elliptical eddies when they were newly separated from the Gulf Stream. Later, however, their ellipticity decreased considerably. In this report the "average" eddy is assumed to be circular.

2. A critical sector was defined around Deepwater Dumpsite 106 (Fig. 17.1) such that its area was defined by one mean radius of an "average" anticyclonic eddy. If the center of an anticyclonic eddy was plotted within the critical sector for the dumpsite, the eddy was considered to be either wholly or partially within the geographic confines of the dumpsite, based on the "average" eddy radius.

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[1]Summarized from NOAA Dumpsite Evaluation Report 76-1.
[2]Atlantic Environmental Group, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.

3. The portion of the anticyclonic eddy trajectory within the critical sector was used to determine the period of time that the dumpsite was either wholly or partially occupied by the eddy.

The above criteria made it possible to compute the amount of time individual eddies affected DWD 106, the total amount of time the dumpsite was affected by anticyclonic eddies during 1974 and 1975, and the average residence time of anticyclonic eddies within the dumpsite.

Using the mean anticyclonic eddy radius of 30 nm (55 km), an area within the generalized anticyclonic eddy trajectory envelope may be delineated (dark shaded portion of Fig. 17.1) about DWD 106. This area was used to calculate the amount of time each of the 13 anticyclonic eddies spent within DWD 106. Since the "average" anticyclonic eddy possessed a mean radius of 30 nm, the center of an eddy plotted within the critical sector would indicate that DWD 106 was wholly or partially occupied by that eddy. Using these spatial criteria, the period each of the 13 eddies spent within DWD 106 was determined (Fig. 17.2). Lifetimes of anticyclonic eddies vary by an order of magnitude from 22 days to 283 days and generally agree with Saunders' (1971) calculated lifetime of six months to one year based on heat loss and dissipation of kinetic energy considerations. The amount of time spent by an anticyclonic eddy within DWD 106 varied between 55 days and 0 days for eddies which either dissipated or were entrained into the Gulf Stream before reaching the DWD 106 sector.

The following calculations and results are summarized in Table 17.1. Of the total 1,683 eddy days (one eddy day is equivalent to one anticyclonic eddy existing for one day) shown in Table 17.1, 7.9% (133 days) were within DWD 106 as defined above. Viewed another way, during 1974 an anticyclonic eddy (as defined by the 15C isotherm at 200 m) was located within DWD 106 about 21.6% of the time. From 1 January through 31 October 1975, an anticyclonic eddy was located within DWD 106 approximately 17.8% of the time. The mean residence time for an anticyclonic eddy at DWD 106 during 1974 and part of 1975 was found to be on the order of 22 days.

Table 17.1.--Summary of calculations.

Total eddy days considered for 1974 and partial 1975:	1,683
Total eddy days spent in DWD 106 for 1974 and partial 1975:	133
Percentage of total eddy days spent in DWD 106 for 1974 and partial 1975:	7.9%
Percent of time in 1974 for which an anticyclonic eddy was wholly or partially within DWD 106:	21.6%
Percent of time in partial 1975 for which an anticyclonic eddy was wholly or partially within DWD 106:	17.8%
Mean residence time for an anticyclonic eddy at DWD 106:	22 days

CONCLUSIONS

This analysis should be interpreted as only preliminary because only 22 months of data were used. However, the calculations suggest that:

1. Three anticyclonic eddies may be expected to affect the dumpsite each year;

2. The average residence time for an eddy within the dumpsite is approximately 22 days; and

3. The dumpsite can be wholly or partially occupied by anticyclonic eddies about 20% of the time or about 70 days each year.

Although one or two years of data analysis represent only a beginning at characterizing the water mass types and circulation at Deepwater Dumpsite 106, it is clear that anticyclonic eddies have been a significant aspect of the physical environment at DWD 106 for the past two years.

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Editors' note: There were 771 eddy days in 1974 and 1,004 eddy days in 1975. A comparison of eddy days by quarter shows a significant increase in eddy days in the last half and especially in the last quarter of 1975. The total does not agree with that in Table 17.1 (1,775 vs. 1,683 eddy days) because the end of the counting period is different (17 December 1975 vs. 31 October 1975).

Table 17.2.--Comparison of eddy days in 1974 and 1975.

	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total
1974	190	229	233	119	771
1975	160	247	305	292	1004

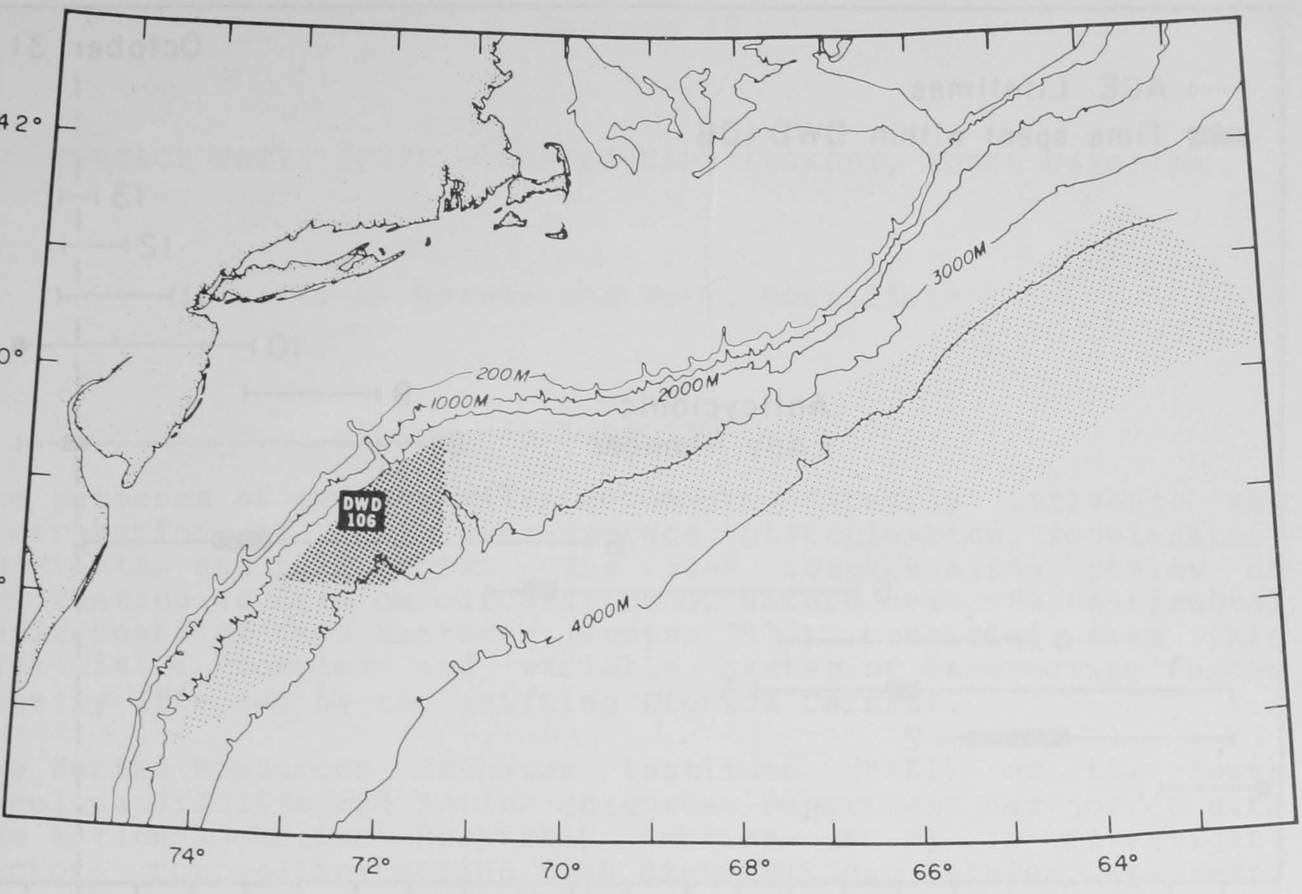

Figure 17.1.—Envelope for anticyclonic eddy trajectories (light shaded area) and critical sector about DWD 106 (dark shaded area).

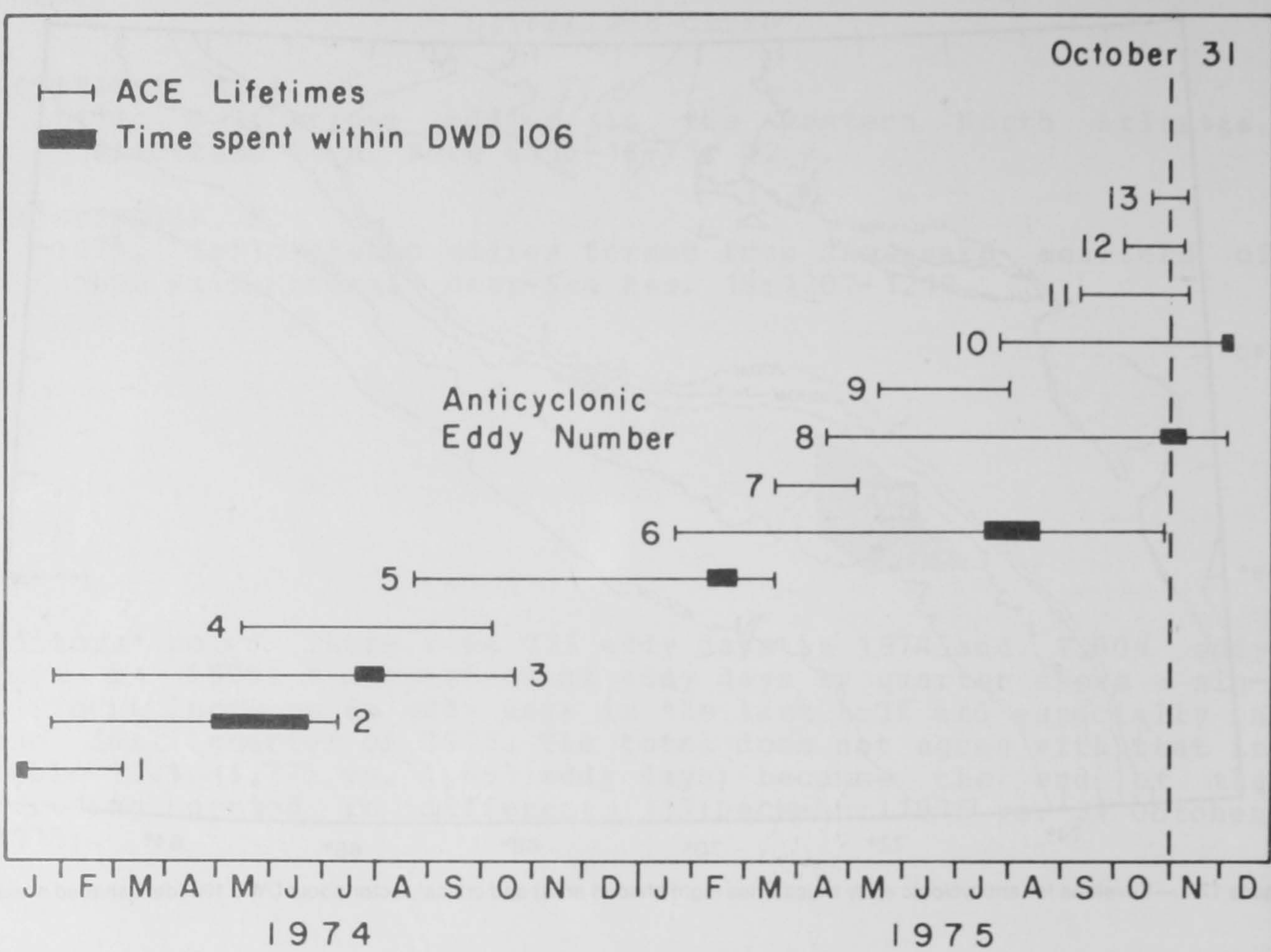

Figure 17.2.—Lifetimes for anticyclonic eddies 1-13.

Section 18

SURFACE WATER DRIFT SOUTH OF CAPE LOOKOUT, NORTH CAROLINA

C. A. Barans and W. A. Roumillat[1]

INTRODUCTION

The patterns of surface water movements directly influence the distribution of many near-surface phytoplankton, zooplankton, nutrients, and pollutants. The most comprehensive review of information to date on circulation of waters over the continental shelf south of Cape Hatteras (Bumpus 1973) concluded that this area is a complex and variable system of interacting forces greatly affected by the shifting Florida Current.

The Marine Resources Research Institute (MRRI) of the South Carolina Wildlife and Marine Resources Department has joined with the National Marine Fisheries Service (NMFS) to investigate factors controlling marine fish distributions between Cape Fear, NC, and Cape Canaveral, FL, as part of the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) Program. To accomplish this objective, MRRI has initiated several studies of the physical and chemical oceanographic conditions of this region in conjunction with major studies of ichthyoplankton and groundfish. The objective of this study was to further describe surface water movements south of Cape Lookout, NC.

METHODS

Drift bottles containing preaddressed return cards of the type described by Norcross and Stanley (1967) were released at a total of 272 stations (5 bottles per station). Primary releases (213 stations) were made between Cape Lookout, NC, and Charleston, SC, during four cruises of the RV Dolphin (September and November 1974; January and April 1975). Stations were located at 18.5-km intervals along 4 to 6 transects parallel to degrees of latitude. Drift bottles were also released at 51

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[1]Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, P.O. Box 12559, Charleston, SC 29412.

groundfish trawling stations between Cape Fear and Cape Canaveral during a cruise in September 1975. Bottles were dropped at eight stations on a single north-south transect through Onslow Bay during a cruise of the RV Palumbo in March 1975, in cooperation with the NMFS's Atlantic Estuarine Fisheries Center, Beaufort, NC.

An attempt was made to limit releases to surface waters inshore of the Florida Current, which was identified by its seasonal temperature and salinity characteristics. However, during the September 1975 cruise, some bottles were released in the Florida Current. Recoveries from most cruises were calculated on the basis of the total number of bottles released during the cruise; recoveries from the September 1975 cruise were calculated on the basis of releases inshore of the Florida Current.

At each station of each cruise, with the exception of the March cruise, a water temperature profile was made with an expendable or mechanical bathythermograph, and surface water temperatures and salinities were taken.

RESULTS

Total card recovery was 13.8% of the number of drift bottles released; the greatest part of the recovery (12.1%) was from bottles released in September, both in 1974 and 1975. The fewest returns were from releases during November 1974.

During September 1974 and 1975, many cards were recovered in northern Florida (Figs. 18.1, 18.2) from bottles released south of Frying Pan Shoals (the submarine projection of Cape Fear). Release sites during 1975 ranged over a greater shelf area and corresponded to recoveries over a large segment of the southeastern coastline (Fig. 18.2), while a release area north of Charleston in September 1974 resulted in recoveries concentrated only in northern Florida (Fig. 18.1). In September 1974, there were no returns from bottles released north of Frying Pan Shoals, while in September 1975, two returns were obtained north of the Shoals (Table 18.1). During September 1975, bottles released north of Frying Pan Shoals generally were recovered northeast of the release point, while those released immediately south of this physiographic feature were recovered to the northwest (Fig. 18.2).

Return locations from the few bottles released in or at the edge of the Florida Current during September 1975, were variable in direction. From one station approximately 115 km due east of Charleston at the edge of the Florida Current, two bottles were recovered in opposite directions. One bottle was recovered just south of Cape Hatteras in 23 days and the other just south of Jacksonville in 64 days at approximately equal distances (376-384 km) from the release point. A single recovery from a release about 59 km due east of the above station (completely under the influence of the Florida Current) also was made just north of Cape Canaveral. A nearshore release within the waters of the Florida Current just north of Cape Canaveral resulted in a northward movement (98 km) and recovery of two bottles.

In November, there were no returns from bottles released south of Frying Pan Shoals, and only a single return north of a release position north of the Shoals. In January, returns were similar to those in November. In March, releases were confined to Onslow Bay, a body of water insulated by Capes Fear and Lookout, with returns limited to only north of release sites. In April, card returns from releases north of Frying Pan Shoals were primarily northeast of release positions, while releases south of Frying Pan Shoals were recovered northwest of release positions.

Current speeds were calculated using the first recovery date from each release station (Table 18.1). Calculated rates of surface water movement south of Frying Pan Shoals ranged from 1.5 km/day in April to 11.3 km/day in September, while inferred rates north of the Shoals ranged from 2.4 km/day in November to 12.7 km/day in April. Pronounced differences existed in card recoveries and monthly calculated current speeds (Table 18.1) for drift bottles released north and south of Frying Pan Shoals.

DISCUSSION

The relatively short duration between release and recovery (1-134 days) of bottles during this study suggests transportation by waters inshore of the influence of the Florida Current. Complete lack of returns within a short period indicates entrainment of bottles and surface waters by the northerly current and removal from the nearshore system or, less likely, total loss of bottles stranded in marshlands along the coast. Bumpus (1955) reported returns from bottles transported from waters off North Carolina by the Gulf Stream ranging from 218 days (from the Azores) to 891 days (from England). During all months except September 1975 recovery of bottles suggests a sharp boundary between the waters of the Florida Current and inner shelf. Several returns from releases in September 1975 in or at the edge of the Florida Current were recovered at much later dates than releases further inshore and, therfore, appear to have been temporarily transported within the northerly current prior to release within the southerly surface system of the inner shelf.

Inferred water movements indicate the importance of Frying Pan Shoals, which extend almost across the whole shelf, for the circulation patterns of this area. The influence of the Shoals area appears especially pronounced during September (Fig. 18.7), when the southerly counter-current dominates the inshore water circulation. Card returns from September releases suggest that the southerly surface water movements may initiate just south of Cape Fear and dissipate north of Cape Canaveral. Atkinson and Jaffe[2] have demonstrated the relationship between the presence of a strong geostrophic force and the strong southerly drift observed inshore during September in this study and previously by Bumpus (1955) and Bumpus and Chase (1964). Bumpus (1973) stated that the highly variable nature of the surface drift in the South Atlantic Bight is due to the interplay of a geostrophic current with southerly influence and the Florida Current with northerly influence.

Limited returns during November, January, and April appear to indicate a weak northerly surface water movement nearshore, especially in Onslow Bay, and suggest entrainment of surface waters over most of the shelf with the northerly-moving Florida Current system. The observed drift directions of bottles released south of the Shoals in April concur with recent findings (see footnote 2) for releases south of Charleston, SC. We found no correlation between estimates of monthly average Ekman transport values (Gunn, Section 13; Ingham 1976) and the direction of inferred surface water drift. Northerly returns within Onslow Bay could reflect slow northerly movement within nearshore surface waters (Bumpus 1955; Bumpus and Lauzier 1965; Stefansson et al. 1971) or more rapid transport within the counterclockwise eddy indicated by results of Stefansson and Atkinson (1967).

The average calculated speed for the northerly surface drift in Onslow Bay during April (12.7 km/day) was significantly greater than that previously reported by Bumpus (1973) during this time of year (5.6-7.4 km/day). The average current speeds calculated for northerly and southerly drift during other months agree with Bumpus (1973).

Additional surface and midwater current studies are in progress in Onslow Bay by NMFS at Beaufort, NC, and south of Charleston by Skidaway Institute of Oceanography and the University of Miami. These should increase our understanding of the circulation patterns over the continental shelf south of Cape Hatteras.

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[2]Atkinson, L. P., and L. Jaffee. Drift bottle returns from four cruises in the Georgia Bight and relationship to the density and wind field. Skidaway Inst. Oceanogr., Savannah, GA 31406. MS.

ACKNOWLEDGMENTS

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Table 18.1.--Drift bottle recovery relative to release north or south of Frying Pan Shoals.

- = No Releases; NR = No Recoveries

	Average Direction From Release		Average Distance From Release (Km)		Average Speed Km/day		Recovery as % of Total Release Each Cruise	
	North	South	North	South	North	South	North	South
September 74	NR	210°	NR	489	NR	11.4	NR	18.1
November 74	063°	NR	100	NR	2.4	NR	0.3	NR
January 75	068°	NR	46	NR	3.1	NR	1.1	NR
March[1] 75	005°	-	14	-	2.9	-	22.5	-
April 75	060°	350°	102	33	12.7	1.5	0.7	3.3
September 75	024°	201°[2]	77	204[2]	3.3	6.6[2]	0.0^+	43.1

[1] Releases only in Onslow Bay; 8 stations.

[2] Calculation does not include returns from 2 stations directly south of Frying Pan Shoals, bottles of which were recovered northwest of release positions.

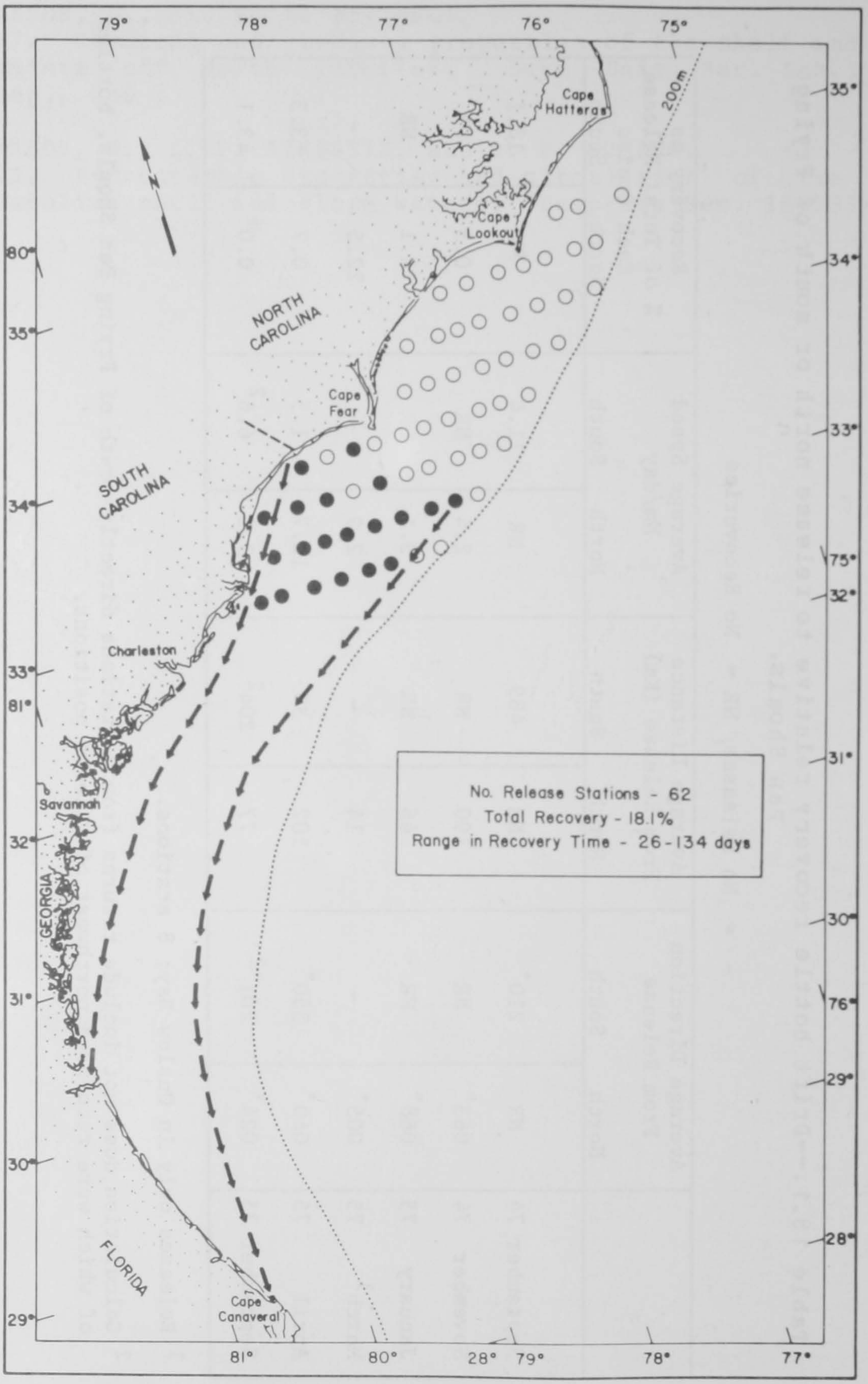

Figure 18.1.—Drift bottle cruise 15-18 September 1974.

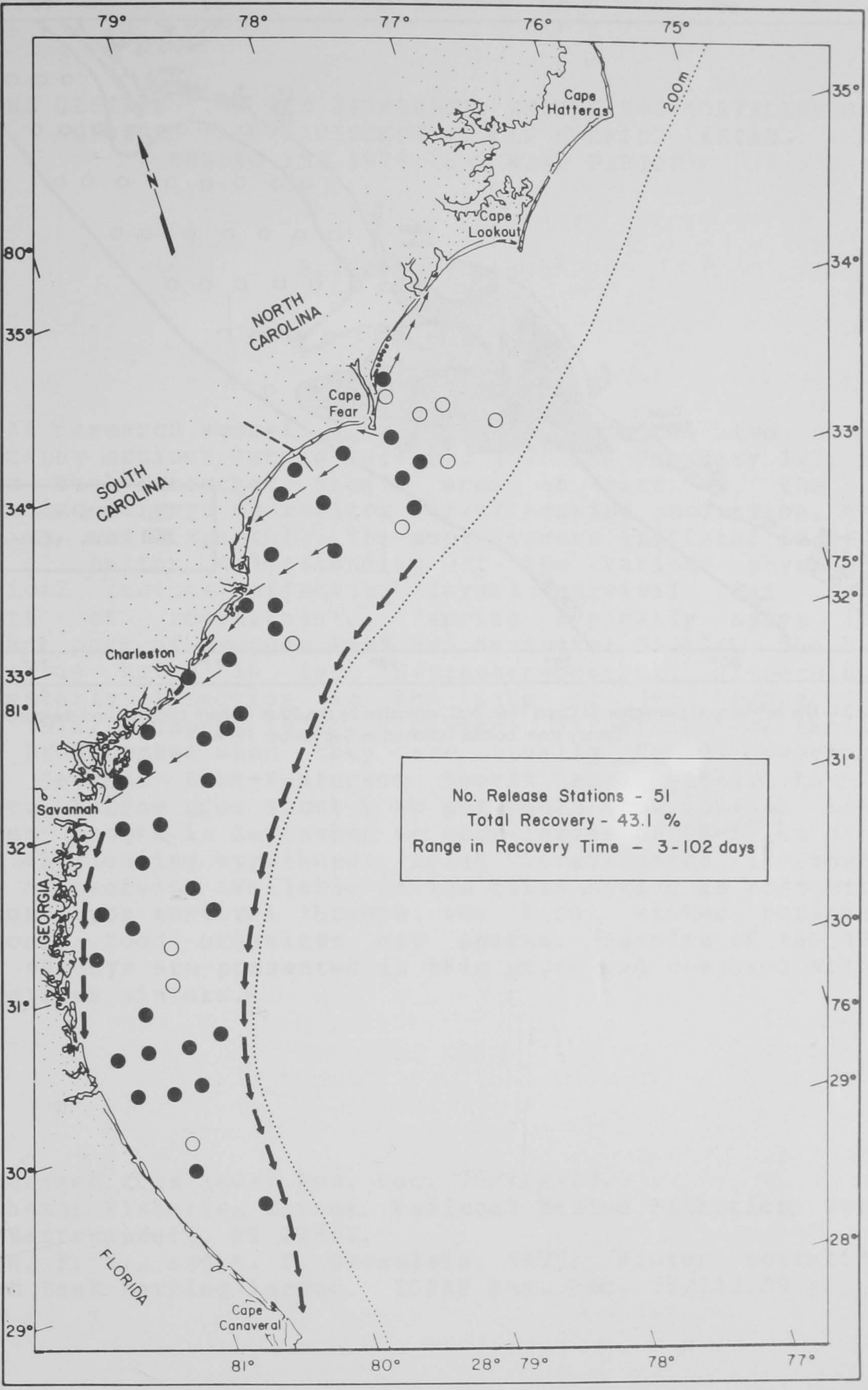

Figure 18.2.—Drift bottle cruise 31 August-19 September 1975.

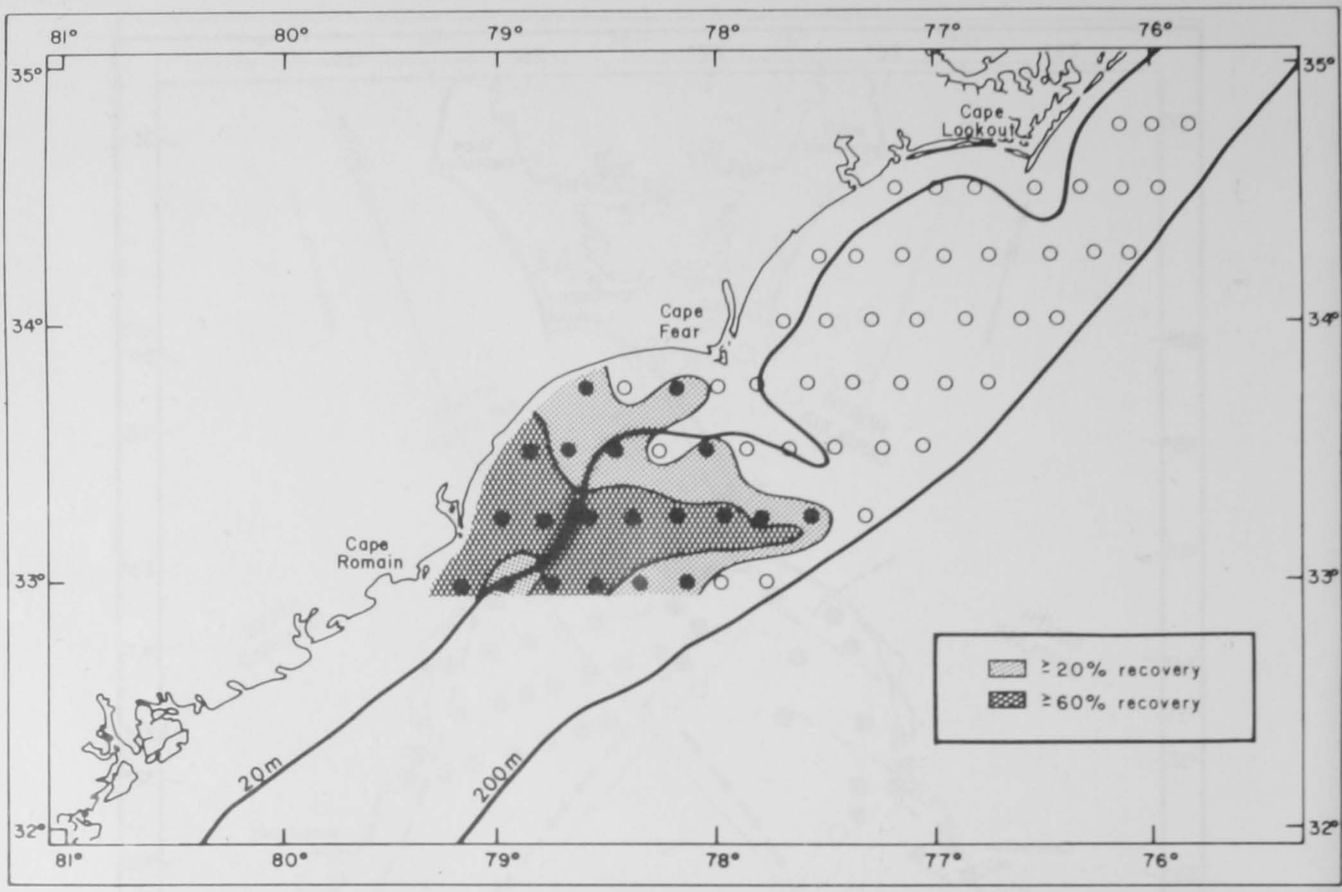

Figure 18.3.—The submerged projection of Cape Fear, N.C. indicated by the 20-m isobath contour, and the percent of drift recovery from bottles released in September 1974.

THE DISTRIBUTION AND ABUNDANCE, GROWTH, AND MORTALITY OF GEORGES BANK-NANTUCKET SHOALS HERRING LARVAE DURING THE 1975-76 WINTER PERIOD[1]

R. Gregory Lough[2]

INTRODUCTION

The NOAA research vessel Albatross IV conducted two plankton-hydrography cruises during December 1975 and February 1976 in the Georges Bank-Nantucket Shoals area as part of the ICNAF cooperative surveys to monitor larval herring production, growth, mortality, and dispersal. The surveys were initiated in 1971 to gain a better understanding of the various physical and biological factors affecting larval survival and relative strength of recruitment. Herring typically spawn in the northeast part of Georges Bank and Nantucket Shoals. The bulk of the larvae hatch in late September-October, dispersing in a southwesterly direction at the rate of 1-5 m/day (Boyar et al. 1973, Bumpus 1976). Maximum dispersion of the larvae occurs by December when they are usually found covering the entire Georges Bank-Nantucket Shoals area within the 100-m contour. Larvae grow about 5 mm per month from initial hatching at 6-mm length in September to post-larvae of 50-55 mm by June. One of the leading hypotheses being investigated is that the number of recruits available in the third spring is most strongly dependent upon survival through the first winter period when planktonic food organisms are sparse. Results of the 1975-76 winter surveys are presented in this paper and compared with the two previous winters.[3]

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[1]Summarized from ICNAF Res. Doc. 76/VI/[illegible]

[2]Northeast Fisheries Center, National [illegible] NOAA, Narragansett, RI 02882.

[3]Lough, R. G., and M. D. Grosslein, [illegible] Georges Bank herring larvae. ICNAF [illegible]

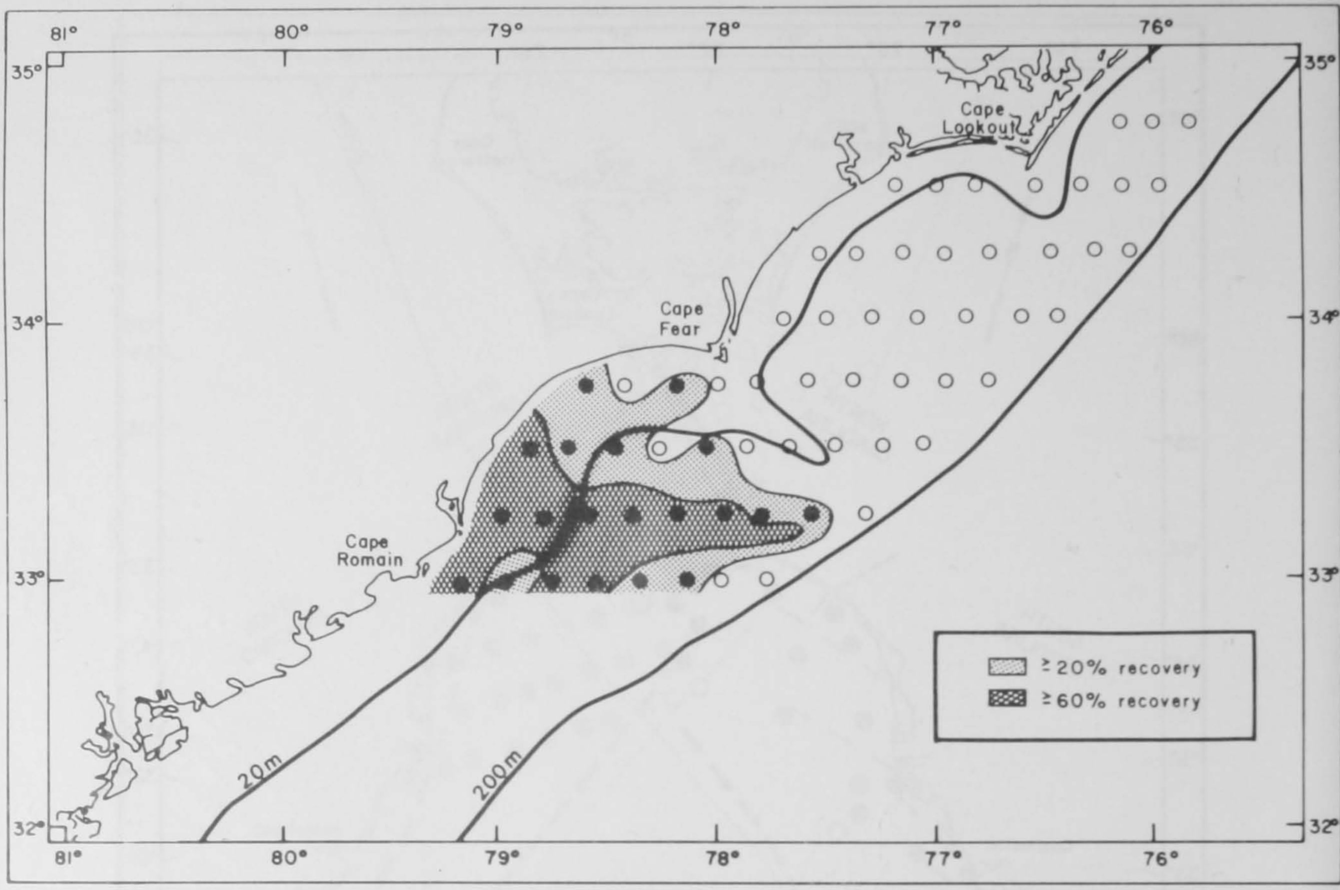

Figure 18.3.—The submerged projection of Cape Fear, N.C. indicated by the 20-m isobath contour, and the percent of drift recovery from bottles released in September 1974.

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[1]Summarized from INCAF Res. Doc. 76/VI/123.

[2]Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.

[3]Lough, R. G., and M. D. Grosslein. 1975. Winter mortality of Georges Bank herring larvae. ICNAF Res. Doc. 75/113:39 p.

RESULTS

Sampling on Georges Bank-Nantucket Shoals proceeded from east to west for both cruises. The December plots of herring larvae per 10 sq m (Figs. 19.1-19.3) show most catches of herring larvae within the 100-m contour area but distributed more on the central-northern edge of Georges Bank and Nantucket Shoals. The westernmost distribution of larvae was not delimited by this cruise. Densities of larvae typically were 10-100/10 sq m (Fig. 19.3). Highest densities occurred along the northern part of Georges Bank and the northern Nantucket Shoals area. Some recently hatched larvae (<10 mm) were observed on a few stations in the northeast Georges Bank and Great South Channel area. Smaller size larvae of 10-15 mm (Fig. 19.2) were distributed more in the Nantucket Shoals area than on Georges Bank.

Larval catches by February 1976 (Fig. 19.4) appeared to be consolidated into three main areas within the 100-m contour: 1) northeast central part of Georges Bank, 2) southwest central Georges Bank-Great South Channel, and 3) a small pocket south of Martha's Vineyard. Few larvae appeared outside the 100-m contour. The western distribution of larvae was clearly defined by the February survey. Densities of larvae generally were lower than in December; however, two stations in the northeast part of Georges Bank had 203 and 507 larvae/10 sq m.

The December 1975 and February 1976 larval length-frequency distributions for Nantucket Shoals and Georges Bank are shown in Figures 19.5 and 19.6. Two length modes appeared during December in the Nantucket Shoals area, 9-15 mm and 16-22 mm, whereas the Georges Bank population had one dominant length mode of 13-24 mm. Mean lengths for the Nantucket Shoals and Georges Bank larval populations were 16.2 mm and 17.4 mm respectively. By February 1976 the larval length means had increased to 30.5 mm for the Nantucket Shoals population and to 31.3 mm for the Georges Bank population. A single broad modal length was observed for the larval population in each area. The three subpopulations of larvae observed during February 1976 were analyzed further for differences among their length-frequency distributions. The small numbers of larvae in the Nantucket Shoals population had a mean length of 1-2 mm greater than the populations in southwest Georges Bank-Great South Channel and northeast Georges Bank. There was no significant difference between the length-frequency populations for northeast Georges Bank and southwest Georges Bank-Great South Channel. A significant difference at the 10% probability level was calculated between the northeast Georges Bank and the Nantucket Shoals population length frequencies, and a significant difference at the 1% level was found between southwest Georges Bank-Great South Channel and Nantucket Shoals length frequencies. The small number of large larvae just south of Martha's Vineyard may indicate a shoreward migration of older larvae in the Nantucket Shoals area.

Larval abundance, mortality, and growth estimates for Georges Bank and Nantucket Shoals areas during December 1975 and February 1976 and the two previous winters are given in Table 19.1. Georges Bank larval abundance in December 1975 was considerably lower (1,120) than for the previous two years (7,410 and 5,076 in 1974 and 1973, respectively), however, the February abundance estimates were similar for all three years (range 406-506). A corresponding change was observed for estimates of mortality, growth, and mean length. Mortality rate decreased from 3.93%/day, December 1973-February 1974, to 1.27%/day, December 1975-February 1976. Larval mean length was greater for each successive December with a considerable increase in mean length by February each year. The same trends in larval mortality and growth rates were shown for the Georges Bank and Nantucket Shoals total; when mortality was low, growth was high, and the converse. The Nantucket Shoals area mortality and growth estimates were somewhat more inconsistent, reflective of the fewer numbers of larvae collected. For instance, the December 1973-February 1974 mortality and growth rates are at variance with the same estimates from the Georges Bank and combined areas. Very few larvae were collected in the Nantucket Shoals area during February 1974.

Water temperatures of 9-11C predominated over the Georges Bank-Nantucket Shoals area during December 1975 (Figs. 19.7-19.9) and 5-6C during February 1976 (Figs. 19.10-19.12). Mean temperatures and other statistics at various levels on Georges Bank and Nantucket Shoals during December 1975 and February 1976 are given in Table 19.2. Temperatures generally increase with depth and seaward of the 100-m depth contour along the southern part of the bank in the area of the warm Slope Water front. Georges Bank mean temperatures (0-50 m) during December and February 1975-76 were the same as the previous year, 1974-75; however, temperatures during the same months in 1973-74 were about 0.5C warmer (Table 19.1). Nantucket Shoals mean temperatures (0-50 m) were similar to those of Georges Bank except that they were about 1C warmer during December. Also, no significant trends were apparent in the mean temperatures from September through December of 1975 compared with the previous year, 1974. On the other hand, Davis (Section 14) found mean October bottom temperatures on Georges Bank to be similarly high for 1973 and 1974 ($\underline{X}$ = 13.4 and 13.2C, respectively), but more than a degree lower ($\underline{X}$ = 12.1) for 1975. It is interesting to note from Davis's study that the eastern part of Georges Bank is always several degrees colder during the fall than the central and western parts even though the yearly temperature trends are similar for all three parts.

DISCUSSION

The distribution of larvae on Georges Bank and Nantucket Shoals was very similar during December 1973 and 1974 (see footnote 3). Uniformly high catches of larvae were observed within the 100-m bottom contour. Larval abundance also was similar for both years. During December 1975, however, the distribution of larvae was markedly different; the population was centered in the northern part of the Great South Channel and along the northern half of Georges Bank. Also, abundance of larvae was reduced compared to the previous two Decembers. No larvae were found beyond the southern 100-m contour in December 1975 as were observed during 1973 and 1974. Larvae observed along the southern boundary would indicate some offshore dispersal of larvae into Slope Waters.

Larval abundance and distribution during February was broadly similar for all three years, 1974-76; the bulk of the larval populations usually is located in a more restricted area in the central part of southwest Georges Bank extending across the Great South Channel into Nantucket Shoals. However, the February 1976 distribution was unusual in that three separate concentrations of larvae were observed; high densities of larvae were collected in the northeast part of Georges Bank in addition to the central part. It appears that the center of the larval population in December 1975 moved to a more southerly position by February 1976. The limited hydrographic data on temperature for these two surveys does not show any evidence for a southerly current transport. A southerly flow of surface waters is suggested for the Georges Bank area during the winter months with a westerly component across the Great South Channel (Bumpus and Lauzier 1965). Surface drift during the fall and winter months is different from the clockwise circulation observed for the other seasons and may respond more to short-term wind effects. Results from past ICNAF Larval Herring Surveys show that advection of larvae is principally southwest and that the larvae are retained in the Georges Bank-Nantucket Shoals area (Bumpus 1976). Recent observations of interest this past season are the occurrence in Georges Bank-Nantucket Shoals of large numbers of the colonial siphonophore, Nanomia cara, a cold-water form found in the Gulf of Maine, but rarely below Cape Cod (Rogers, Section 20). Their southerly occurrence on Georges Bank during fall 1975 corresponds with the more southerly movement of herring larvae. These changes in the distribution of animal populations suggest changes in circulation patterns in the study area that may result in potentially different prey-predator interactions. Their impact on the larval herring population still needs to be assessed.

Size and growth rates of the Georges Bank-Nantucket Shoals herring larvae are indicators of the population's physiolcgical condition and are closely linked to mortality rates. According to recent theoretical models by Jones and Hall (1974), Cushing (1973, 1974, 1975), and Ware (1975), mortality and growth during larval life are believed to be a density-dependent process regulated by the availability of food. If food is abundant, larvae are able to grow rapidly through a succession of decreasing predatory fields, thereby reducing their mortality. The three winters of Georges Bank-Nantucket Shoals larval herring data presented here also suggest that density-dependent growth and mortality have occurred. A decrease in larval abundance was associated with an increase in growth rate and a decrease in mortality rate. According to Ware's (1975) theoretical model based on larval studies of plaice, haddock, and mackerel, larval growth exceeds mortality (M = 0.7G) under average conditions. Only the 1975-76 winter growth rate exceeded the mortality rate for Georges Bank-Nantucket Shoals herring larvae. More refined estimates of growth and mortality will be made in the future, but the following considerations must be taken into account when one attempts to relate field estimates of population parameters with theoretical models:

1. Winter growth and mortality rates for Georges Bank-Nantucket Shoals herring larvae are estimated for a relatively short period and may well vary at other periods or from the average condition for the entire larval life. Growth was assumed to be an exponential curve but this may not necessarily be true during the winter period. Also, the length to weight regression was based on samples combined over four years; this relationship varies from year to year depending on condition of the larvae.

2. The low mortality estimate (1.27%/day) for Georges Bank larvae during the 1975-76 winter compared to the previous two winters (about 3.9%/day) might have been due to a greater westward dispersal of the Georges Bank larval population into the Nantucket Shoals area. That is, dispersal may have been responsible for a high loss rate and not mortality per se. Based on the separate and combined estimates of mortality and growth for both areas, it appears that dispersal of larvae from Georges Bank into Nantucket Shoals is small at this time in their life and does not significantly alter the dominant trends in mortality and growth.

3. Growth rate of late larvae may be underestimated due to avoidance of the sampling gear, particularly if larvae are of greater size in the same time period from one year to the next. Perhaps growth rates of late larvae should be estimated from larvae collected during night tows only.

4. The increased size of Georges Bank larvae in December with the concomitantly greater growth through the winter during the three years in both areas may have been influenced to a great extent initially by conditions during the early larval period in the fall. Considerable variability was observed during the past three years in the time of initial hatching of larvae, total production, and the duration of the spawning-hatching season as indicated by length-frequency modes.[4] Production of larvae was high in 1973 and 1974, but considerably lower for the 1975 season as suggested by the December and November surveys.[5] Recently hatched larvae were observed on Georges Bank in late September 1973, early October 1974, and late October 1975. Despite the increasing lateness of the hatching season from 1973 to 1975, larvae were successively larger by December. There is some evidence to suggest that bottom-water temperatures were cooler during October 1975 than the previous two years at a time when most of the larval hatching occurs. While temperature conditions in the spawning beds may control the maturation of eggs and hatching times from year to year, they would not appear to have a direct effect on growth and mortality of the larvae. Significant differences in temperature trends during December and February were not observed over the three years. The growth and mortality process are more likely a function of the available food supply and predators. Analyses of the zooplankton community and larval gut contents are in progress and may elucidate some of the causal mechanisms in the larval-plankton-environment matrix.

It is desirable at this time to examine possible relations among early and late larval abundance and the size of the recruited year class for sea herring. Studies off coastal Maine by Graham et al. (1972) and Graham and Davis (1971) indicated that the initial abundance of larvae in the fall was reduced to a common level by early winter each year. Although mortality was higher in the fall than the winter, the winter period was considered critical in that years of low winter mortality were subsequently related to a greater percentage of that year class as 2-yr-old fish in the fishery. A comparison is made in Table 19.3 of the available data on initial larval production (larvae <10 mm standard length), December larval abundance (>15 mm), and catch

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[4]Schnack, D. 1975. Summary of ICNAF Joint Larval Herring Surveys in Georges Bank-Gulf of Maine areas, September-December 1974. ICNAF Res. Doc. 75/112, 23 p.

[5]Jcakimsson, G., 1976. Report of the ICNAF larval herring cruise, R/V Anton Dohrn, November 1975, in Georges Bank-Nantucket Shoals areas. ICNAF Res. Doc. 76/VI/80, 17 p.

per tow of 3-yr-old herring in the Georges Bank-Nantucket Shoals area. No estimate could be made for the 1975 initial abundance of larvae as all the data are not available yet. The time series of data is still too short to permit firm conclusions, but several points seem to corroborate past thinking. The initial production of larvae does not appear to be directly related to the size of the subsequent recruited year class, and in fact, there may be an inverse relationship at the extremes of abundance--a density-dependent function. Also, the relative abundance of larvae as late as December still appears to be proportional to the initial production of larvae in the fall. However, differential winter mortality occurs between December and February, and by February (Table 19.1) it does appear that the size of the recruited year class may be set. We believe, therefore, that for herring in the Georges Bank-Nantucket Shoals area, the winter period is critical in establishing the year class. We still need to study the entire larval period to understand the processes which may influence survival through the winter period and more unusual events that occur in early larval life.

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Table 19.1.--Mortality and growth estimates for Georges Bank-Nantucket Shoals herring larvae and mean water temperature during three winter periods. See text for details.

Sampling period midpoint	Larval abundance ($n \times 10^{-8}$)	Instantaneous mortality rate (-Z)	Instantaneous mortality rate (% per day)	Mean length (mm)	Specific growth (L) rate (% per day)	Instantaneous growth (wt) rate (% per day)	Mean temperature(°C) (0-50 m)
			GEORGES BANK				
Dec. 13, 1973	5076			15.1			10.4
Feb. 14, 1974	406	0.040	3.93	22.9	0.661	3.08	6.3
Dec. 13, 1974	7410			16.5			9.9
Feb. 14, 1975	506	0.040	3.87	26.7	0.708	3.30	5.7
Dec. 9, 1975	1120			17.4			9.9
Feb. 16, 1976	457	0.013	1.27	31.1	0.830	3.87	5.7
			NANTUCKET SHOALS				
Dec. 13, 1973	2801			15.5			11.6
Feb. 14, 1974	57	0.062	6.00	27.6	0.916	4.27	6.1
Dec. 13, 1974	2944			14.2			11.0
Feb. 14, 1975	103	0.049	4.81	27.1	0.950	4.43	5.9
Dec. 9, 1975	647			16.4			11.6
Feb. 16, 1976	149	0.021	2.08	30.5	0.886	4.13	5.9
			GEORGES BANK & NANTUCKET SHOALS TOTAL				
Dec. 13, 1973	7877			16.7			11.0
Feb. 14, 1974	463	0.044	4.40	23.5	0.542	2.53	6.2
Dec. 13, 1974	10354			15.8			10.5
Feb. 14, 1975	609	0.042	4.08	26.7	0.772	3.60	5.8
Dec. 9, 1975	1767			17.1			10.8
Feb. 16, 1976	606	0.015	1.52	31.0	0.850	3.96	5.8

Table 19.2.--Temperature statistics for Georges Bank and Nantucket Shoals during December, 1975 and February, 1976.

Statistic	0 m	10 m	30 m	50 m	0-50 m
			GEORGES BANK		
			December 2-17, 1975		
$\bar{x}$	9.7	9.8	9.9	10.0	9.9
s^2	1.2	1.0	1.2	2.3	1.4
s	1.1	1.0	1.1	1.5	1.2
n	43	43	43	37	166
			February 10-25, 1976		
$\bar{x}$	5.5	5.6	5.8	6.0	5.7
s^2	3.6	4.0	4.8	6.3	4.7
s	1.9	2.0	2.2	2.5	2.2
n	51	51	51	46	199
			NANTUCKET SHOALS		
			December 2-17, 1975		
$\bar{x}$	11.0	11.0	11.6	12.6	11.6
s^2	6.8	6.8	7.8	9.0	7.8
s	2.6	2.6	2.8	3.0	2.8
n	33	33	33	26	125
			February 10-25, 1976		
$\bar{x}$	5.3	5.3	5.5	7.3	5.9
s^2	1.4	1.2	1.4	4.4	2.0
s	1.2	1.1	1.2	2.1	1.4
n	46	45	45	33	169

Table 19.3.--A comparison of production of early herring larvae (<10 mm standard length), abundance of December larvae (>15 mm), and an index of abundance at age 3 from the juvenile herring surveys in the Georges Bank-Nantucket Shoals area.

Year-Class	Initial Larval Production <10 mm length ($n \times 10^{-11}$)	December Larval Production >15 mm length ($n \times 10^{-9}$)	Index of Abundance (age 3) (no. per 30 min. tow)
		GEORGES BANK	
1971	150	180	924
1972	49	47	42
1973	1200	550	10
1974	1300	650	-
1975	-	89	-
		NANTUCKET SHOALS	
1971	13	50	608
1972	180	36	5
1973	850	180	33
1974	230	130	-
1975	-	42	-
		GEORGES BANK & NANTUCKET SHOALS TOTAL	
1971	160	230	1532
1972	230	80	47
1973	2100	730	43
1974	1600	780	-
1975	-	131	-

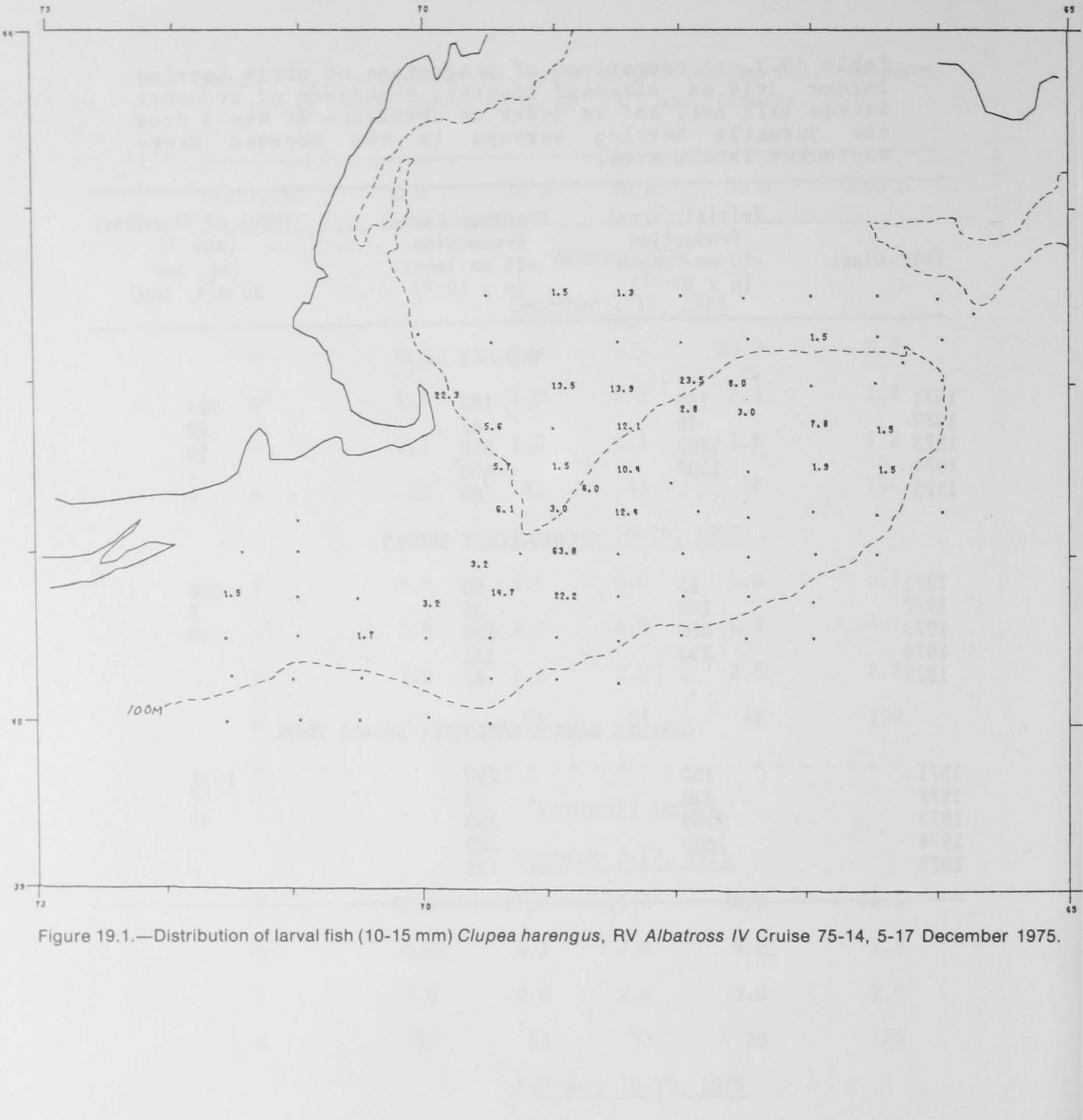

Figure 19.1.—Distribution of larval fish (10-15 mm) *Clupea harengus*, RV *Albatross IV* Cruise 75-14, 5-17 December 1975.

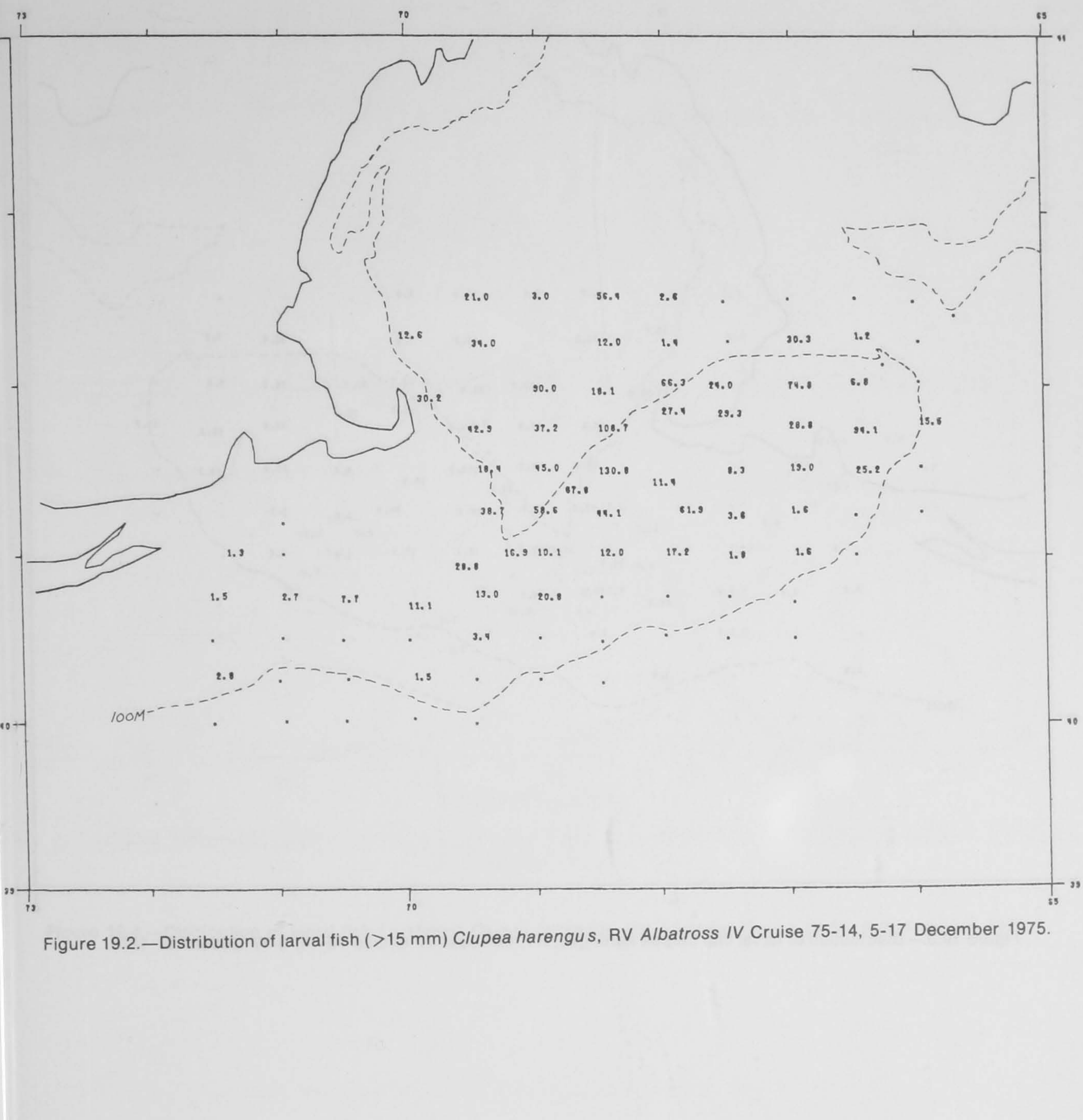

Figure 19.2.—Distribution of larval fish (>15 mm) *Clupea harengus*, RV *Albatross IV* Cruise 75-14, 5-17 December 1975.

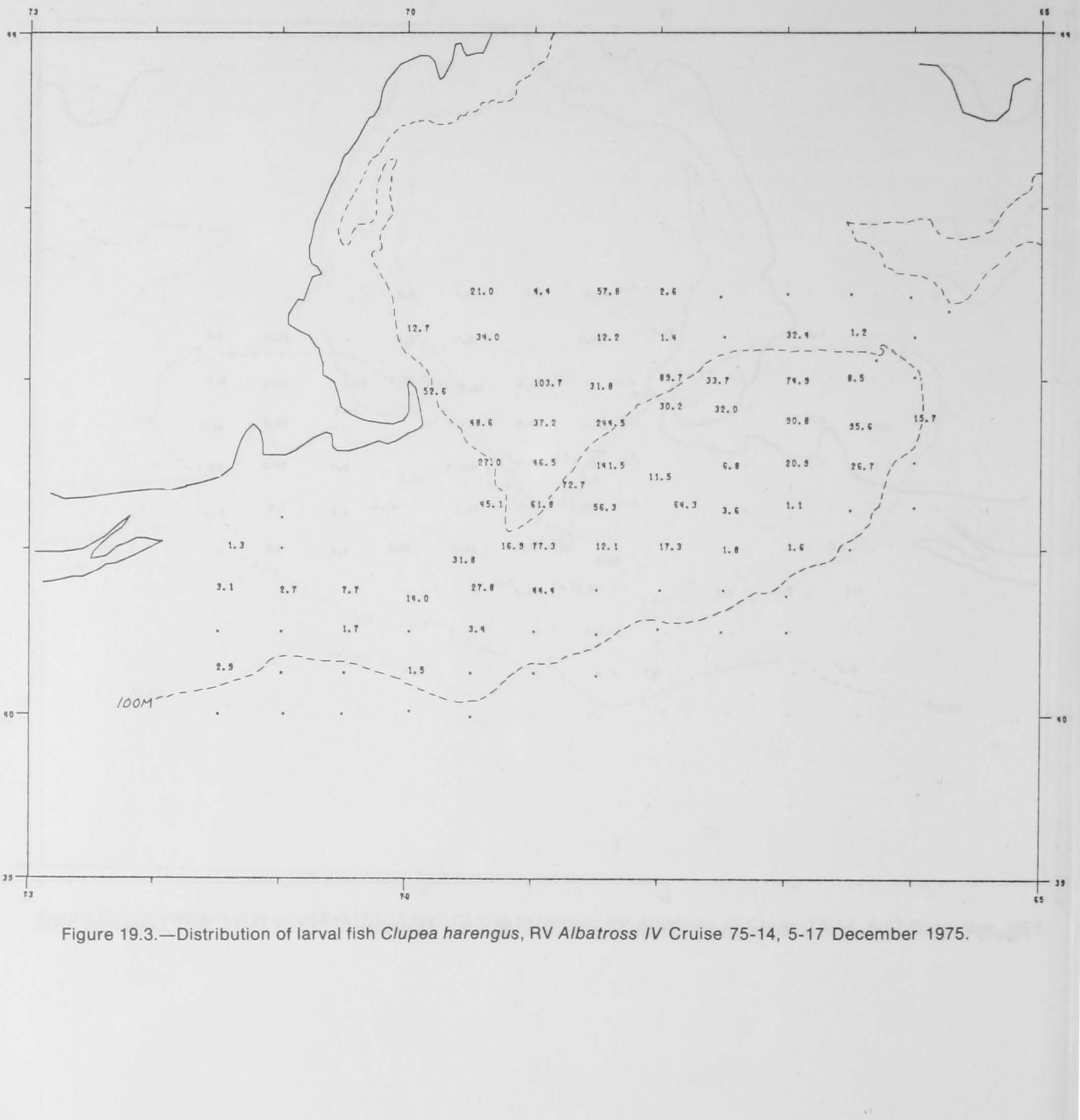

Figure 19.3.—Distribution of larval fish *Clupea harengus*, RV *Albatross IV* Cruise 75-14, 5-17 December 1975.

Figure 19.4.—Distribution of larval fish (>15mm) *Clupea harengus*, RV *Albatross* Cruise 76-01, 9-25 February 1976.

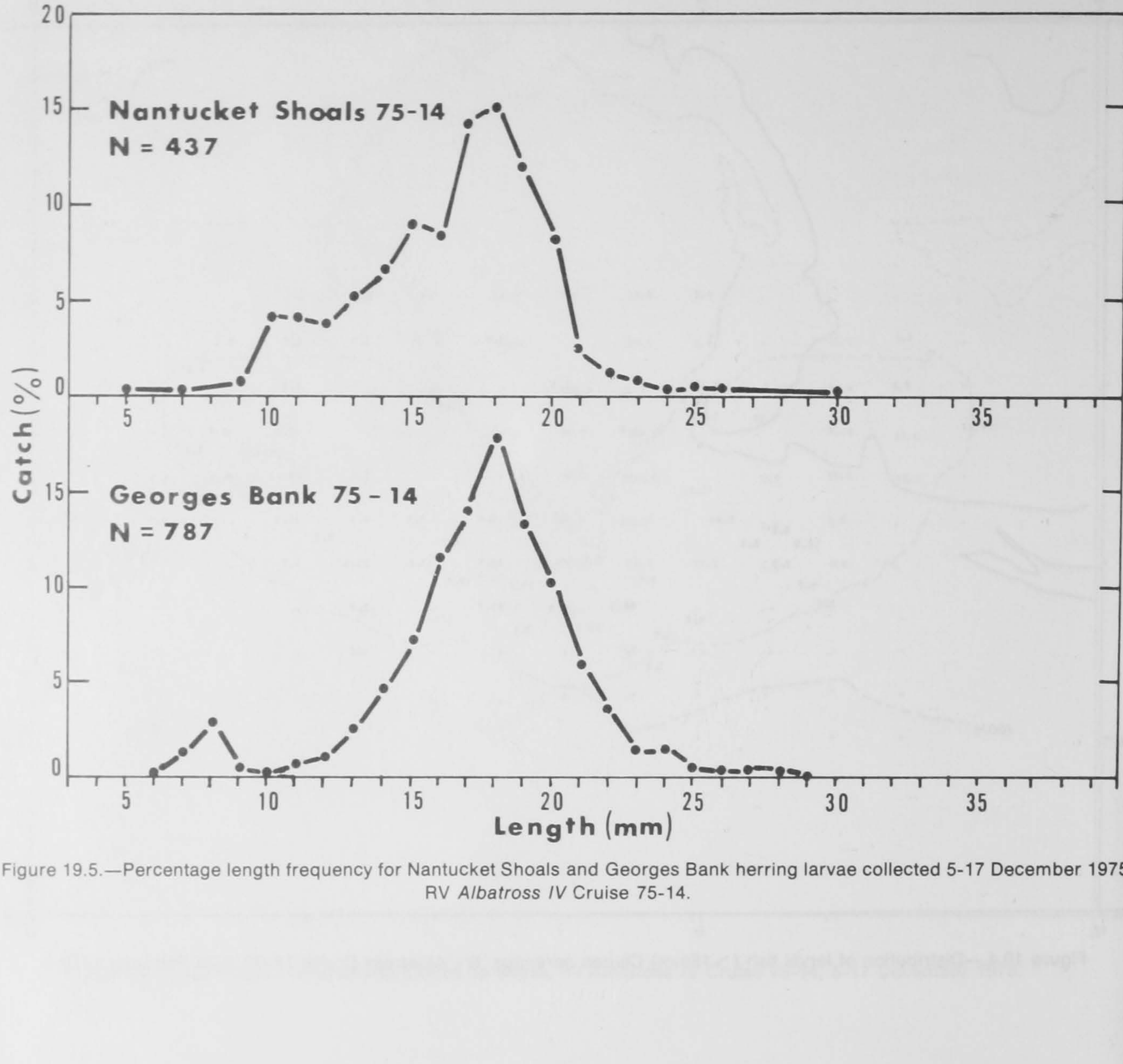

Figure 19.5.—Percentage length frequency for Nantucket Shoals and Georges Bank herring larvae collected 5-17 December 1975, RV *Albatross IV* Cruise 75-14.

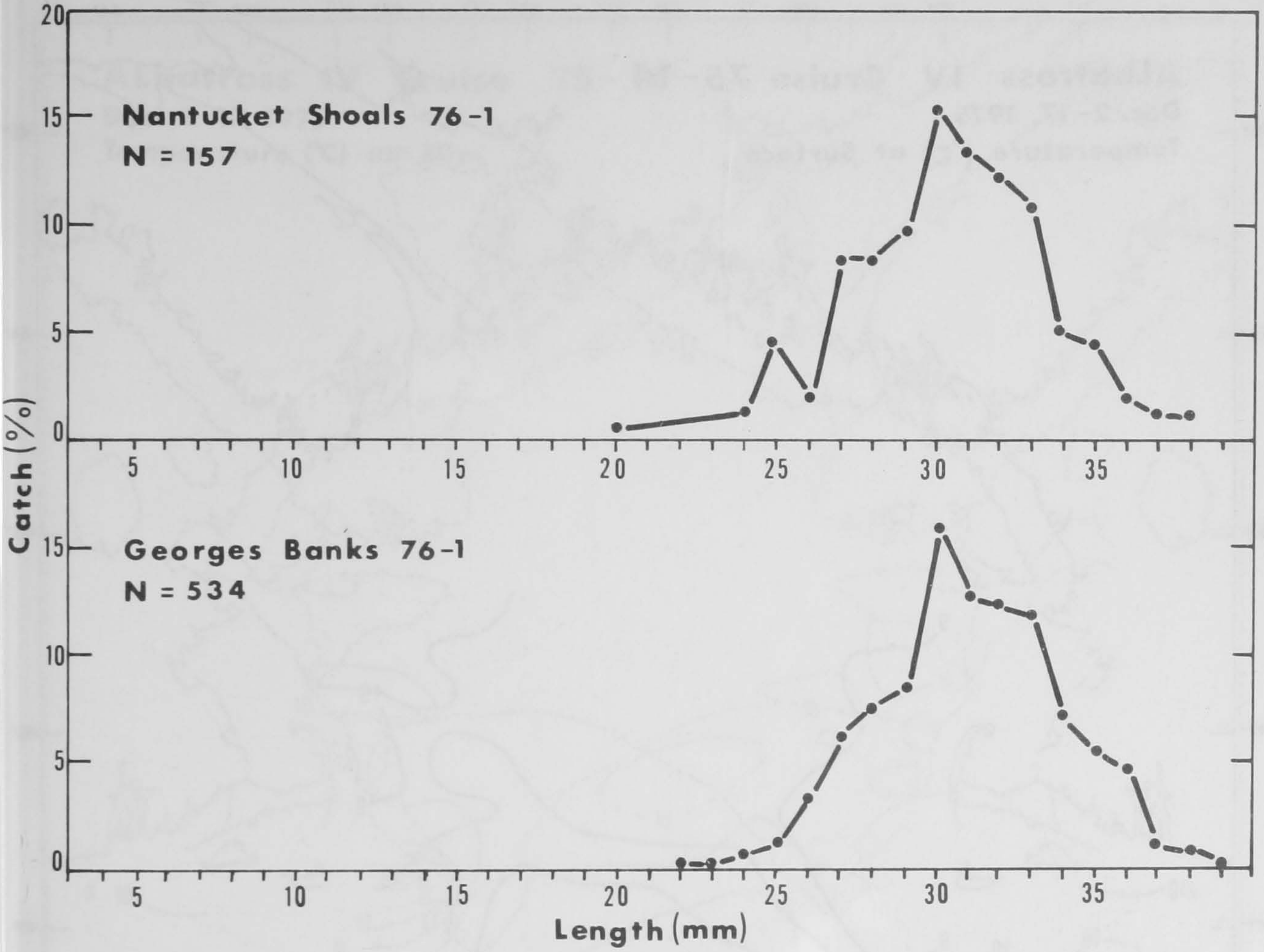

Figure 19.6.—Percentage length frequency for Nantucket Shoals and Georges Bank herring larvae collected 10-25 February 1976, RV *Albatross IV* Cruise 76-01.

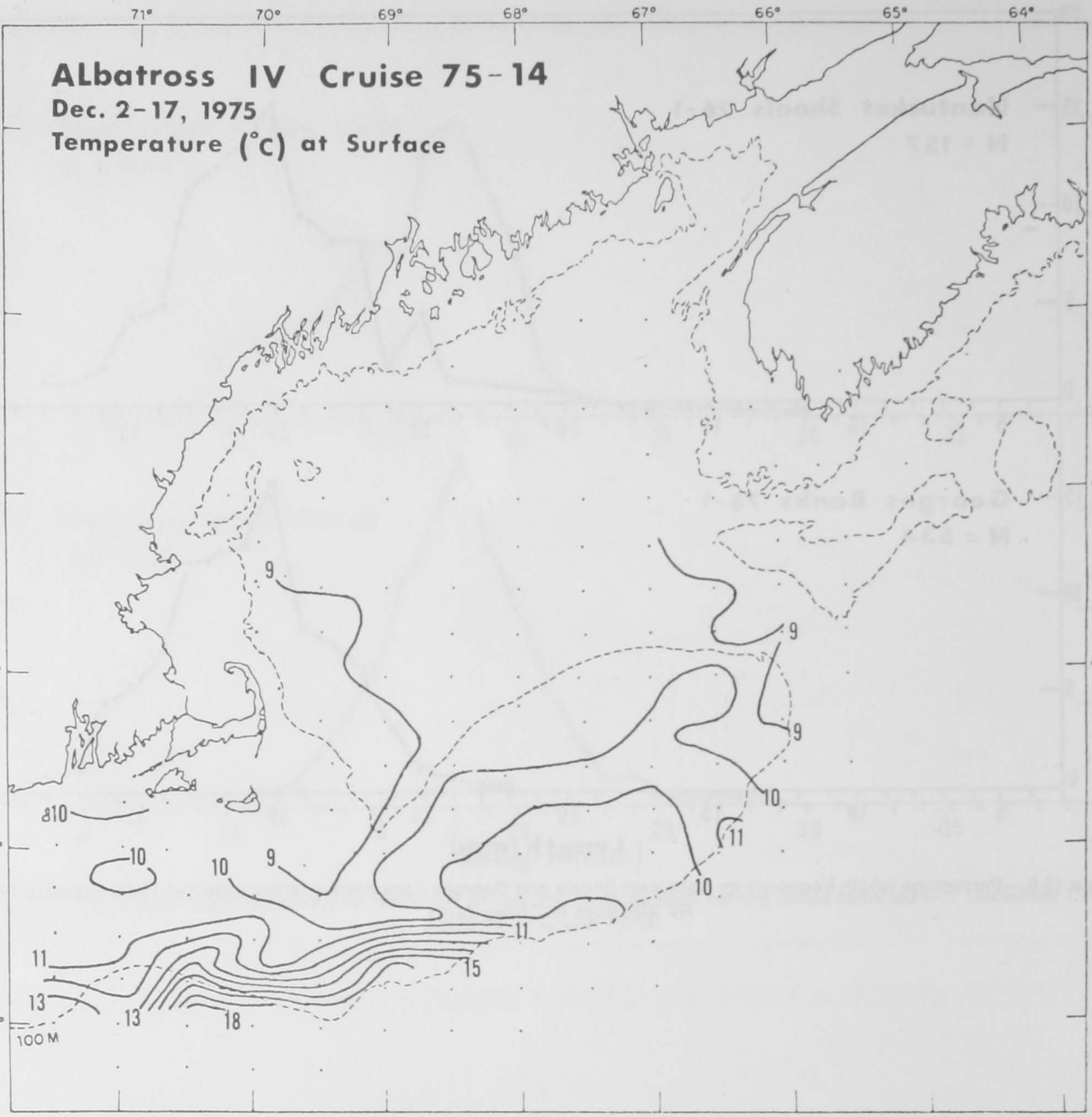

Figure 19.7.—Sea surface temperature (degrees C), RV *Albatross IV* Cruise 75-14, 2-17 December 1975.

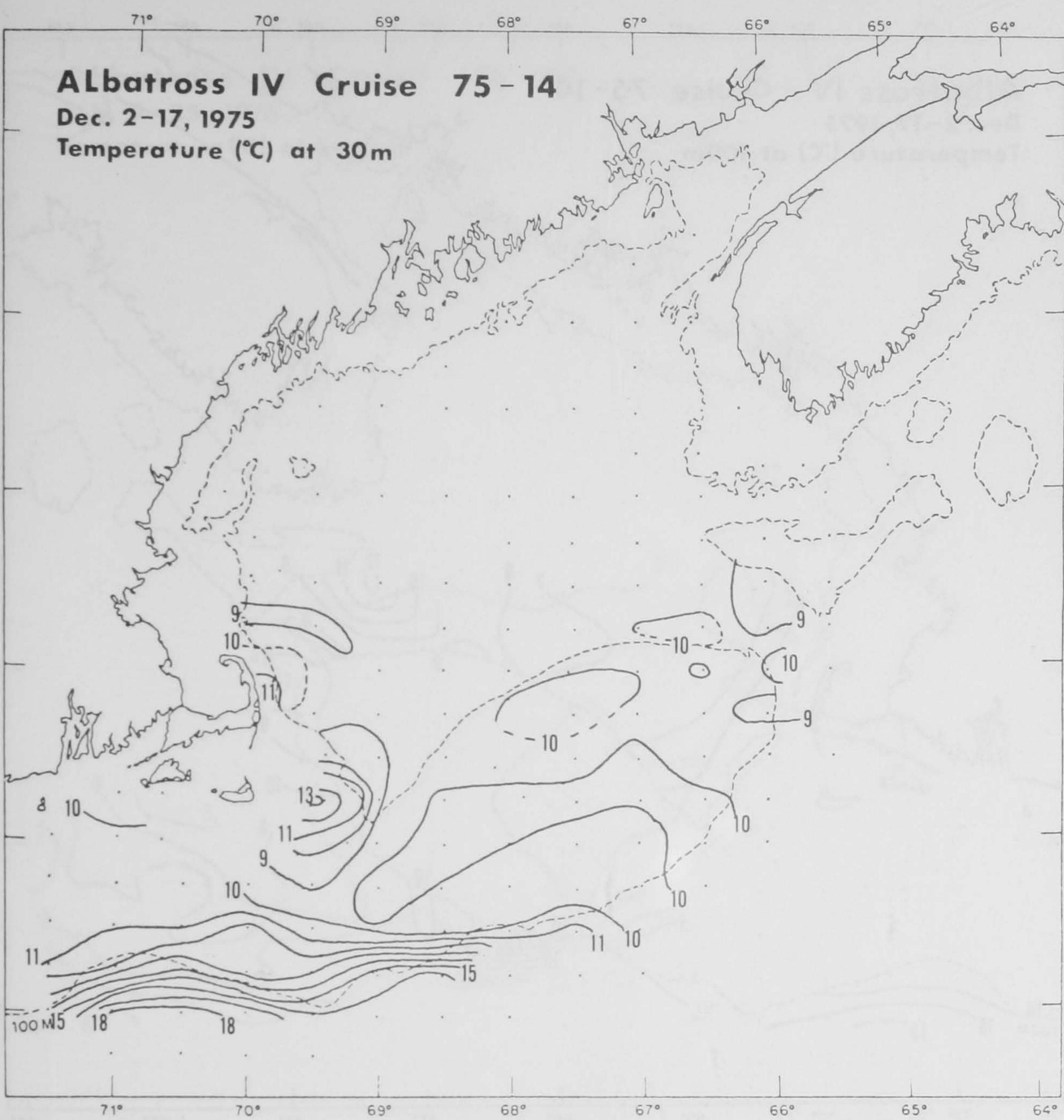

Figure 19.8.—Seawater temperature (degrees C) at 30 m, RV *Albatross IV* Cruise 75-14, 2-17 December 1975.

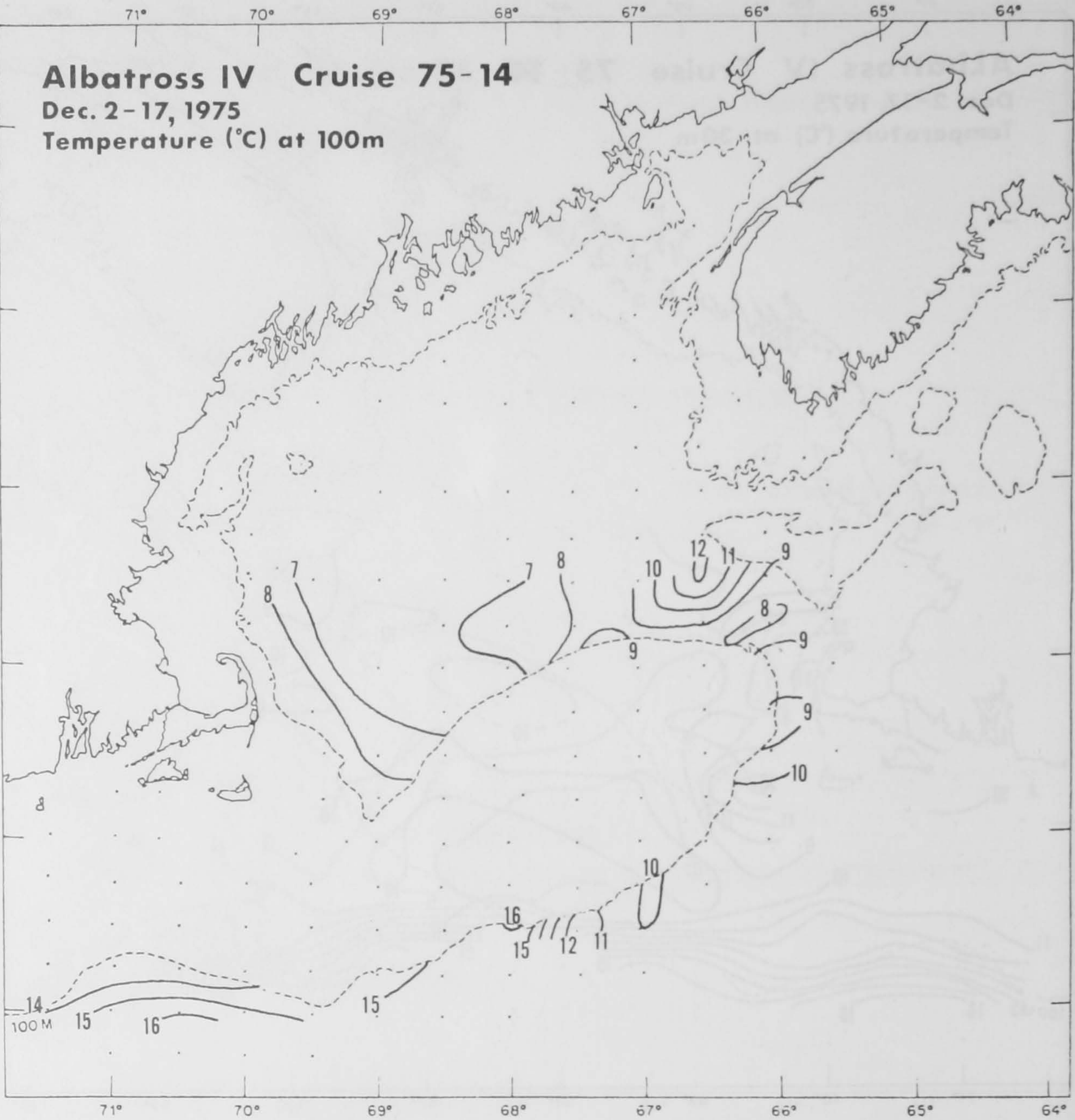

Figure 19.9.—Seawater temperature (degrees C) at 100m, RV *Albatross IV* Cruise 75-14, 2-17 December 1975.

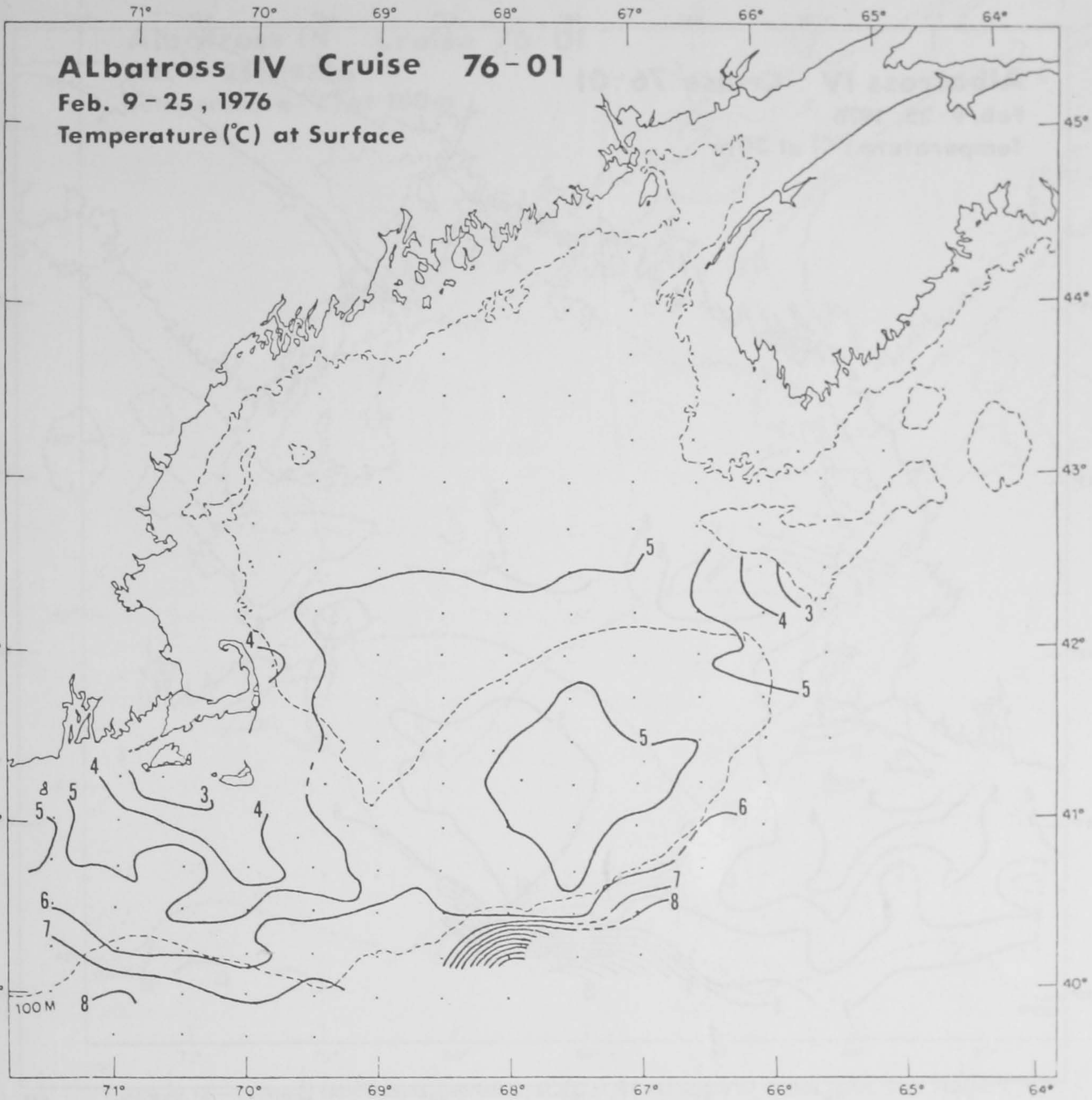

Figure 19.10.—Sea surface temperature (degrees C), RV *Albatross IV* Cruise 76-01, 9-25 February 1976.

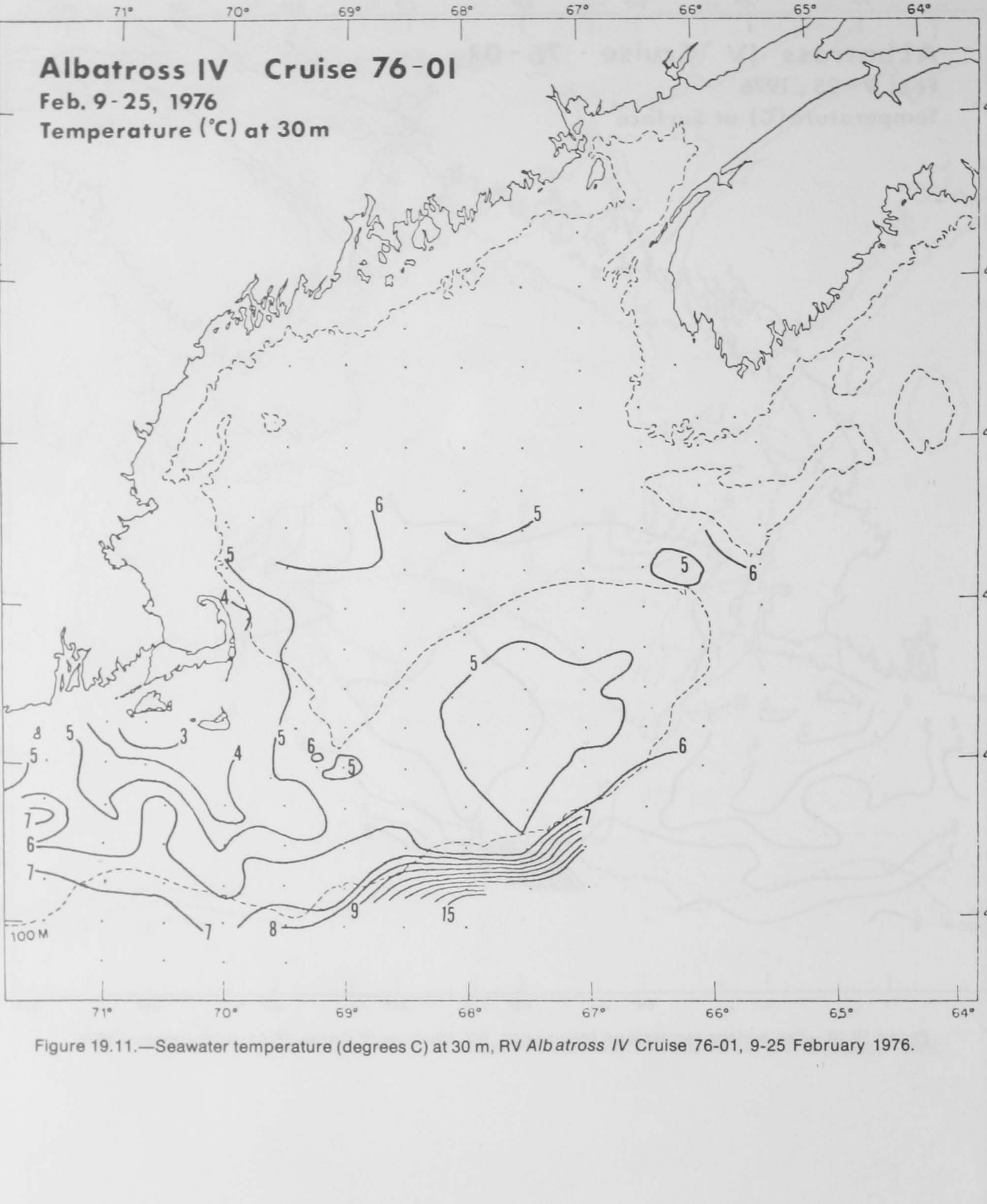

Figure 19.11.—Seawater temperature (degrees C) at 30 m, RV *Albatross IV* Cruise 76-01, 9-25 February 1976.

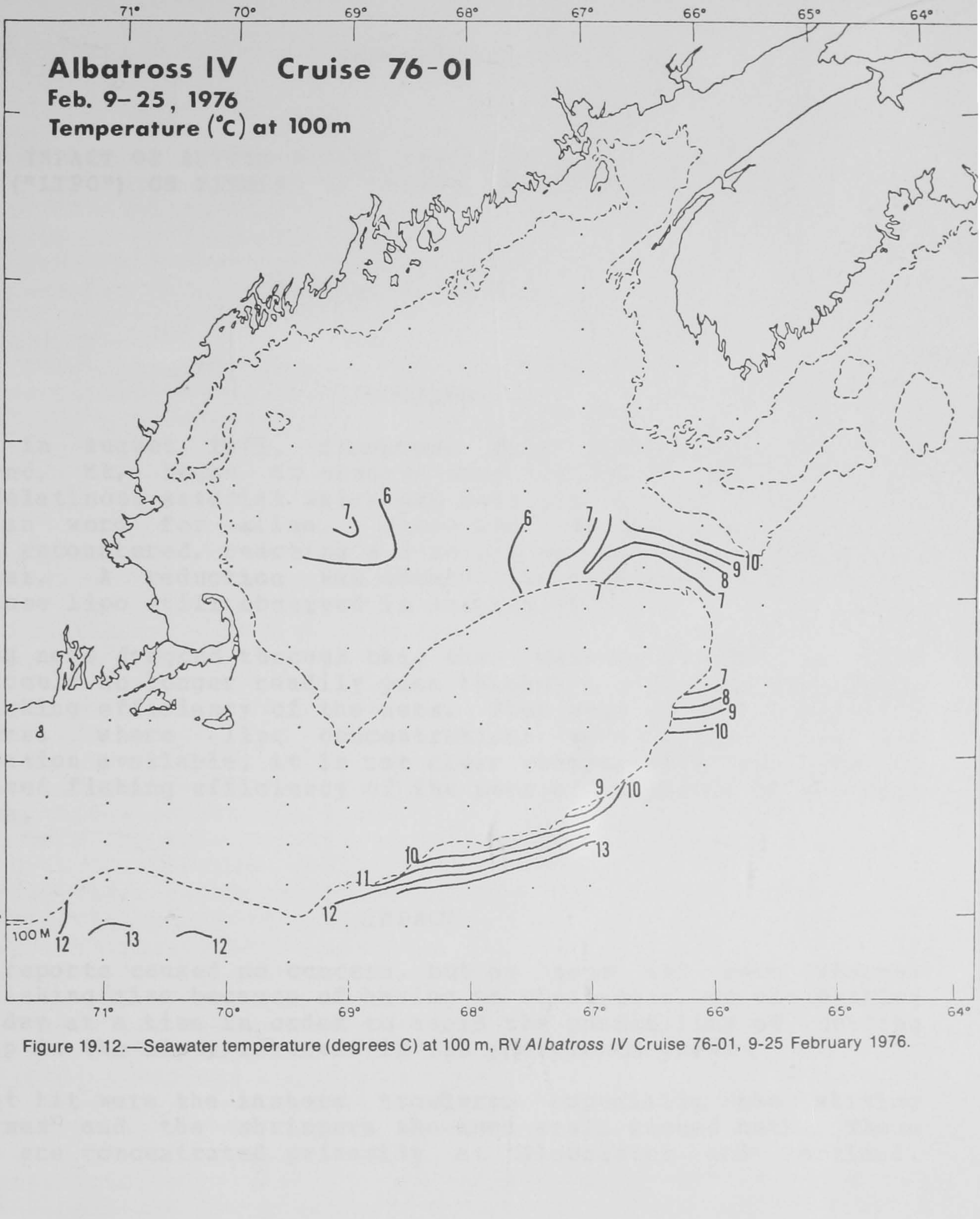

Figure 19.12.—Seawater temperature (degrees C) at 100 m, RV *Albatross IV* Cruise 76-01, 9-25 February 1976.

Section 20

IMPACT OF AUTUMN-WINTER SWARMING OF A SIPHONOPHORE ("LIPO") ON FISHING IN COASTAL WATERS OF NEW ENGLAND[1]

Carolyn A. Rogers

PROBLEM

Early in August 1975, fishermen from Gloucester, MA, and Portland, ME, began to observe some fouling of their nets by a pink gelatinous material which was referred to as "lipo," the Sicilian word for slime. There was a gradual increase in the amount encountered, reaching a 3-mo maximum between October and December. A reduction was observed in middle to late December with some lipo still observed in January 1976.

Fishing nets dragged through this mass became clogged so that water could no longer readily pass through the meshes, decreasing the fishing efficiency of the nets. Fish were seldom caught in an area where lipo concentrations were high. From the information available, it is not clear whether this was due to decreased fishing efficiency of the nets or avoidance of the mass by fish.

IMPACT

Early reports caused no concern, but as more and more vessels lost fishing time because of having to clean gear, or not fishing for a day at a time in order to avoid the possibility of getting hung up in the lipo, interest in the phenomenon grew.

Hardest hit were the inshore trawlers, especially the whiting fishermen and the shrimpers who used small meshed nets. These fleets are concentrated primarily at Gloucester and Portland.

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[1]Summarized from Environmental Impact Report 1-76, MARMAP Contribution No. 112, and Environmental Impact Report 2-76, MARMAP Contribution No. 120.

[2]Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Narragansett, RI 02882.

Boston and Provincetown, MA, port agents indicated that there was no problem, but these fleets fished offshore and used larger meshed nets.

Robert Morrill, NMFS port agent at Portland, indicated that all of the 75 vessels there encountered a problem with the lipo at least once during the 3-mo period (October-December 1975). He estimated an overall 20% loss of fishing time to the shrimp trawlers. Similar reports were received by James Thomas, State of Maine biologist at Boothbay Harbor, and Peter Marckoon, NMFS Port Agent at Rockland, ME.

Arv Poshkus, NMFS port agent in Gloucester, reported that, by a conservative estimate, 60 inshore trawlers were involved and that up to 20% of fishing time was lost either in cleaning gear or by not fishing.

In a recent (26 December 1975) letter to William Gordon, Regional Director of NMFS Northeast Region, Salvatore J. Favazza, Executive Secretary of the Gloucester Fisheries Commission stated that ". . . it (lipo) has caused an economic loss to Gloucester fishermen of at least $100,000 in 1975 and possibly as much as $300,000." Although no figures were made available for loss to the Maine shrimp industry, it is probable the losses were comparable.

DISTRIBUTION

Helgoland Observations

The siphonophore Nanomia cara was observed during the Helgoland underwater habitat mission (5 August-21 November 1975) on Jeffries Ledge (Rogers et al., in press). Personnel on surface vessels noted its presence near the surface and H. Wes Pratt, a diver for the mission, reported that siphonophores were most numerous during August and September, but were scarce in October and November. He estimated a density of about one per cubic meter in the area of the Helgoland habitat (Location X, Fig. 20.1) during the high density periods. The length of a total colony was approximately 30 cm. In situ, most of the animal was transparent except for the gonophores which were pink to salmon. The siphonophores appeared very fragile. They were densest in the top 2-3 m; below 15 m few were observed. Pratt stated that their daytime distribution was patchy in both space and time in the vicinity of the Helgoland habitat. Kevin McCarthy, a support diver for the mission, corroborated these observations.

Survey Results

According to reports from the fishermen, the siphonophore masses occurred at depths of 40-100 m and were recorded on depth sounding equipment as being up to 50 m thick. They reported traces at the bottom during the daylight and off the bottom in the dark, indicating the ability of the siphonophores to migrate vertically. Fishermen encountered siphonophores from Stellwagen Bank off Massachusetts Bay to Rockland, ME.

Plankton samples were taken in the Gulf of Maine on four Albatross IV cruises (75-12 II, 75-12 III, 75-13, 75-14) as part of the MARMAP survey and monitoring program of the Northeast Fisheries Center (NEFC). The cruises included the period 7 October-17 December, 1975. A Delaware II cruise (75-17) 15 October-7 November 1975, also part of the MARMAP program, sampled the area from Cape Cod, MA, to Cape Hatteras, NC. A Challenge cruise (75-1), part of NEFC's Biome Survey, sampled the coastal waters of Maine 4-9 September 1975. All samples were collected with paired bongo samplers fitted with 0.333-mm and 0.505-mm mesh nets. Oblique tows, at 1.5-3.5 kn, were made through the water column from the surface to within 10 m of the bottom or to 100 m maximum depth. The bongos were set out at 50 m/min and retrived at 20 m/min, the maximum time of a plankton tow being approximately 23 min. Because of the fragile nature of N. cara, only fragments were available in the samples for examination. A total of 422 samples was examined at a magnification of 10X by the NEFC Plankton Sorting Group at Narragansett, RI. A summary of N. cara occurrence, as well as the occurrence of another siphonophore tentatively identified as Halistemma sp., was given in the more complete version of this report. The distribution over the continental shelf and area plots showing relative abundance and size are given in Figures 20.2-20.9. Although no siphonophores of the species N. cara were found in samples taken on the Delaware II cruise, Figures 20.6 and 20.7 were included to show more clearly that the normal range of N. cara does not extend very far south of Cape Cod. I recognize the subjective nature of relative size and abundance information, but felt that horizontal projections of area distributions would be a useful means for locating areas of maximal swarming. The samples are available for further examination and analysis should more precise data be required.

A September survey of coastal fish stocks in New England waters made during Biome operations yielded N. cara only in the offshore stations [15-20 mi (24-32 km) from the coast] and only in stations north of Penobscot Bay (Figs. 20.1, 20.8, 20.9). This coincides with the inshore distribution of siphonophores found on Albatross IV cruises 75-12 II and III, 7 October-18 November (Figs. 20.4, 20.5).

During this period the distribution of N. cara extended into the Bay of Fundy and occurred in almost all samples taken in the Gulf of Maine and eastward around the periphery of Georges and Browns Banks. The later cruise (2-17 December) sampled the southern portion of the Gulf of Maine, Georges Bank, and the region south of Cape Cod (Figs. 20.1, 20.4, 20.5).

Plankton samples from the Delaware II cruise (15 October-7 November) had few siphonophores (Figs. 20.6, 20.7). Four stations off the New Jersey and Long Island coasts and five stations somewhat clustered just north of Cape Hatteras were the only areas in which they were found. All stations were within the 15-fathom line. On first examination they appeared to be N. cara, but when D. C. Biggs, siphonophore expert from Woods Hole Oceanographic Institution, examined them he tentatively identified them as Halistemma sp. The species within this genus are typically tropic to temperate so their presence in these areas is not surprising.

The Gulf of Maine samples showed that in October and early November the individual colonies of N. cara were generally small and constituted only a small portion of the zooplankton biomass. The December samples showed a greater range of small to large individuals and they often made up a more substantial portion of the zooplankton biomass. In general, in the earlier months the greatest mass of siphonophores was found within 15 mi (24 km) of the coast, but by December the concentration was centered farther offshore.

The colonies of N. cara also had a high density of lipids, probably as a result of feeding on overwintering populations of oil-rich calanoid copepods.[3] Biggs feels that the swarming of N. cara may be behavioral, that because of heavy concentrations of copepods, the siphonophores may be altering their swimming behavior to stay in areas of high food density. An effort will be made to determine if copepod abundance was greater during the fall and winter months of 1975 than in previous years.

Larry Davis, NEFC, Narragansett, RI, has been studying long-term temperature trends of the Gulf of Maine. According to his data, there has been a net warming trend in the autumn from 1968 through 1974. In 1975 the average temperature of an 8-year mean for the entire Gulf of Maine dropped 0.6C (Davis, Section 14). Ed Cohen,[4] in cooperation with the Atlantic Environmental Group

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[3]Personal communication from D. C. Biggs, Woods Hole Oceanographic Institution, Woods Hole, MA 02543.
[4]Monthly temperature transect for the Gulf of Maine, August through December (unpub. doc.), NEFC, Woods Hole, MA 02543.

at Narragansett, RI, has been compiling temperature data on transects from Bar Harbor to Yarmouth and comparing the results to Colton and Stoddard's (1973) 20- to 23-year means. The 1975 monthly data (June-December) indicate that the southern portion of the Bay of Fundy is warmer than the 20-yr monthly means (Chamberlin et al., Section 15).

Data from Challenge 75-1 and Albatross IV 75-12 cruises show siphonophores occurring in waters with surface temperatures as high as 18.5C and bottom temperatures as high as 13.5C. The respective temperature lows for the combined cruises were 10.0C and 5.5C. Maximum numbers of siphonophores were found at surface temperatures of 6.0C and above. Fishermen reported that the siphonophores diminished in the coastal waters as temperatures dropped from autumn to winter.

SUMMARY

The lipo described by the fishermen is identified as a colonial siphonophore *Nanomia cara* which has a maximum growth peak in late fall when surface temperatures range from 10C to 14C. Underwater observations (Rogers et al., in press) indicated that the colonies were approximately 30 cm long and at densities close to 1/cu m. There is some indication that as nearshore waters cool, the numbers diminish, although it is not clear whether the siphonophores move offshore or if many of them die off.

The reasons for the explosive growth in the fall of 1975 are not yet fully understood, but the warmer than average water temperatures possibly leading to a higher than average autumn-winter density of food organisms may have triggered the swarming.

An attempt will be made through the MARMAP monitoring program to follow the seasonal distribution of lipo and correlate its presence and abundance with temperature and other factors which may appear important. Through this monitoring program it should be possible to alert the inshore fishing fleets to future siphonophore swarming.

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COLTON, J. B., Jr., and R. R. STODDARD.
1973. Bottom-water temperatures on the Continental Shelf, Nova Scotia to New Jersey. U.S. Dep. Commer., NOAA Tech. Rep., NMFS CIRC-376, 55 p.

ROGERS, C. A., D. C. BIGGS, and R. A. COOPER.
In press. An aggregation of the siphonophore Nanomia cara Agassiz, 1865 in the Gulf of Maine: Observations from a submersible. Fish. Bull., U.S. 76:281-284.

Editors' note: Figures 20.10 through 20.12 are contours of abundance and size of siphonophore colonies for the data presented in Figures 20.2 through 20.5. In October-November the distribution of siphonophores apparently followed the mean circulation patterns in the Gulf of Maine-Georges Bank region (Bumpus 1976) with possible origins in the coastal regions. In December the apparent origin of the siphonophore distributions had moved south and again the distribution seemed to follow the mean circulation patterns.

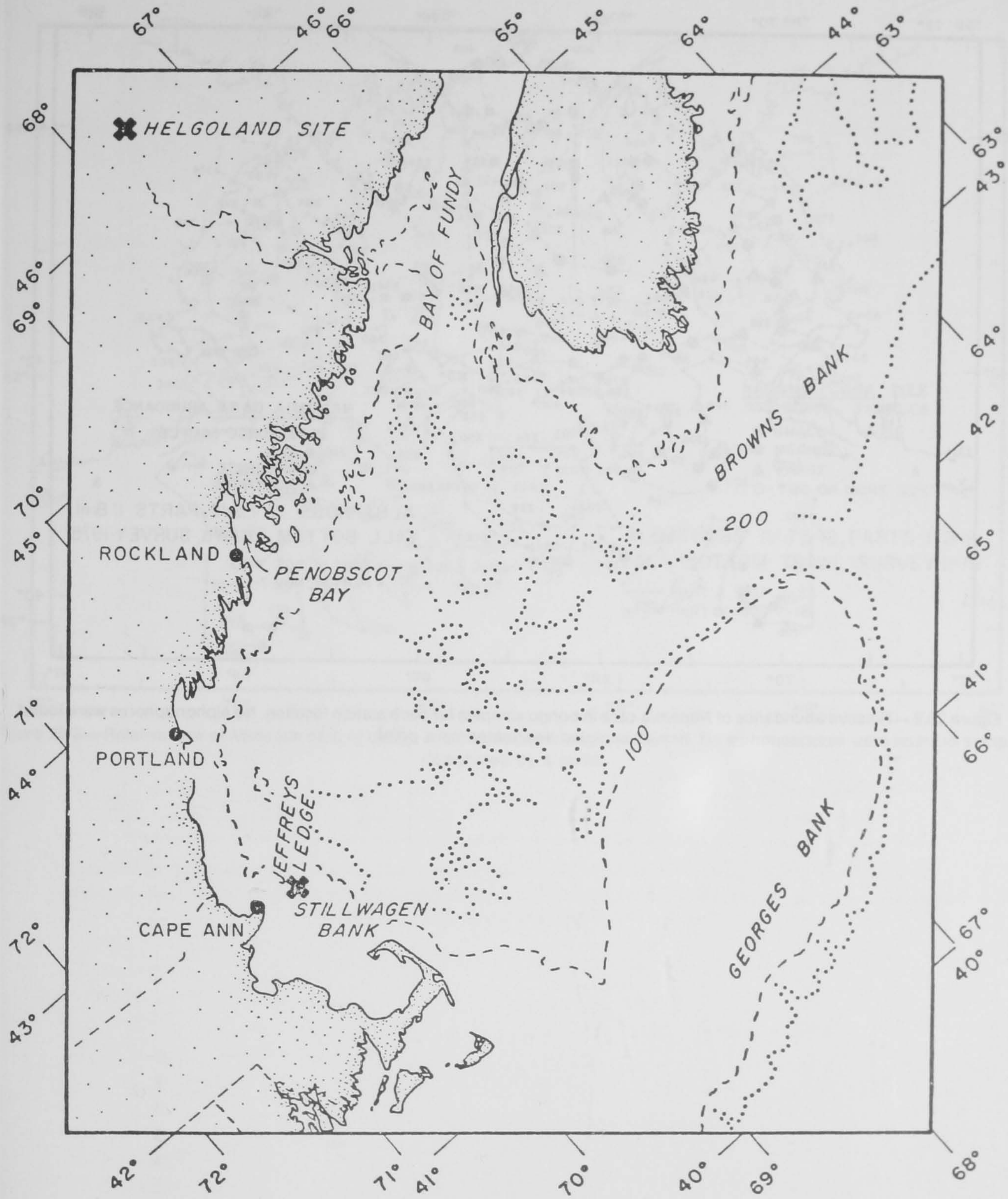

Figure 20.1.—Area in which bongo and neuston net tows were made to sample for the presence of siphonophores.

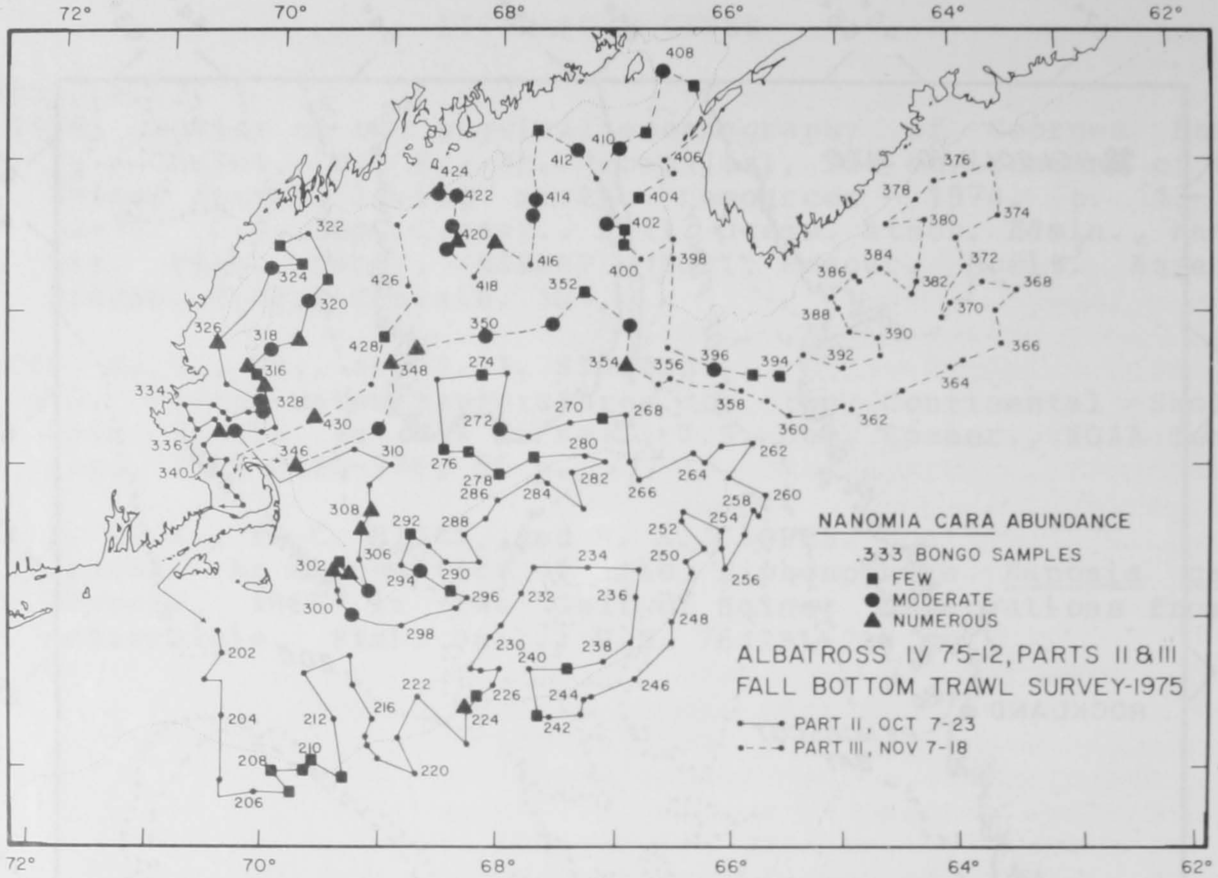

Figure 20.2.—Relative abundance of *Nanomia cara* in bongo samples for each station location. No siphonophores were found in samples designated by a point.

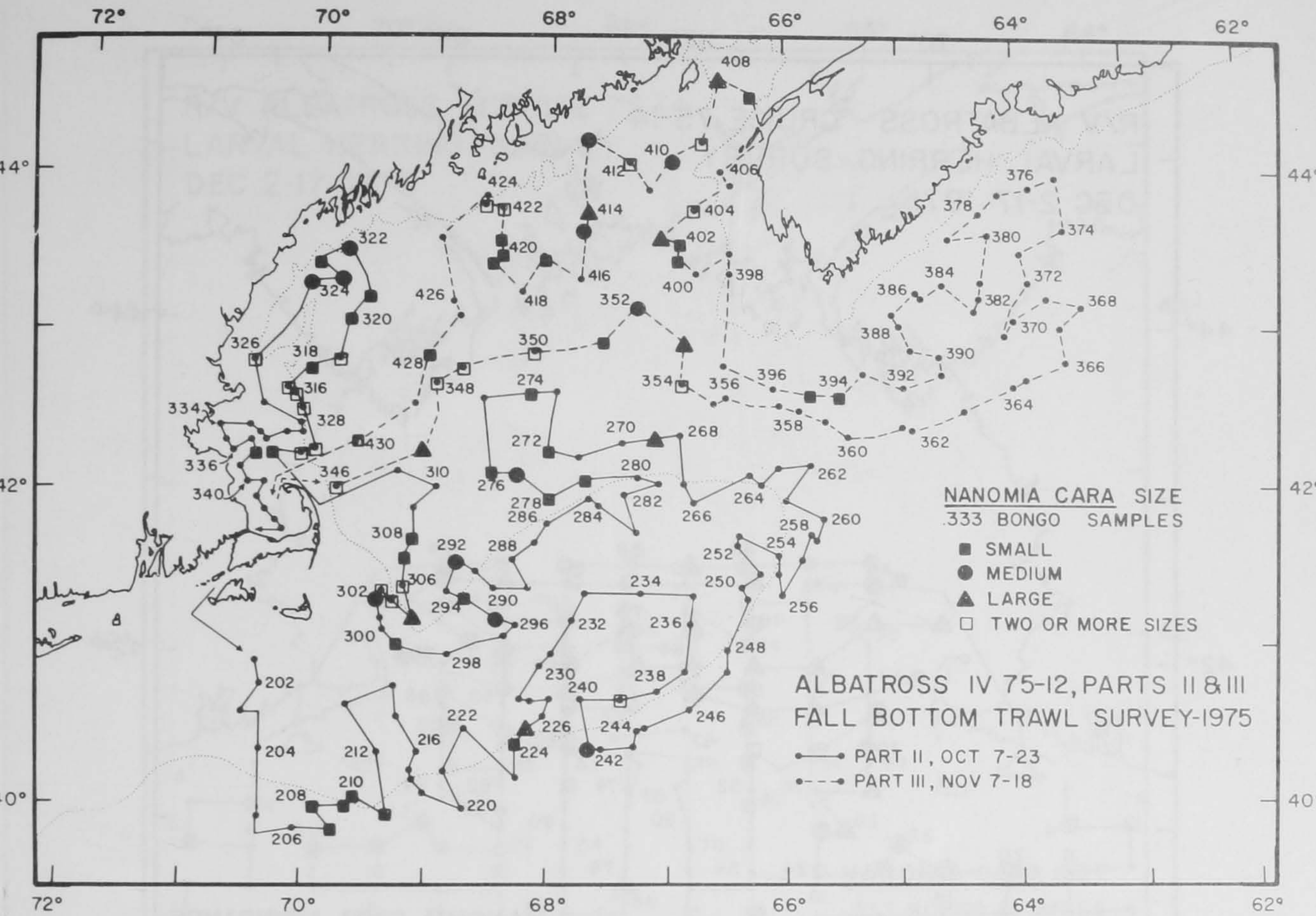

Figure 20.3.—Relative size of *Nanomia cara* in bongo samples for each station location. No siphonophores were found in samples designated by a point.

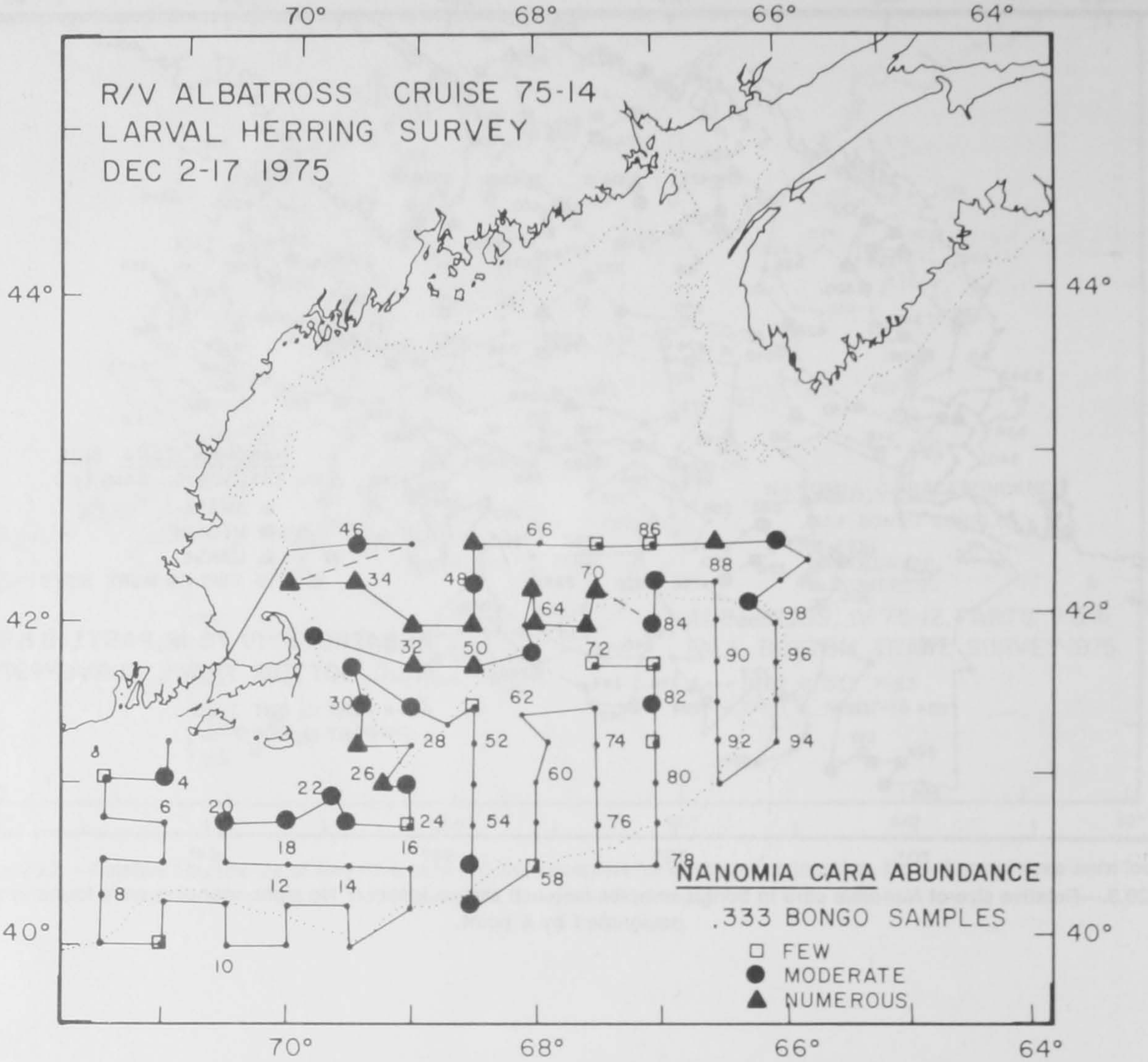

Figure 20.4.—Relative abundance of *Nanomia cara* in bongo samples for each station location. No siphonophores were found in samples designated by a point.

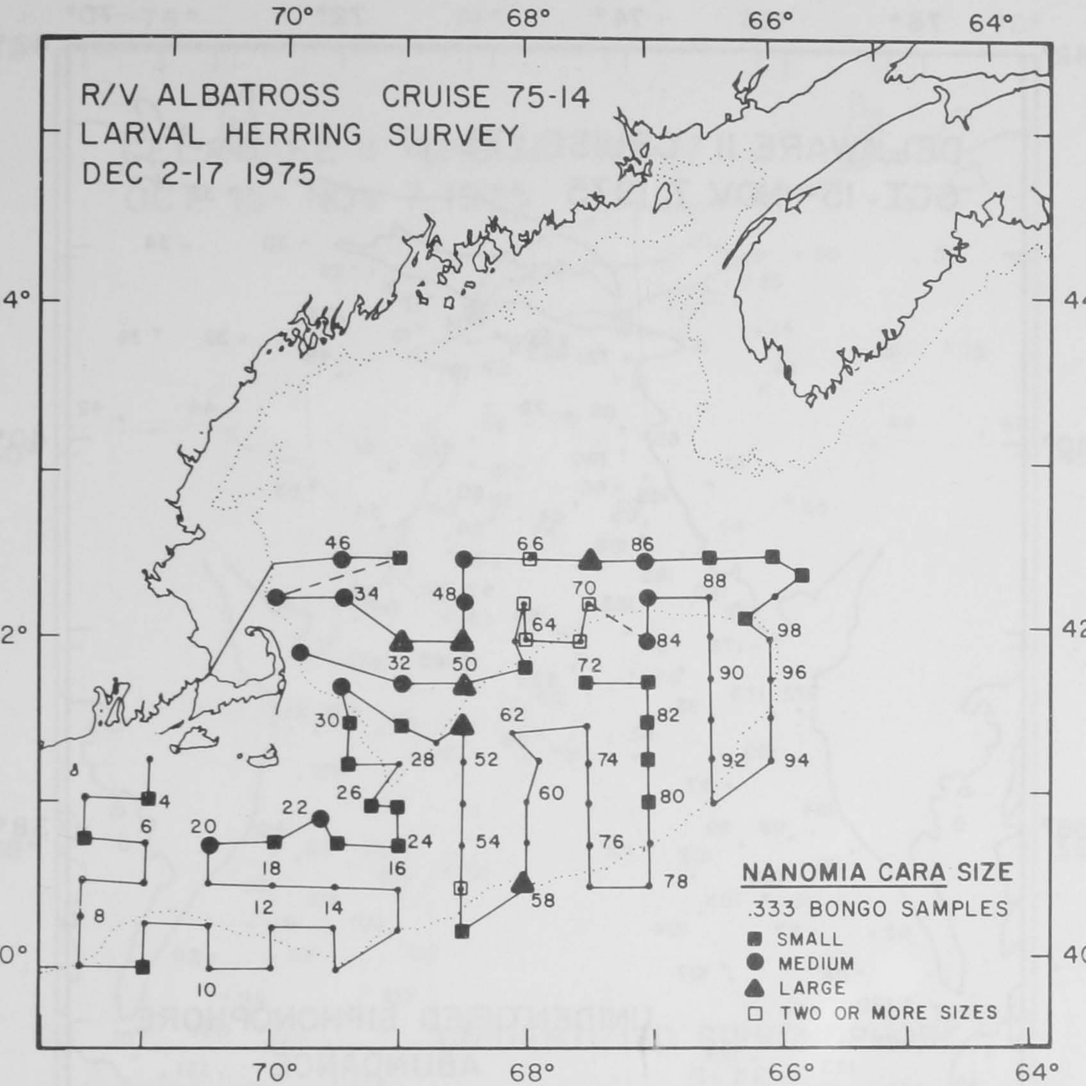

Figure 20.5.—Relative size of *Nanomia cara* in bongo samples for each station location. No siphonophores were found in samples designated by a point.

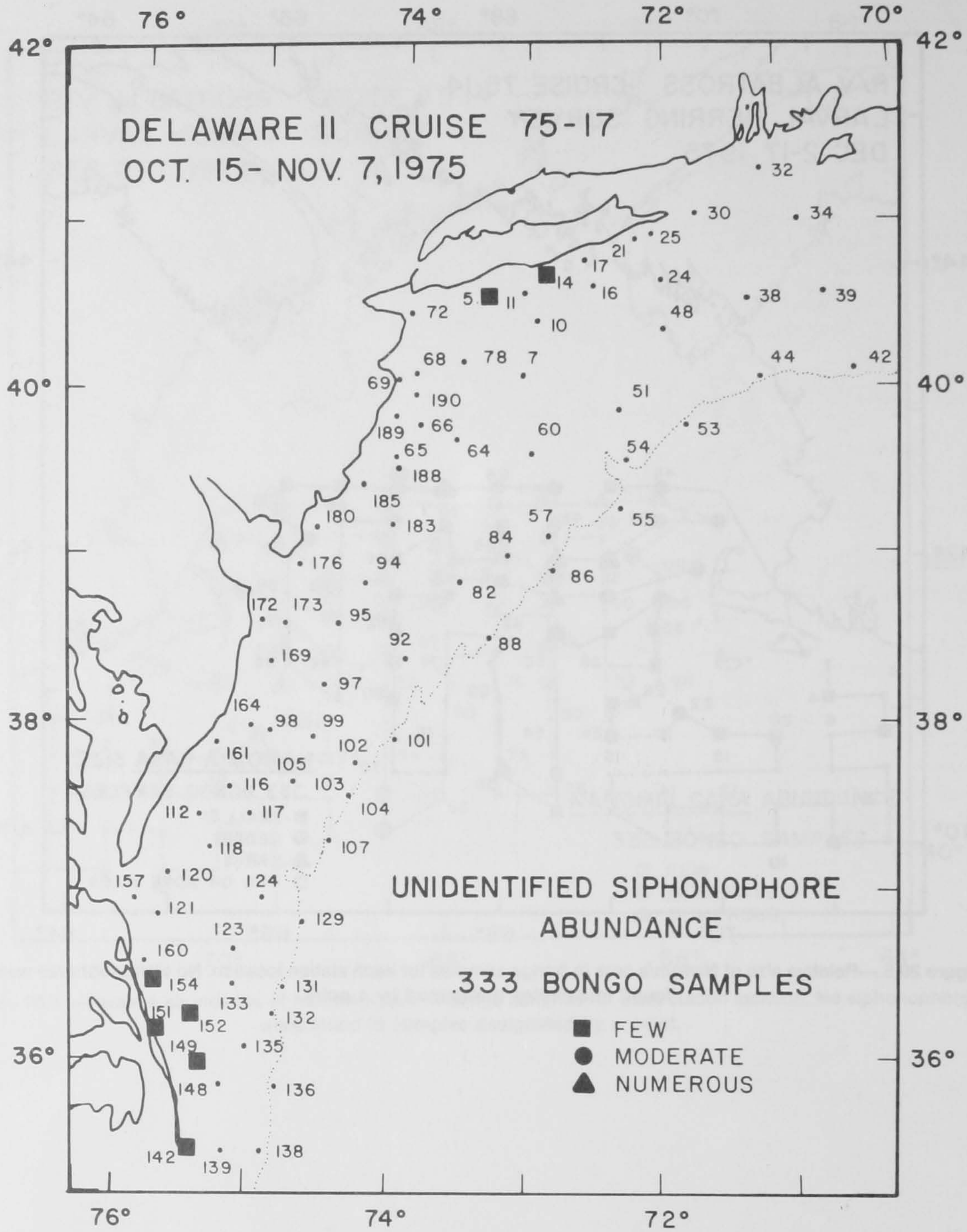

Figure 20.6.—Relative abundance of an unidentified siphonophore in bongo samples for each station location. No siphonophores were found in samples designated by a point.

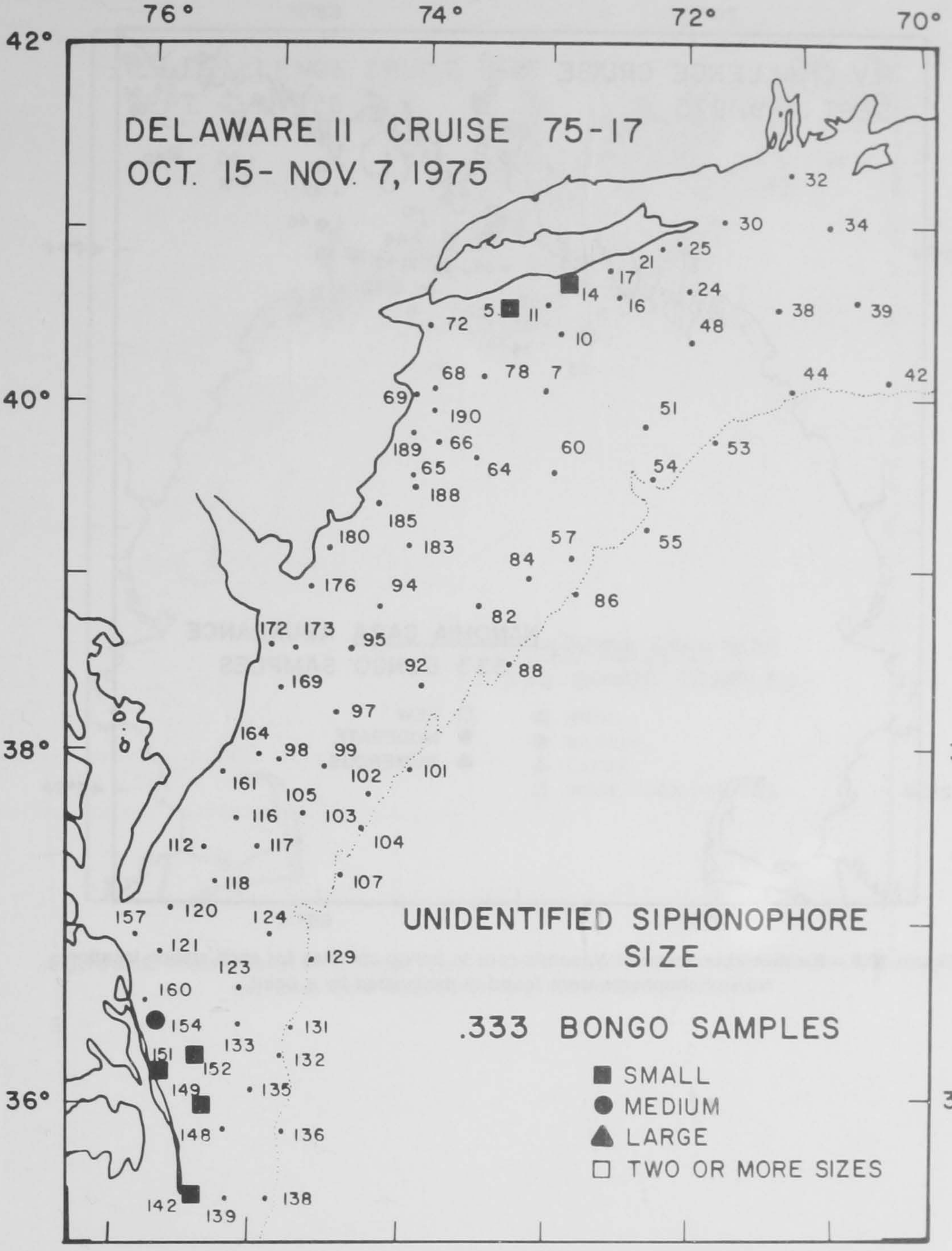

Figure 20.7.—Relative size of an unidentified siphonophore in bongo samples for each station location. No siphonophores were found in samples designated by a point.

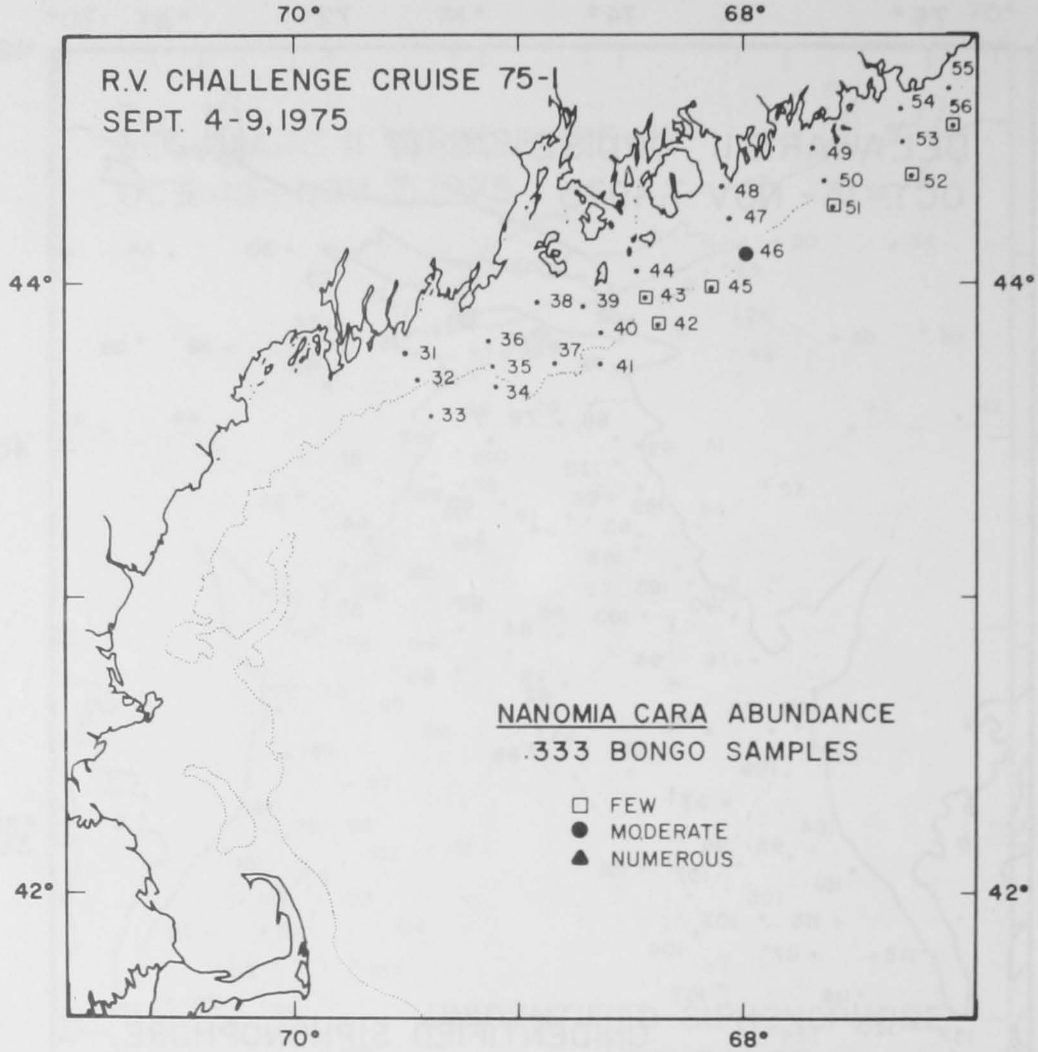

Figure 20.8.—Relative abundance of *Nanomia cara* in bongo samples for each station location. No siphonophores were found in designated by a point.

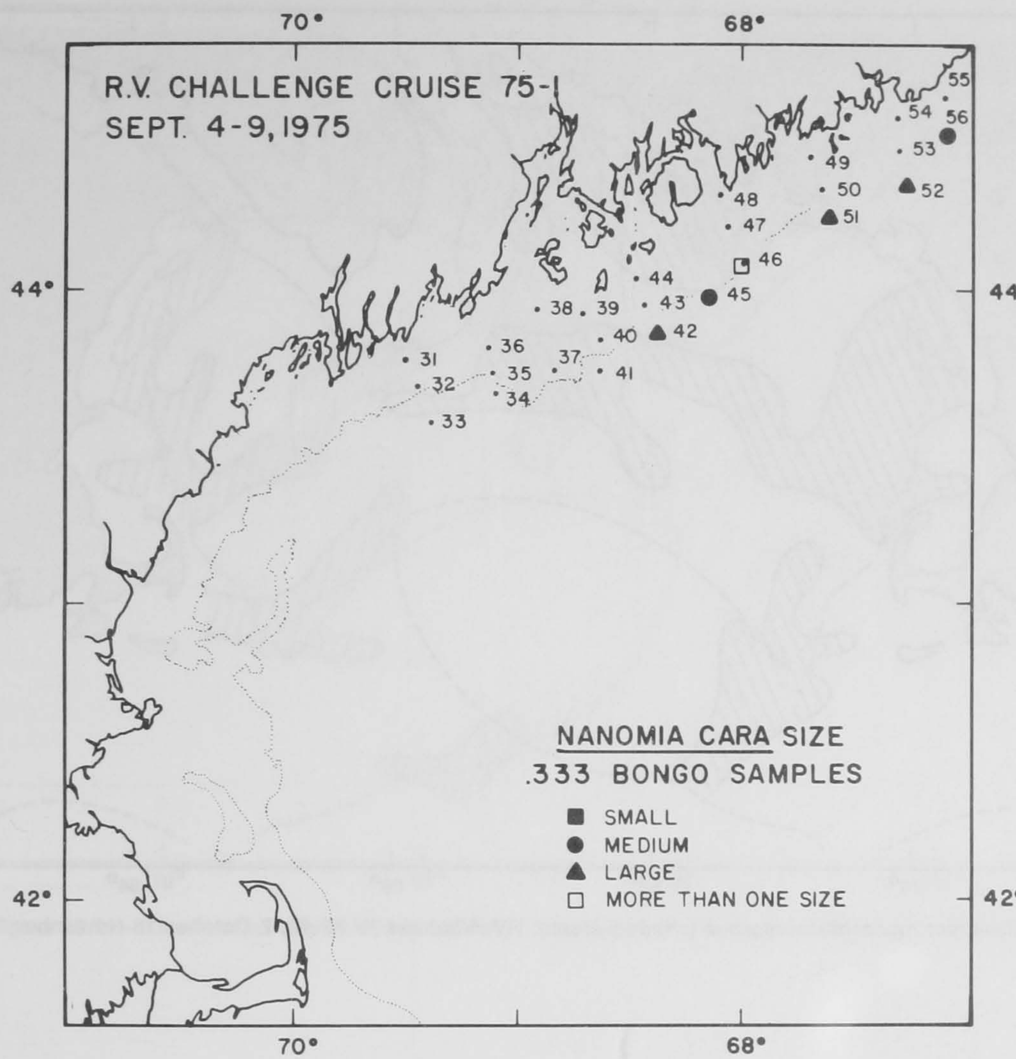

Figure 20.9.—Relative size of *Nanomia cara* in bongo samples for each station location. No siphonophores were found in samples designated by a point.

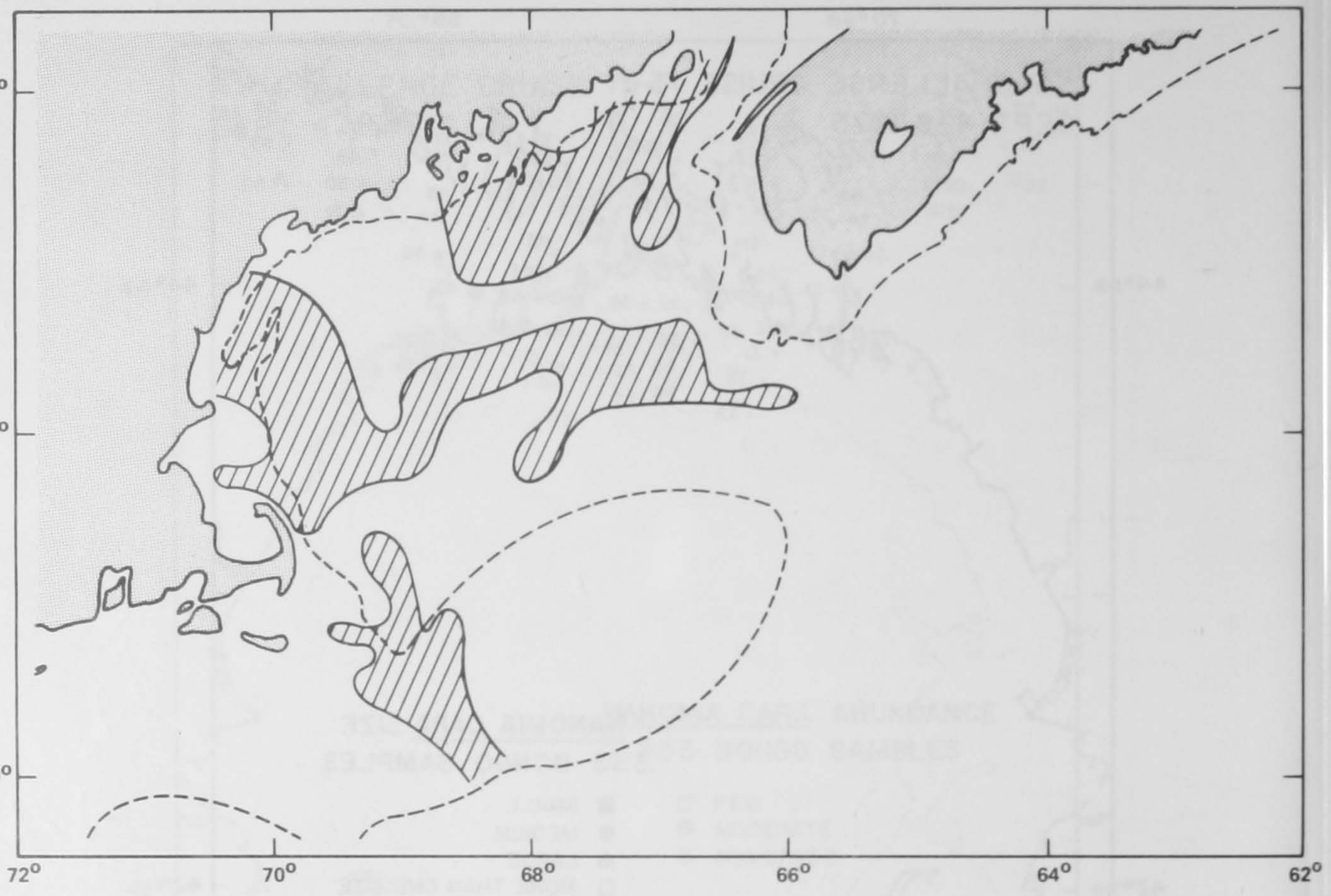

Figure 20.10.—Lipo: moderate/numerous (shaded areas), RV *Albatross IV* 75-12, 7 October-18 November 1975.

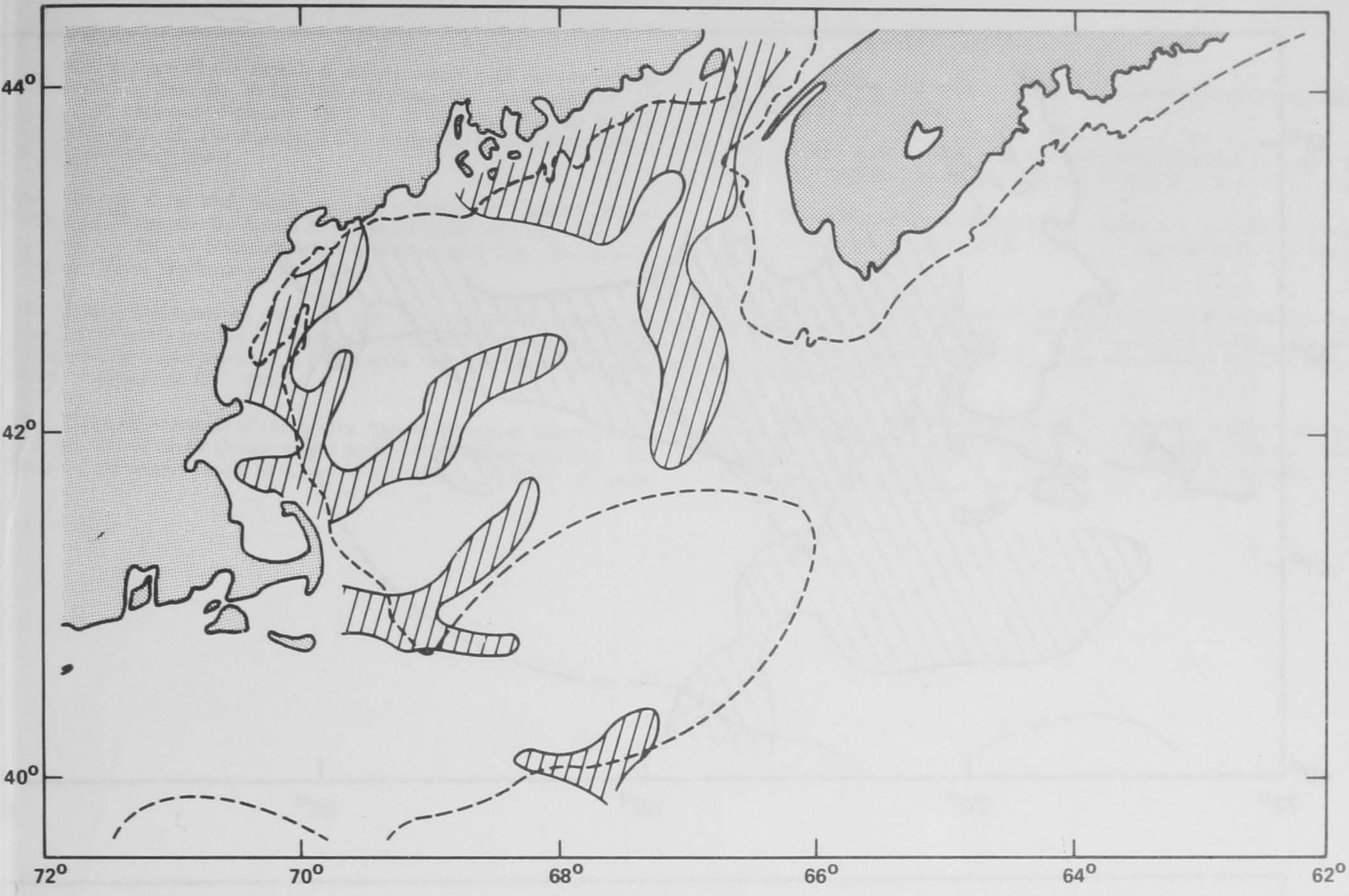

Figure 20.11.—Lipo: medium/large (shaded areas) RV *Albatross IV* 75-12, 7 October-18 November 1975.

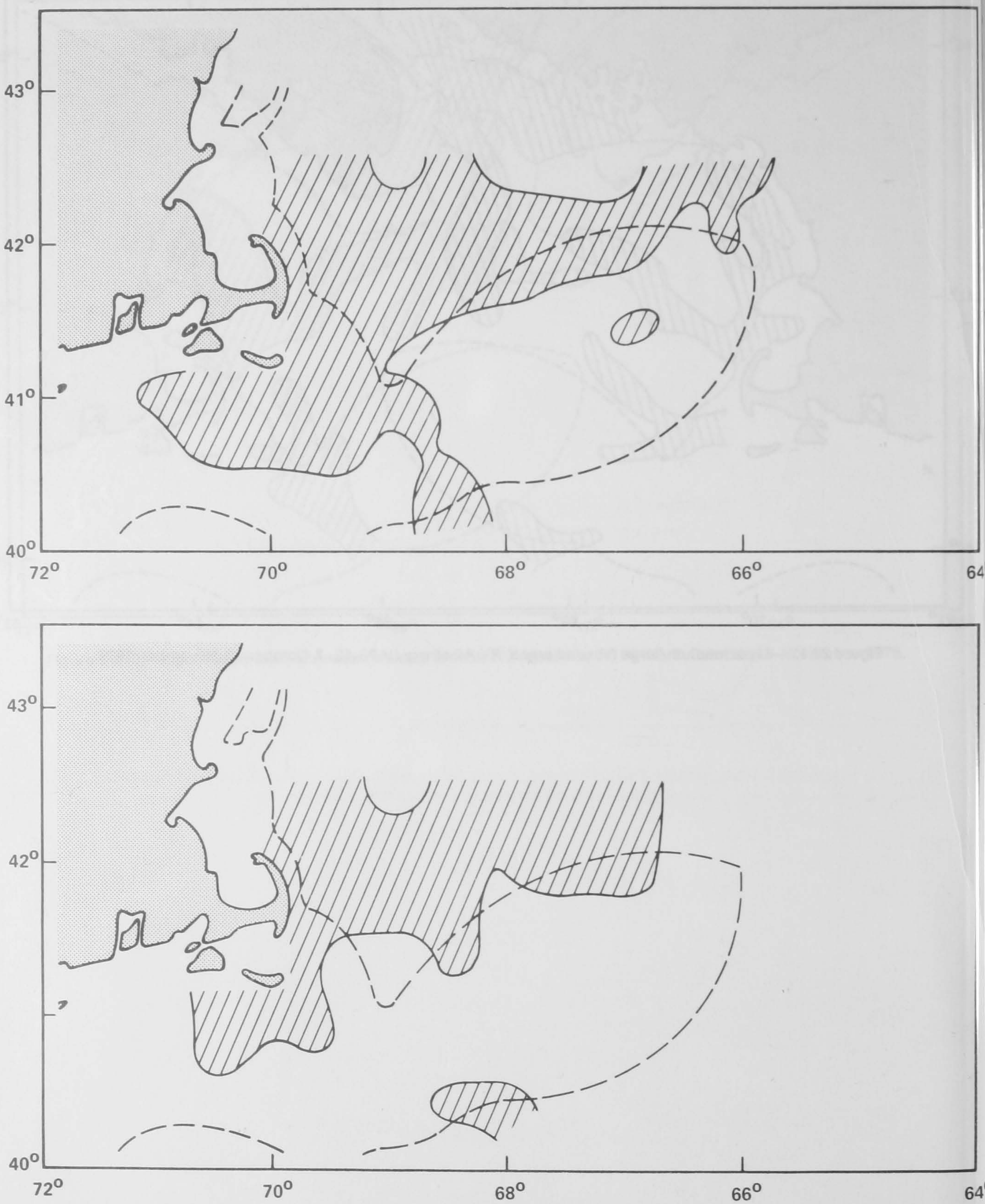

Figure 20.12.—Areas of moderate/numerous (upper) and medium/large (lower) siphonophores, RV *Albatross IV* 75-14, 2-17 December 1975.

☆GPO. 1978-696-707/460-10

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