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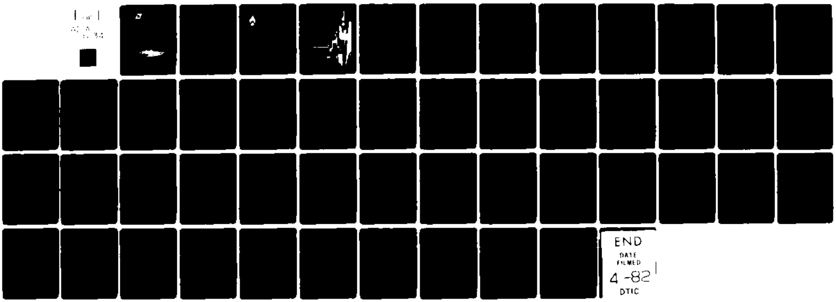

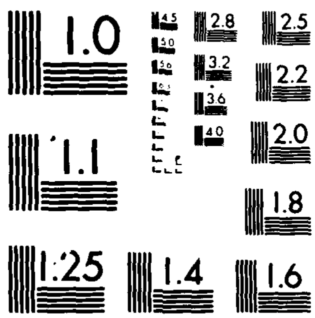

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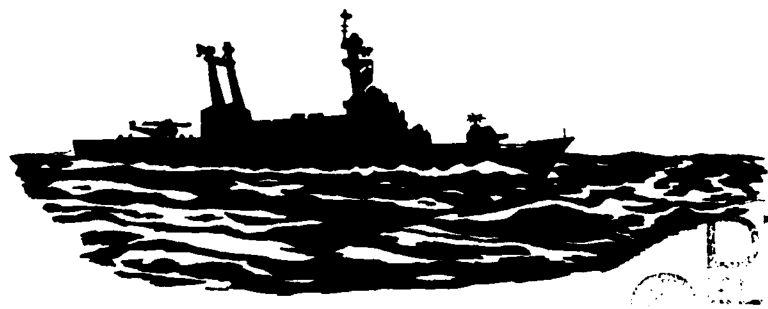
DEPARTMENT OF TRANSPORTATION

COAST GUARD

OCEANOGRAPHIC OBSERVATIONS

NORTH ATLANTIC OCEAN STATION DELTA

TERMINAL REPORT 1966 - 1973



OCEANOGRAPHIC REPORT No. 373-80

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG 573-80	—	

4. Title and Subtitle	5. Report Date
Oceanographic Observations North Atlantic Ocean Station Delta Terminal Report 1966 - 1973	November 1979
	6. Performing Organization Code
7. Author(s): Jones, D.	8. Performing Organization Report No.
9. Performing Organization Name and Address: USCG Oceanographic Unit, Bldg 159 E, Navy Annex, Washington, DC 20593	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Oceanographic data on Ocean Station DELTA is analyzed and presented for the period 1966 to 1973. A typical one year cycle is described. The entire water column () to 1500 meters consists of North Atlantic Central Water during the winter months. Subsurface salinities of greater than 36 ppt are present in significant amounts only in later summer and early fall. During this period the surface salinities are at a yearly minimum. The subsurface salinity maximum is, therefore, not a result of differences between evaporation and precipitation (E-P). This water mass is determined to be of North Atlantic Current origin. The oscillation of the North Atlantic Current from the northwest onto and sometimes across Ocean Station DELTA is a regular feature of this area and varies in intensity from year to year. The oscillation of the North Atlantic Current apparently is controlled by changes in the transport of the Labrador Current and the North Atlantic Current. No appreciable long term changes in temperature and salinity were noted in the seven years of data analyzed.

17. Key Words	18. Distribution Statement
Ocean Station Delta 1966 - 1973 North Atlantic Central Water	Releasable to the public

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLAS	UNCLAS	54	

Form DOT F 1700.7 (8-72)

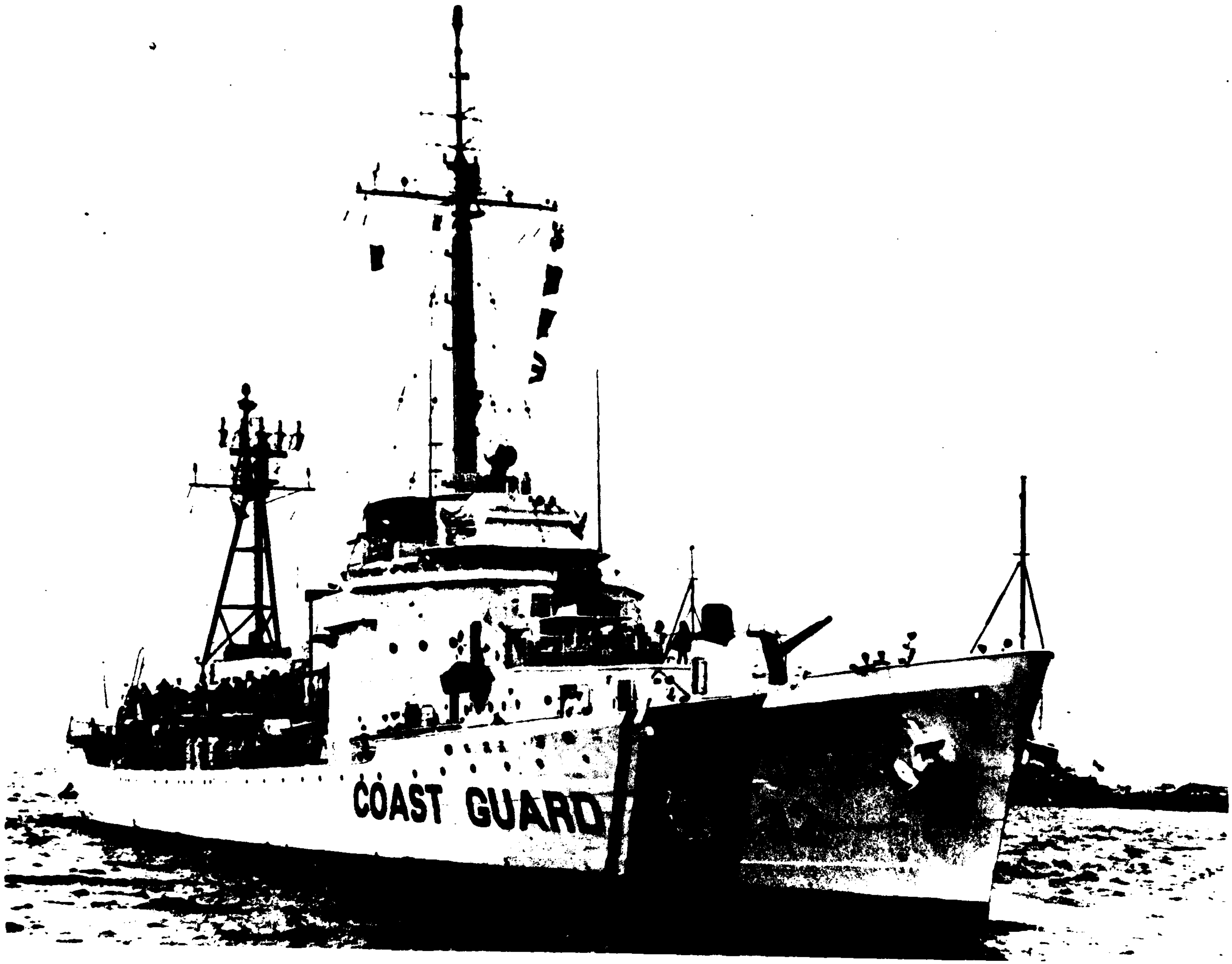
OCEANOGRAPHIC REPORT
No. CG 373 - 80

NORTH ATLANTIC
OCEAN STATION DELTA
TERMINAL REPORT
1966 - 1973

David Jones

November 1979

United States Coast Guard
Oceanographic Unit
Washington, D.C.



USCGC CAMPBELL (WHEC 32)

(44 deg 00 min N, 41 deg 00 min W) parts/thousand

ABSTRACT

Oceanographic data on Ocean Station DELTA is analyzed and presented for the period 1966 to 1973. A typical one year cycle is described. The entire water column (0 to 1500 meters) consists of North Atlantic Central Water during the winter months. Subsurface salinities of greater that 36 ‰ are present in significant amounts only in later summer and early fall. During this period the surface salinities are at a yearly minimum. The subsurface salinity maximum is, therefore, not a result of differences between evaporation and precipitation (E-P). This water mass is determined to be of North Atlantic Current origin. The oscillation of the North Atlantic Current from the northwest onto and sometimes across Ocean Station DELTA is a regular feature of this area and varies in intensity from year to year. The oscillation of the North Atlantic Current apparently is controlled by changes in the transport of the Labrador Current and the North Atlantic Current. No appreciable long term changes in temperature and salinity were noted in the seven years of data analyzed.

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TERMINAL REPORT

1966-1973

by

David T. Jones[1]

INTRODUCTION

The U.S. Naval Oceanographic Office conducted a series of five cruises at Ocean Station DELTA (44°00'N, 41°00'W), between June 1962 and July 1963. The U.S. Coast Guard investigations began during April 1963. The Coast Guard initiated continuous observations at DELTA in July 1966 and terminated all operations on DELTA in June 1973 (Table 1).

Several investigators have reported on the earlier observations (McGary and Morse, 1964; Corton, 1967; Husby, 1969; Hammond, 1973; Hannon, 1976). These reports indicated the complexity of the region due to the presence of several water masses, most notably: water of Gulf Stream origin, Mediterranean water, Subarctic Intermediate water, North Atlantic Deep water, and Labrador Sea water.

This report describes seasonal and long term variations in the conditions at DELTA for 93 cruises from July 1966 to June 1973. Also presented are the individual station listings for 60 cruises from September 1969 to June 1973, the data listings for DELTA not previously published in the Coast Guard Oceanographic Report (CG 373) series. Summaries and listings for the earlier cruises (1966-1969) are contained in the Coast Guard reports cited.

SAMPLING TECHNIQUES

The sampling program at DELTA consisted of daily Nansen bottle casts to a depth of 1500 meters, weather and other operations permitting. On those ships equipped with the Plessey Model 9040 S/T/D *Environmental Profiling System* (STD) the program was one to four STD casts to 1500 meters daily. Nansen equipped ships were directed to take one deep cast per cruise and STD equipped ships were directed to take at least one 3000 meter cast per week.

Quality control and processing procedures were those outlined in Rosebrook (1971). Processed temperature and salinity data for each cruise were submitted to the National Oceanographic Data Center (NODC), Washington, D.C. The interpolated temperatures, salinities, sigma-t values, geopotential anomalies, and sound velocities for the standard depths were computed by NODC and are contained in the station listings in Appendix A.

DISCUSSION

The location of DELTA in relation to the other Atlantic Ocean Stations and the Coast Guard's standard monitoring sections (fig. 1) and DELTA's

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location in relation to the major current systems of the North Atlantic (fig. 2) show the complexity of the region. There is a definite lack of regular sampling in the immediate vicinity of DELTA, and even at the Ocean Station itself, daily sampling was not always possible due to weather or operational requirements.

A total of 1535 oceanographic stations were taken on 97 cruises during the period July 1966 to June 1973 at DELTA. To reduce this large volume of data to a manageable number of points, a computer program was used which calculated the monthly mean temperature and salinity at selected standard depths and provided a T-S plot of the month's stations. For the purpose of describing conditions on DELTA, the computer program discarded any station taken outside a 30 nmi (56 km) radius of station center. The stations that were discarded are included, however, in the listings in Appendix A. While it certainly is advantageous for time series analysis to have almost daily sampling at a single point, there is still the drawback that it is, after all, only one point. Although conditions and variations may be very well documented at that point, nothing is known about the mechanism of the variations without data from surrounding points. Because of the complexity of the region, not even the source of the change can be positively determined without other inputs. Of course, identification of the water masses passing through a point will enable the observer to surmise the circulation mechanism, aided by a reasonable assumption about the surrounding area (Corton, 1967).

DELTA is, for oceanographic purposes, treated as a single geographical point, with the attendant constraints previously mentioned. A further drawback is the dearth of information about the surrounding area. Observers are generally in agreement on the location of the Gulf Stream or North Atlantic Current (NAC) until it reaches about 50°W. East of 50° W theories vary considerably. No one has undertaken a large scale survey to accurately describe the circulation. Although there are standard monitoring sections in the area (fig. 1), most of the occupations of these sections are conducted by, or in support of, the International Ice Patrol (IIP). Consequently, the main interest of these occupations is the dynamic trough between the Labrador and North Atlantic Currents, and sampling is usually ended before the eastern edge of the NAC is located, if the NAC is even reached.

To get some idea of the conditions surrounding DELTA, this report also includes a series of 41 stations which were part of the ROMEOS cruise. The portion of ROMEOS cited consists of a trackline from Ocean Station JULIET to DELTA (fig. 3) and a grid across DELTA (fig. 4) in September 1970. A similar section was taken by CGC GALLATIN in December 1969 (fig. 5). These sections, plus 23 stations from CGC CAMPBELL in June 1972 (Appendix A, Table XLV) during prolonged operations at the WNW edge of DELTA, provided clues to the conditions and circulation around DELTA.

ANALYSIS

DELTA is in an oceanographically complex region. Up to eight different water masses have been identified by various investigations at DELTA (Corton, 1967; Hannon, 1976). The intrusions of some of these water masses were so deep or so infrequent as to have no appreciable influence. The disadvantages of single point sampling previously noted are especially hindering at depth, since so little data are available at depth in any region. Deep water masses have already been adequately discussed in previous DELTA reports, hence this report will deal only with the upper 1500 meters of DELTA.

Annual Cycle

For simplicity, the composition of the water column on DELTA is presented as it varied through a typical annual cycle. The typical cycle is based on repetitive patterns observed in the seven years of data analyzed. These patterns can be seen in figures 6 through 33, the North Atlantic Central Water (NACW) curve (Iselin, 1936), plots of monthly mean temperature and salinity at selected depths, the monthly mean salinity maximum and its depth, the monthly envelopes of temperature and salinity and the monthly T-S envelopes.

Winter

In winter (January, February, March) the water column at DELTA was entirely North Atlantic Central Water (NACW). The T-S envelopes (figs. 11, 13 and 15) show how closely the water column adhered to the NACW curve (fig. 6). Generally the upper 200 meters were isothermal and isohaline (figs. 10, 12 and 14). The intrusion of Mediterranean water was intermittent between 700 and 1000 meters, but not enough to cause a noticeable bulge in the temperature or salinity envelopes. The January envelopes were wider because during some years the annual cycles extended into January before concluding.

Spring

During the spring (April, May, June) NACW still dominated (figs. 17, 19, and 21). During this period the thermocline and halocline began to develop, reaching about 50 meters, indicative of the onset of summer seasonal changes (figs. 16, 18, and 20).

Summer

In summer (July, August, September) the seasonal warming continued, with surface temperatures reaching a maximum during late August or early September (figs. 22 to 27). Surface salinities at the same time reached a minimum. A subsurface salinity maximum developed at 75 meters, as water of higher salinity moved in (figs. 22 to 27).

Fall

During the fall months (October, November, December) seasonal cooling lowered the surface temperature while the subsurface salinity maximum increased and deepened to 150 meters, as higher salinity water continued to move in (figs. 28 to 33). The maximum salinity decreased in October, but increased again in November, and decreased in December, indicating passage of the higher salinity water across DELTA and back again. The subsurface salinity maximum deepened in late December/early January and then disappeared, as the higher salinity water left the area and the water column once again became entirely NACW.

Gulf Stream/North Atlantic Current

The most significant feature noted in the data from DELTA was the regular appearance, in late summer and early fall, of water with a salinity greater than 36 °/oo (fig. 7). At the same time the temperatures in the upper 400 meters were also at an annual maximum (fig. 8). These higher temperatures can be largely attributed to seasonal warming. The higher salinities, however, cannot be related to any seasonal shift in the evaporation minus precipitation (E-P) balance, because the salinity maximum noted (►36 °/oo) was subsurface, while the surface salinity was at an annual minimum, sometimes as low as 34.9 °/oo (figs. 7 and 9). Since this high salinity water was not formed by some climatic variation on DELTA, it must have come from some external source.

In this region the only source of such water is the Gulf Stream, or more properly, that branch known as the North Atlantic Current (NAC). Husby (1969) said the higher salinity was anomalous, while Hammond (1973) attributed it to a change in intensity or position of the North Atlantic Current. Similarly, Corton (1967) concluded that the surface water at DELTA was of Gulf Stream origin, the result of mixing. These three reports were limited by the use of only one year's data. The use of seven years of data permits more definite conclusions as patterns became clear. As previously noted, 36 °/oo water was observed every year at DELTA (fig. 7) at approximately the same time of year. It can also be seen from this figure that the plot of the depth of the salinity maximum agreed fairly well with the plot of the salinity maximum, i.e. as the salinity value increased the depth of the salinity maximum increased. More notably, however, the plot of the depth of the 15 °C isotherm agreed precisely with that of the salinity maximum. When there was no 15 °C isotherm there was no 36 °/oo salinity water. The reverse was not true. The presence of a 15 °C isotherm without the 36 °/oo salinity was always in the late spring/early summer, when seasonal warming was just beginning and the 15 °C isotherm was very shallow, or in the month immediately following the last appearance of 36 °/oo water. Traditionally, the 15 °C isotherm at 200 meters has marked the western boundary of the Gulf Stream (Fuglister and Voorhis, 1965). While no such delineation has been made for the NAC, it would be expected that because of the reduced transport and corresponding horizontal spreading the 15 °C isotherm would be shallower, but still indicative of the North Atlantic Current. Thus the close correlation of the 15 °C isotherm and 36 °/oo isohaline showed that NAC, or a filament of it, appeared on DELTA each year from 1966 through 1972.

Circulation

Having identified the source of the most significant feature, the next step logically is the mechanism by which it comes and goes at DELTA. Again the problem was encountered that little was known about what happened to the NAC east of 50°W longitude and, of course, the nagging constraints of single point sampling. From which direction did NAC approach DELTA, and how?

The possibility of a meander or eddy was rejected because the feature occurred too regularly to have been so random a phenomenon. Analysis of the monthly mean wind at DELTA for the seven years involved showed no pattern or correlation with the NAC intrusion. Hence it was assumed that this feature regularly approached DELTA from the same direction each year.

Neumann and Pierson (1966, p. 443) indicated that annual surface salinity variations in the northwestern Atlantic Ocean are not dependent on differences in (E-P). They suggested that the Labrador Current injected its salinity into the NAC, which spread its characteristics by mixing and turbulent diffusion in the northeasterly and southeasterly directions. This correlated very well with the salinity profiles at DELTA during August, September, October and November (figs. 24, 26, 28, 30) with very low surface salinities and subsurface salinity maxima of NAC origin (►36 °/oo). Since the Labrador Current is northwest of DELTA, it could be postulated that the mixing and turbulent diffusion in the southeasterly direction was the cause of this salinity structure at DELTA. This was further supported by the data collected on the ROMEOS cruise in September, 1970 (fig. 4). Only stations 140, 141 and 142 had a salinity over 36 °/oo, which placed the NAC northwest of DELTA. At the same time the time series salinity plots (fig. 7 and 9) showed the NAC had not yet reached DELTA in September, but did in October. In addition, the contours of dynamic depth anomaly (fig. 4) showed a current flowing to the southwest, which was consistent with the counter currents expected at the eastern and western edge of the northeasterly flowing NAC. This was a further indication that the NAC was just to the westnorthwest of DELTA, but moving towards it. In addition, the occupation of CGC CAMPBELL in June, 1972 (Appendix A, Table XLV) was spent entirely at the northwest limits of DELTA. The stations from this cruise show significant amounts of 36 °/oo water, again to the northwest of DELTA but not yet actually on it.

Fuglister (1951) depicted the annual variation in Gulf Stream flow as reaching a maximum in June-July, then decreasing steadily to a minimum in October-November. Data from IIP and other Coast Guard cruises indicated that the transport of the Labrador Current showed a sharp annual increase in June from the lower winter values. The volume flow increased from winter values of about 3 sverdrups to sometimes as much as 11 to 12 sverdrups. Data unfortunately was too sparse to trace this increase later into the summer. The timing of the variation in flow of these two currents suggested the mechanism of the appearance of the NAC at DELTA and the accompanying salinity structure.

The NAC, as an extension of the Gulf Stream (fig. 2), has a flow variation similar to that of the parent current, decreasing in August through October. At the same time the transport of the Labrador Current has just sharply increased. At the intersection of the two currents the mixing and diffusion depicted by Neumann and Pierson (1966) occurred. A mechanism similar to that described by McLellan et. al. (1953) for the formation of slope water, and the surface mixing, would produce the lower surface salinities later found at DELTA. At the same time the NAC moved or was pushed to the southeast as its flow decreased. This southeasterly movement brought the NAC to DELTA. Later in the fall, as the flow of the NAC increased again, and the Labrador Current transport decreased, the NAC began to move back to the northwest, pushing the Labrador Current. With the departure of NAC, the 36 °/oo salinity water was no longer seen at DELTA, and the cycle was completed.

Correlation

Like any natural phenomenon, this cycle at DELTA varied in intensity from year to year, but still the basic cycle was seen in each of the seven years studied. This variation was indicated in figure 7 as the intrusion of the subsurface salinity maximum of the NAC ranged from well over 36 °/oo for up to six months (1967) to just barely over 36 °/oo for only two months (1970). Correlation of extremes within the cycle with external sources reinforced the hypothesis of the mechanism involved.

It was evident from figure 7 that the NAC presence at DELTA in 1967 was very intense and long. That year the oceanographic report on the cruises of the International Ice Patrol (IIP) (Morgan and Kelley 1969) showed the dynamic trough was much further south than indicated on the normal charts (Soule, 1964). So too, evidently, was the NAC. By the same token, in 1970, figure 7 shows that the NAC intrusion was very slight and of short duration. The IIP oceanographic summary for that year (Ettle and Wolford, 1972) shows the dynamic trough further north than the normal charts. Thus the intensity of the NAC intrusion at DELTA can vary as it is influenced by several factors: variation from year to year in the flow of the Gulf Stream and/or Labrador Current, residual effects when the interface was much farther north or south then normal when the cycle ended the previous year, or even a prolonged period with the wind from the same direction. All these factors aid or retard the movement of the NAC towards DELTA.

In some years the NAC intrusion at DELTA apparently passed entirely across DELTA as it moved southeasterly, so the water column on DELTA at that point was primarily mixed water from the western side of the NAC. Then, the NAC could be seen moving back across DELTA and NACW once more dominated the water column. This is evident from the monthly maximum mean salinities (fig. 7) and the monthly mean salinities at selected standard depths from 0 to 400 meters (fig. 9). In these figures it was noted that the maximum salinity decreased in October or November, increased the following month and decreased again the month after. This could be seen in 1968, 1969, 1971, and 1972. Even in 1967, when the NAC intrusion was greatest, this oscillation was evident from the drop in salinity in October, although the western edge never passed through DELTA. In 1970 there was such a small intrusion that the oscillation was not evident. Further correlation came from a special section of CGC GALLATIN in early December 1969 (fig. 5). The section was essentially the same track as the ROMEOS cruise previously mentioned from JULIET to DELTA, but without the extra grid of stations across DELTA. The only stations with a salinity over 36 °/oo were 14 through 18, northeast of DELTA. This agreed with the salinity maxima (fig. 7 and 9), indicating that the NAC had moved in an easterly direction and completely across DELTA. Later the NAC moved back across DELTA to the west-northwest, as indicated by the salinity fluctuation (fig. 7), completing the annual cycle.

Long Term Variation

The time series plots (fig. 7, 8, 9) show the considerable seasonal variation at DELTA. No appreciable long term changes were noted in conditions at DELTA. This is contrary to the recent cooling and freshening trend observed in regions to the northwest (Shuhy, 1974). The NAC, however, to the northwest of DELTA, would act as a buffer, minimizing the effects of this trend at DELTA.

SUMMARY

From the data presented herein, and the external sources cited, a distinct circulation pattern was defined for DELTA. The NAC was shown to oscillate annually across DELTA, with varying intensity. The mechanism of this oscillation was controlled by the annual decrease in the flow of the NAC coupled with the increased flows of the Labrador Current. Resultant mixing and horizontal diffusion produced the salinity structure seen at DELTA in later summer and early fall. This salinity structure was seen moving southeast to DELTA, where it appeared during all seven years studied. Some years the NAC oscillation was of sufficient intensity to pass completely across DELTA, so that mixed water from the western side of the NAC dominated the upper water column until the NAC moved back across DELTA.

Significantly, no long term changes in temperature and salinity were observed at DELTA. This was a further indication of the NAC effect at DELTA, buffering DELTA from observed changes in nearby regions. The regular oscillation of the NAC is the significant feature of this area. Further study in adjacent areas might define the circulation more precisely, possibly quantifying it.

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TABLE 1. Summary of Oceanographic Observations on Ocean Station DELTA (44°N, 41°W), 1963 to 1973.

CRUISE NUMBER	COAST GUARD CUTTER	DATES	NUMBER OF STATIONS	NODC REFERENCE NUMBER
D-1	CGC CASCO	03/28/63-04/19/63	23	31-0502
D-2	CGC ESCANABA	07/15/66-08/02/66	18	31-0699
D-3	CGC CAMPBELL	08/27/66-09/16/66	13	31-0762
D-4	CGC HUMBOLDT	10/12/66-11/02/66	17	31-0772
D-5	CGC CHINCOTEAGUE	11/26/66-12/17/66	16	31-0826
D-6	CGC DUANE	01/10/67-01/31/67	11	31-0850
D-7	CGC CASCO	03/20/67-04/11/67	23	31-0888
D-8	CGC OWASCO	05/26/67-06/17/67	20	31-1082
D-9	CGC SPENCER	07/11/67-08/03/67	18	31-1091
D-10	CGC INGHAM	08/24/67-09/16/67	18	31-1158
D-11	CGC CHINCOTEAGUE	09/22/67-10/10/67	14	31-1171
D-12	CGC ESCANABA	10/11/67-11/03/67	22	31-1176
D-13	CGC OWASCO	11/26/67-12/19/67	10	31-1184
D-14	CGC ABSECON	01/11/68-02/03/68	6	31-1202
D-15	CGC CASCO	02/26/68-03/20/68	19	31-1210
D-16	CGC ABSECON	03/20/68-04/12/68	9	31-1238
D-17	CGC COOK INLET	04/18/68-05/05/68	19	31-1241
D-18	CGC DALLAS	05/05/68-05/28/68	23	31-1265
D-19	CGC CASTLEROCK	05/28/68-06/20/68	19	31-1269
D-20	CGC HAMILTON	06/20/68-07/13/68	13	31-8042
D-21	CGC DALLAS	07/13/68-08/05/68	23	31-1339
D-22	CGC COOK INLET	08/05/68-08/26/68	14	31-1316
D-23	CGC ABSECON	08/26/68-09/18/68	19	31-1319
D-24	CGC ESCANABA	09/18/68-10/11/68	10	31-1323
D-25	CGC CASCO	10/11/68-11/03/68	10	31-1348
D-26	CGC CHASE	11/03/68-11/24/68	10	31-8072
D-27	CGC ANDROSCOGGIN	11/24/68-12/14/68	18	31-8074
D-28	CGC DALLAS	12/14/68-01/09/69	24	31-1414
D-29	CGC MCCULLOCH	01/09/69-02/01/69	6	31-1404
D-30	CGC DUANE	02/01/69-02/24/69	12	31-1425
D-31	CGC DALLAS	02/24/69-03/19/69	14	31-1422
D-32	CGC ESCANABA	04/11/69-05/04/69	42	31-8095
D-33	CGC CASTLEROCK	05/04/69-05/27/69	15	31-1456
D-34	CGC HALF MOON	05/27/69-06/19/69	22	31-1450
D-35	CGC BIBB	06/19/69-07/12/69	18	31-1482
D-36	CGC INGHAM	07/12/69-08/04/69	9	31-1519
D-37	CGC YAKUTAT	08/04/69-08/27/69	40	31-8124
D-38	CGC GALLATIN	08/27/69-09/19/69	22	31-1539
D-39	CGC COOK INLET	09/19/69-10/12/69	29	31-8129
D-40	CGC YAKUTAT	10/12/69-11/04/69	64	31-8147
D-41	CGC GALLATIN	11/04/69-11/27/69	22	31-8135
D-42	CGC DUANE	11/27/69-12/20/69	1	31-1527
D-43	CGC MCCULLOCH	12/20/69-01/12/70	11	31-1582
D-44	CGC MORGENTHAU	01/12/70-02/04/70	11	31-8152
D-45	CGC COOK INLET	02/04/70-02/27/70	39	31-8156
D-46	CGC CASTLEROCK	02/27/70-03/22/70	14	31-1610
D-47	CGC OWASCO	03/22/70-04/14/70	12	31-1616
D-48	CGC CHINCOTEAGUE	04/14/70-05/12/70	20	31-1625
D-49	CGC MCCULLOCH	05/12/70-05/30/70	18	31-8163

CRUISE NUMBER	COAST GUARD CUTTER	DATES	NUMBER OF STATIONS	NODC REFERENCE NUMBER
D-50	CGC MORGENTHAU	05/30/70-06/22/70	9	31-1641
D-51	CGC INGHAM	06/22/70-07/15/70	14	31-1664
D-52	CGC ESCANABA	07/15/70-08/07/70	30	31-8181
D-53	CGC OWASCO	08/07/70-08/30/70	16	31-8176
D-54	CGC DUANE	08/30/70-09/22/70	7	31-1688
D-55	CGC DALLAS	09/22/70-10/15/70	6	31-1687
D-56	CGC MCCULLOCH	10/15/70-11/07/70	9	31-1745
D-57	CGC BOUTWELL	11/07/70-11/30/70	54	31-8234
D-58	CGC ANDROSCOGGIN	11/30/70-12/22/70	11	31-8236
D-59	CGC OWASCO	12/22/70-01/14/71	4	31-1790
D-60	CGC SEBAGO	01/14/71-02/06/71	10	31-8250
D-61	CGC CHASE	02/06/71-03/01/71	21	31-8262
D-62	CGC OWASCO	03/01/71-03/24/71	8	31-1810
D-63	CGC INGHAM	03/24/71-04/16/71	12	31-1826
D-64	CGC CHINCOTEAGUE	04/18/71-05/09/71	20	31-8266
D-65	CGC ABSECON	05/09/71-06/01/71	18	31-1857
D-66	CGC GALLATIN	06/01/71-06/24/71	31	31-8268
D-67	CGC SEBAGO	06/24/71-07/14/71	16	31-1882
D-68	CGC MENDOTA	07/14/71-08/04/71	12	31-1877
D-69	CGC MCCULLOCH	08/04/71-08/27/71	14	31-1918
D-70	CGC INGHAM	08/27/71-09/20/71	6	31-1912
D-71	CGC ESCANABA	09/20/71-10/14/71	12	31-1926
D-72	CGC BIBB	10/14/71-11/07/71	15	31-1927
D-73	CGC CAMPBELL	11/07/71-12/01/71	15	31-1928
D-74	CGC SEBAGO	12/01/71-12/21/71	12	31-1929
D-75	CGC MENDOTA	12/21/71-12/31/71	6	31-1930
D-76	CGC CAMPBELL	01/12/72-02/03/72	9	31-1970
D-77	CGC OWASCO	02/03/72-02/27/72	16	31-8301
D-78	CGC ANDROSCOGGIN	02/27/72-03/24/72	12	31-2083
D-79	CGC CHASE	03/24/72-04/19/72	21	31-8302
D-80	CGC DUANE	04/19/72-05/13/72	8	31-2076
D-81	CGC ANDROSCOGGIN	05/13/72-06/02/72	14	31-2078
D-82	CGC CAMPBELL	06/02/72-06/26/72	23	31-2084
D-83	CGC ESCANABA	06/26/72-07/20/72	20	31-8314
D-84	CGC MUNRO	07/20/72-08/15/72	24	31-2114
D-85	CGC HAMILTON	08/17/72-09/08/72	18	31-2128
D-86	CGC DUANE	09/08/72-10/02/72	18	31-2129
D-87	CGC MUNRO	10/02/72-10/28/72	17	31-2130
D-88	CGC TANEY	10/28/72-11/17/72	3	31-2143
D-89	CGC CHAUTAUQUA	12/14/72-01/04/73	9	31-2122
D-90	CGC ESCANABA	01/04/73-01/26/73	2	31-2120
D-91	CGC BIBB	01/26/73-02/15/73	12	31-2164
D-92	CGC OWASCO	02/15/73-03/09/73	12	31-2184
D-93	CGC INGHAM	03/09/73-03/27/73	8	31-2203
D-94	CGC CAMPBELL	03/27/73-04/19/73	12	31-2178
D-95	CGC PONCHARTRAIN	04/19/73-05/11/73	12	31-2196
D-96	CGC MORGENTHAU	05/11/73-06/06/73	18	31-2218
D-97	CGC CAMPBELL	06/06/73-06/30/73	14	31-2231

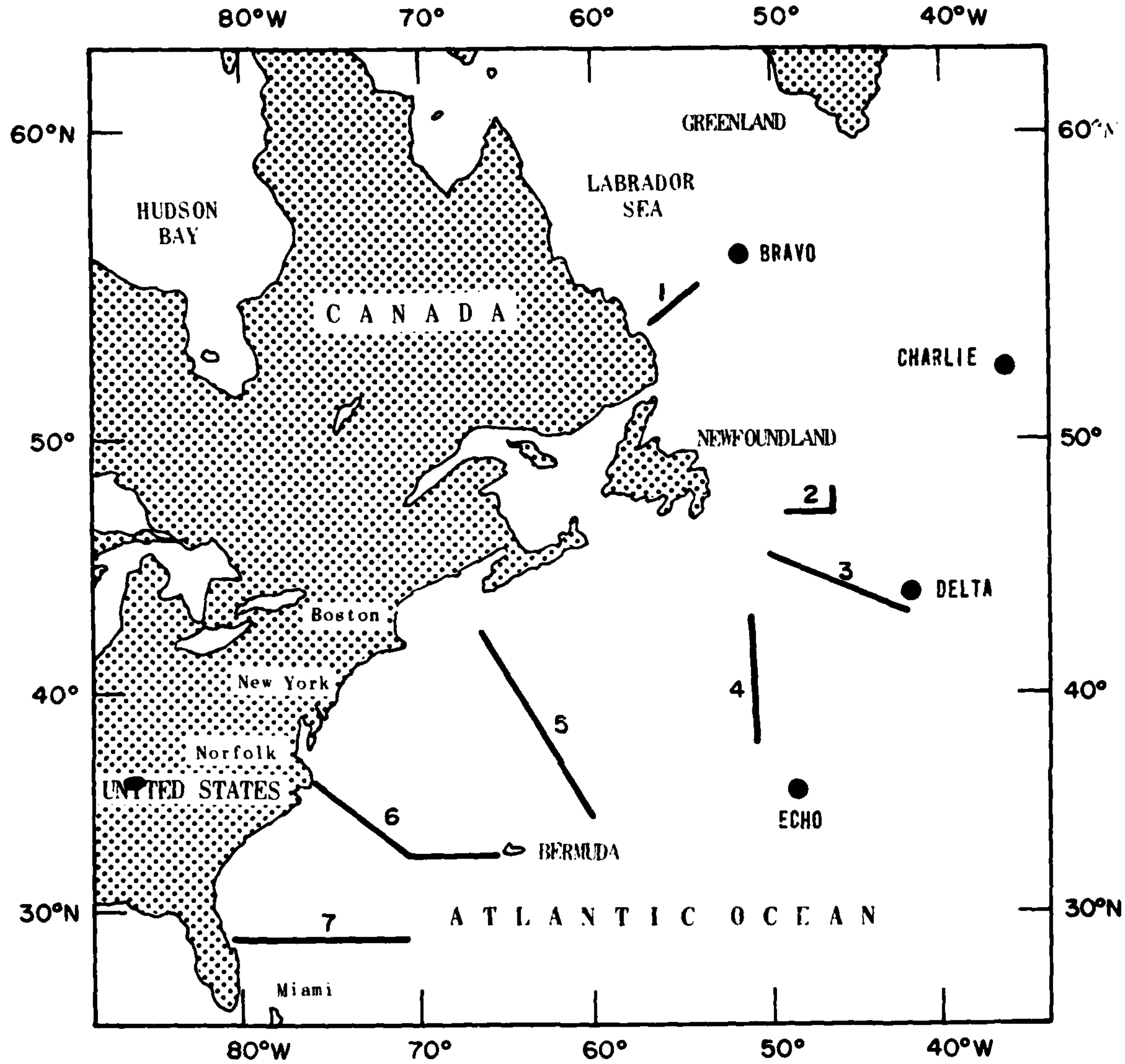

Figure 1.—U.S. Coast Guard North Atlantic Ocean Stations and Standard Monitoring Sections, 1966-1973.

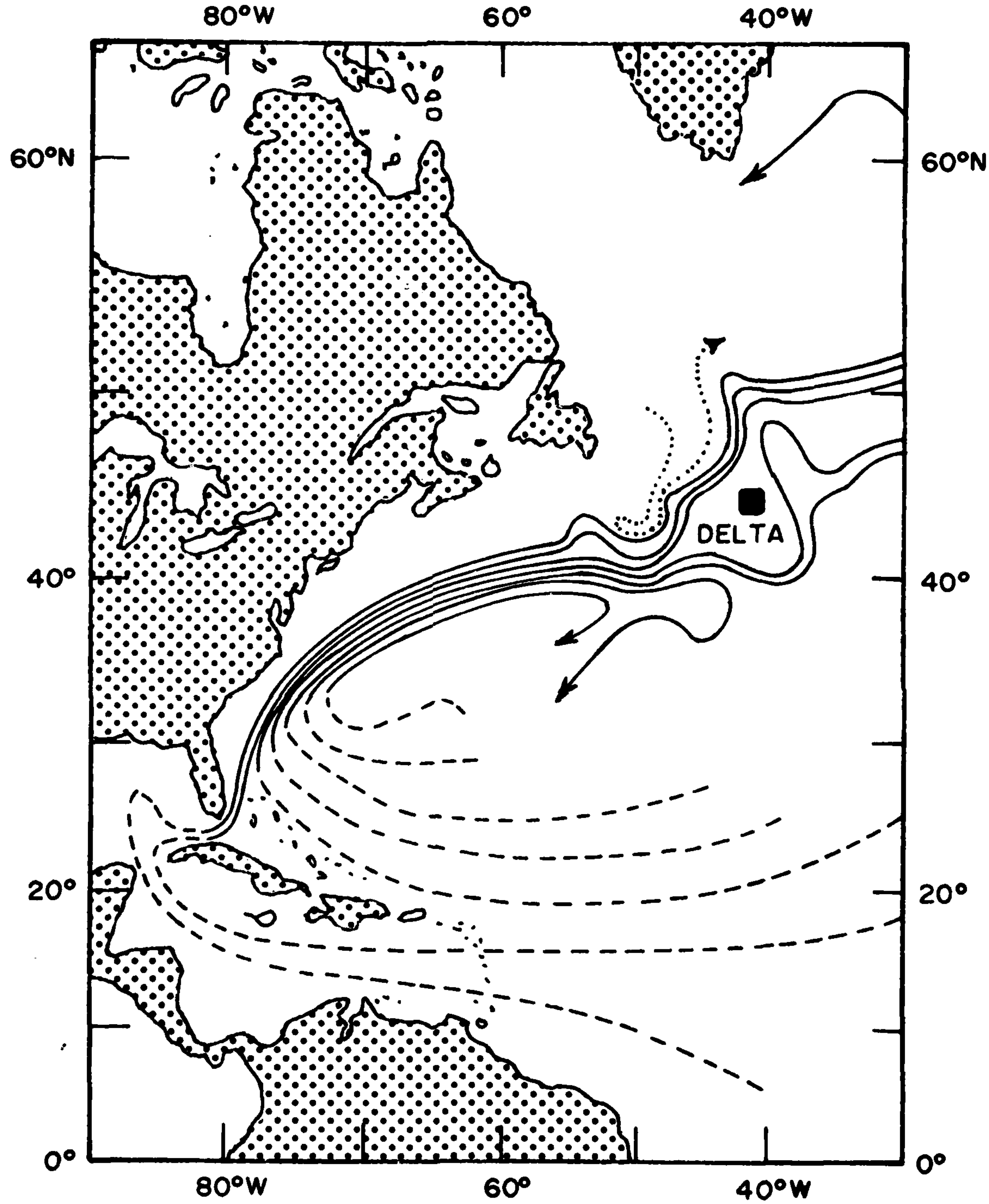

Figure 2.—Ocean Station DELTA and major North Atlantic currents (after Iselin, 1936).

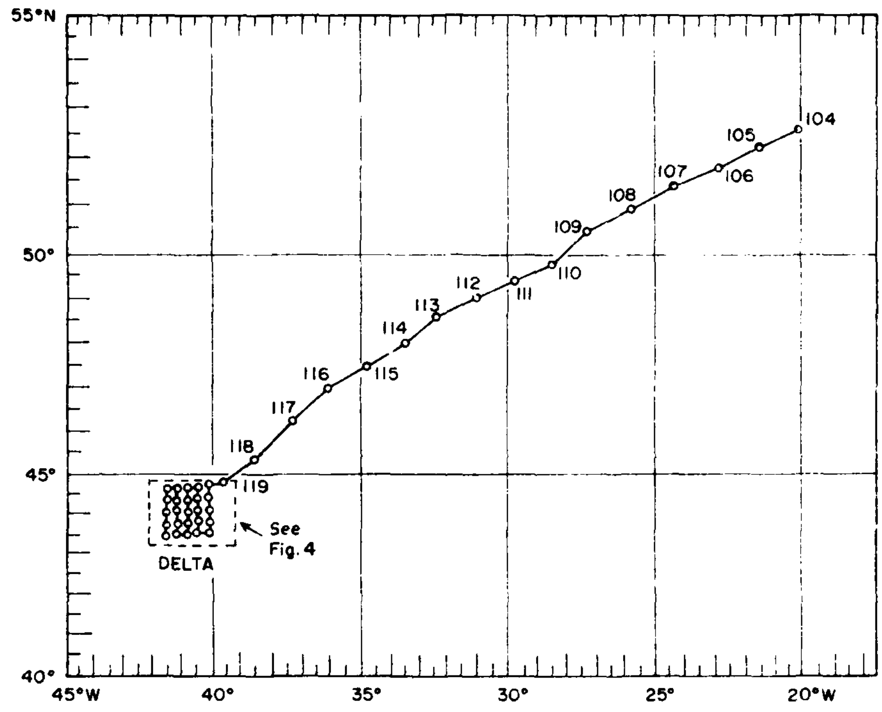

Figure 3.—ROMEOS stations from Ocean Station JULIET to Ocean Station DELTA, September 1970.

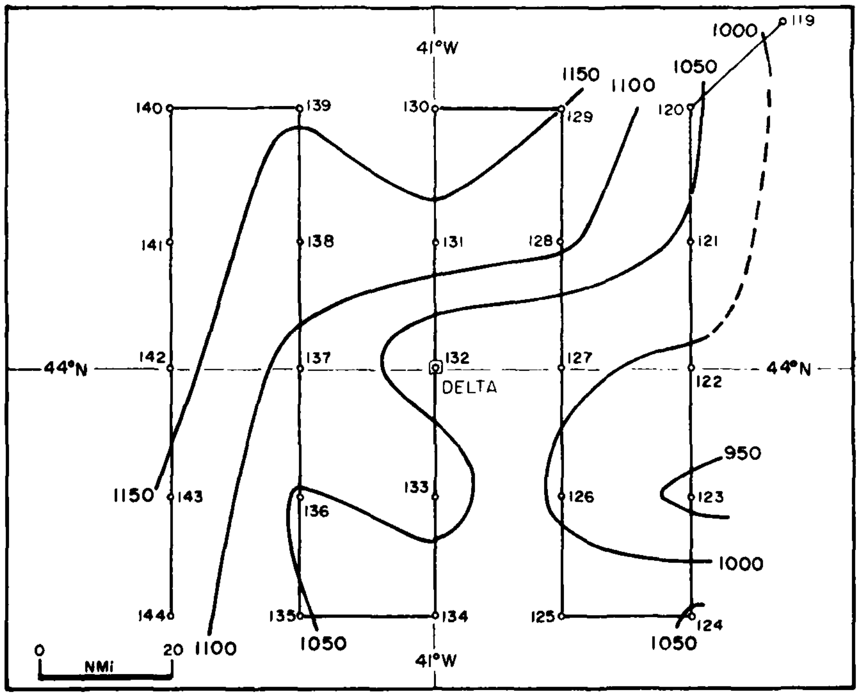

Figure 4.—ROMEOS station grid on Ocean Station DELTA, and the dynamic depth anomaly contours (x10³), September 1970.

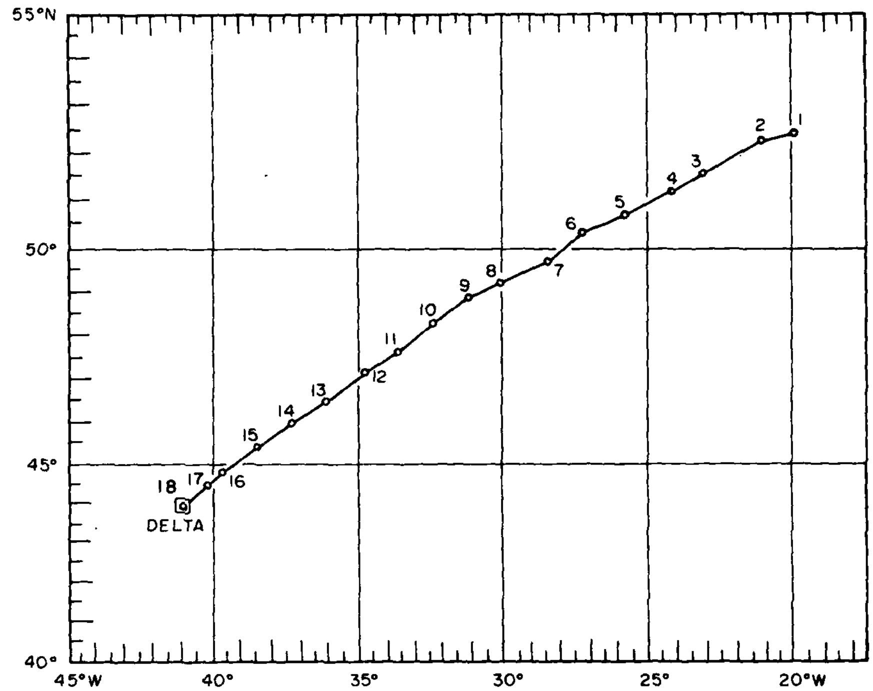

Figure 5.—USCGC GALLATIN stations from Ocean Station JULIET to Ocean Station DELTA, December 1969.

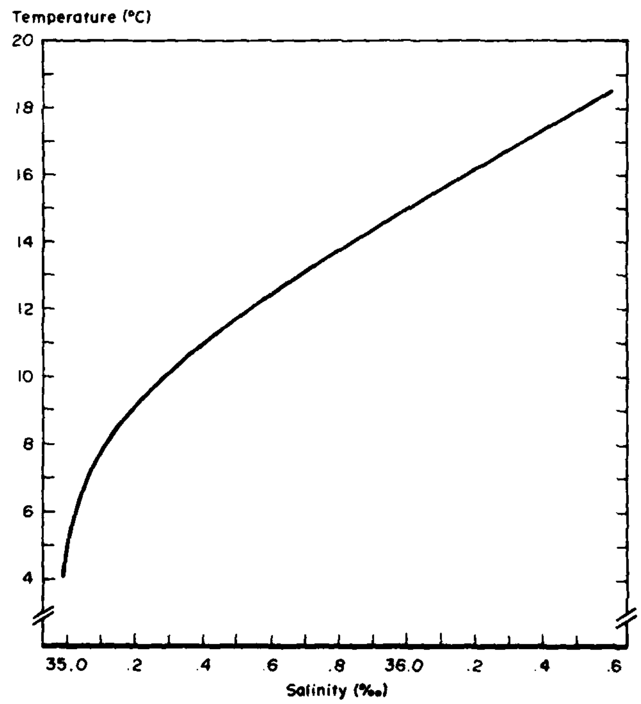

Figure 6.—T-S curve for North Atlantic Central Water (NACW) (after Iselin, 1936).

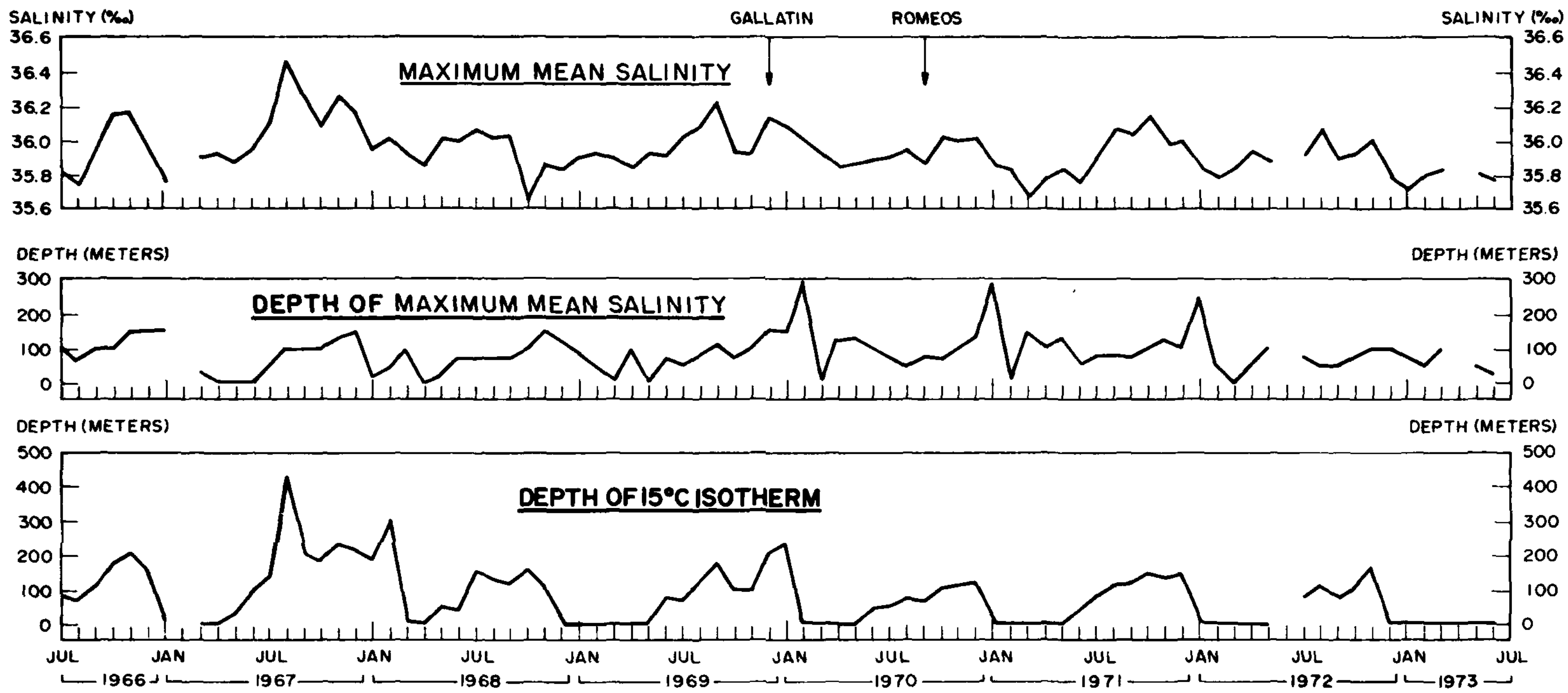

Figure 7.—Plot of monthly mean salinity maximum, depth of the salinity maximum and depth of 15°C isotherm for Ocean Station DELTA (44°N, 41°W), July 1966—June 1973.

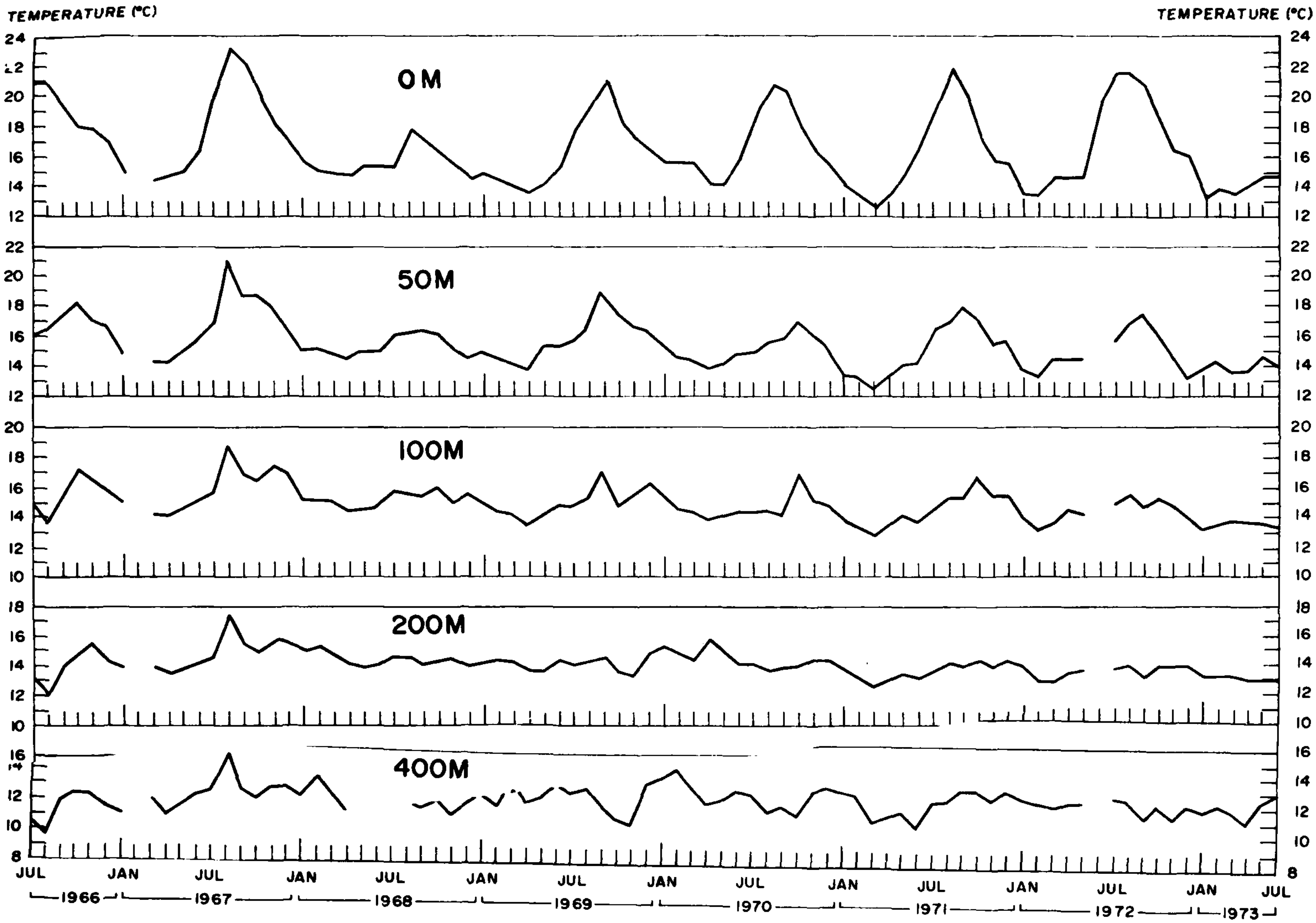

Figure 8.—Plot of monthly mean temperature at 0, 50, 100, 200, 400m for Ocean Station DELTA (44°N, 41°W), July 1966—June 1973.

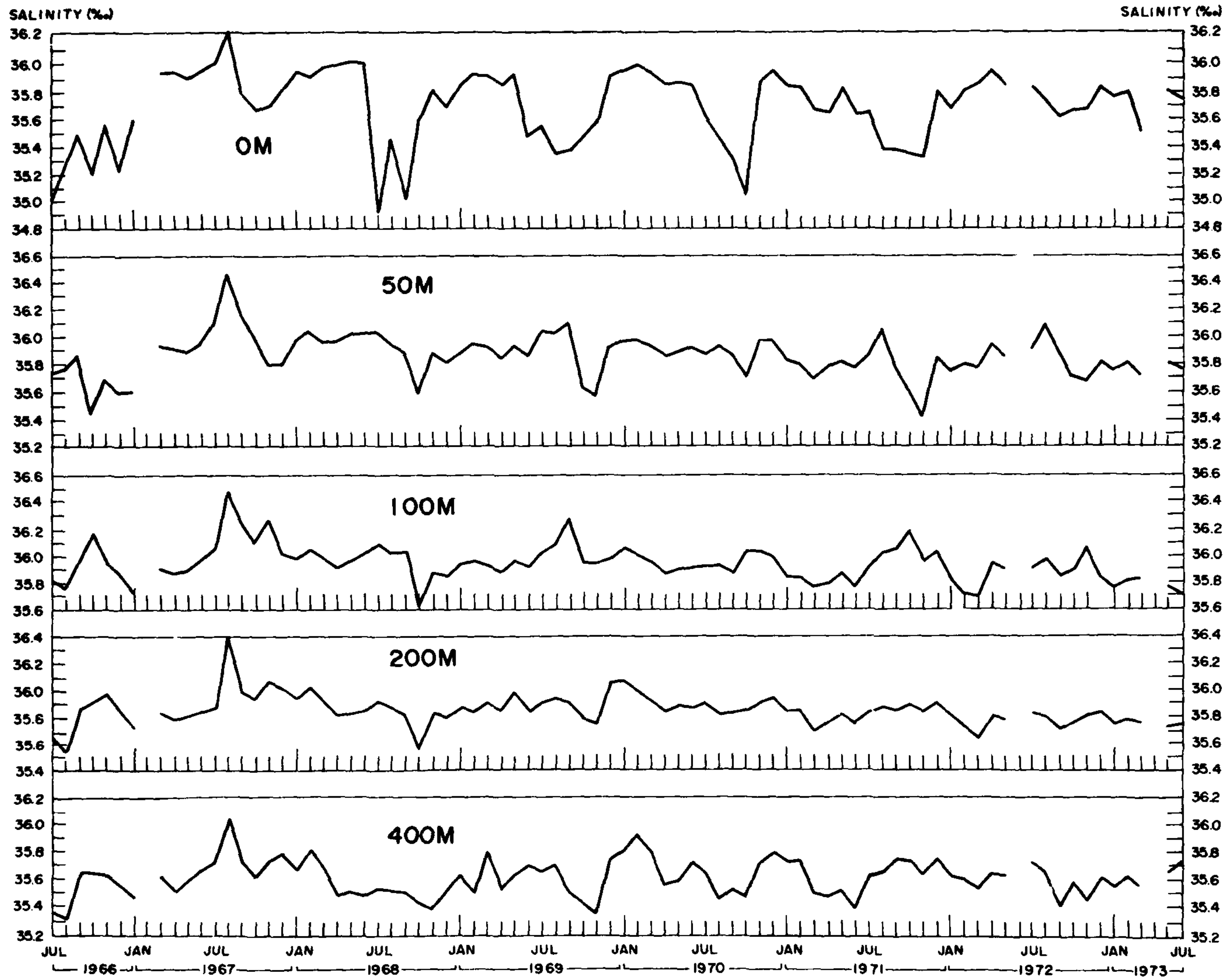

Figure 9.—Plot of monthly mean salinity at 0, 50, 100, 200, 400m for Ocean Station DELTA (44°N, 41°W), July 1966—June 1973.

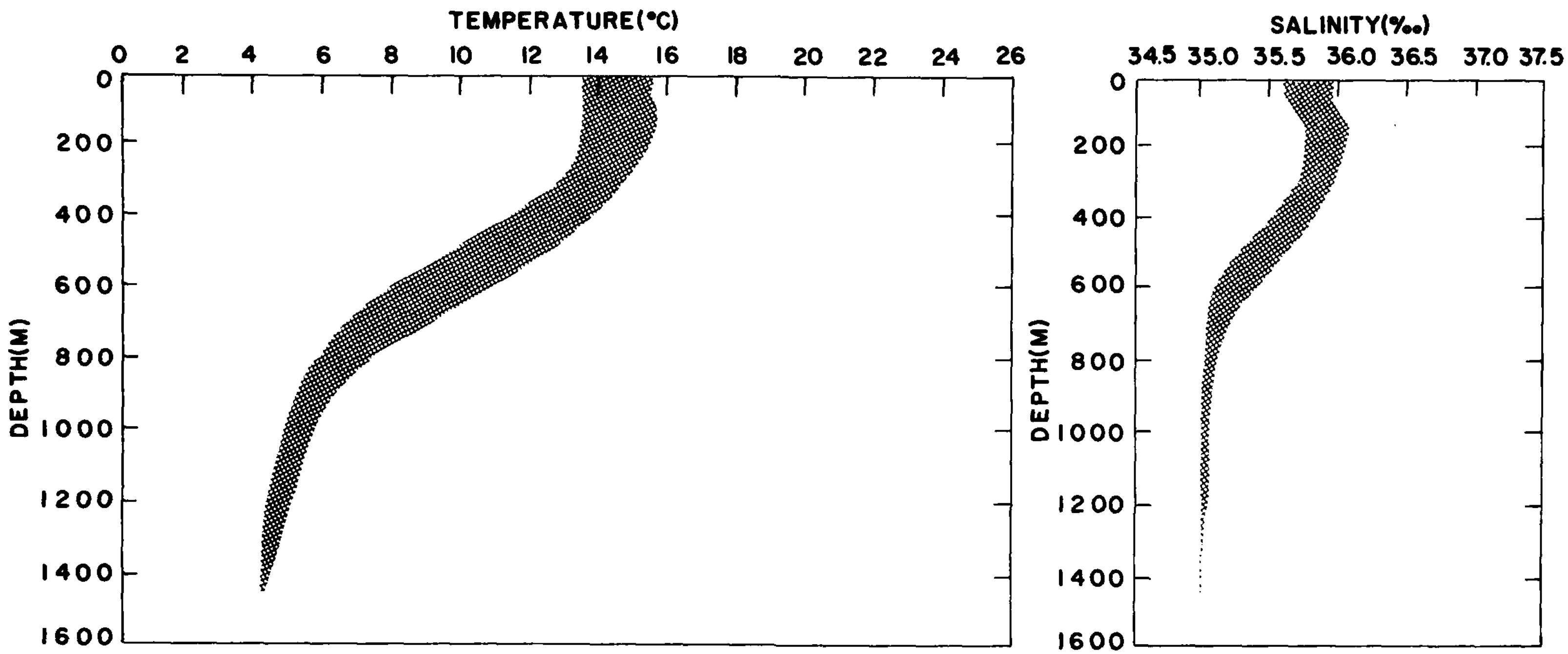

Figure 10.—January vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1967—1973.

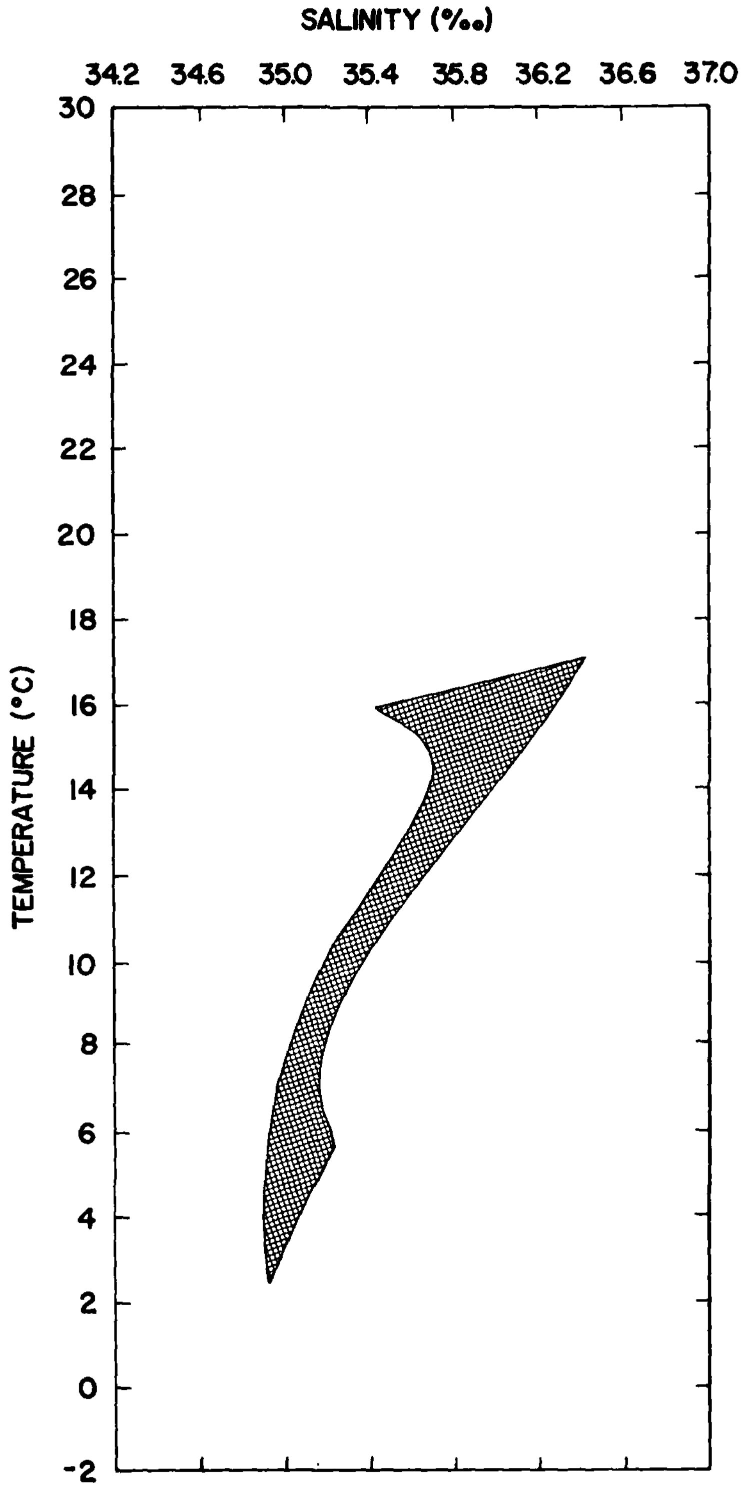

Figure 11.—January T-S envelope for Ocean Station DELTA (44°N, 41°W), 1967—1973.

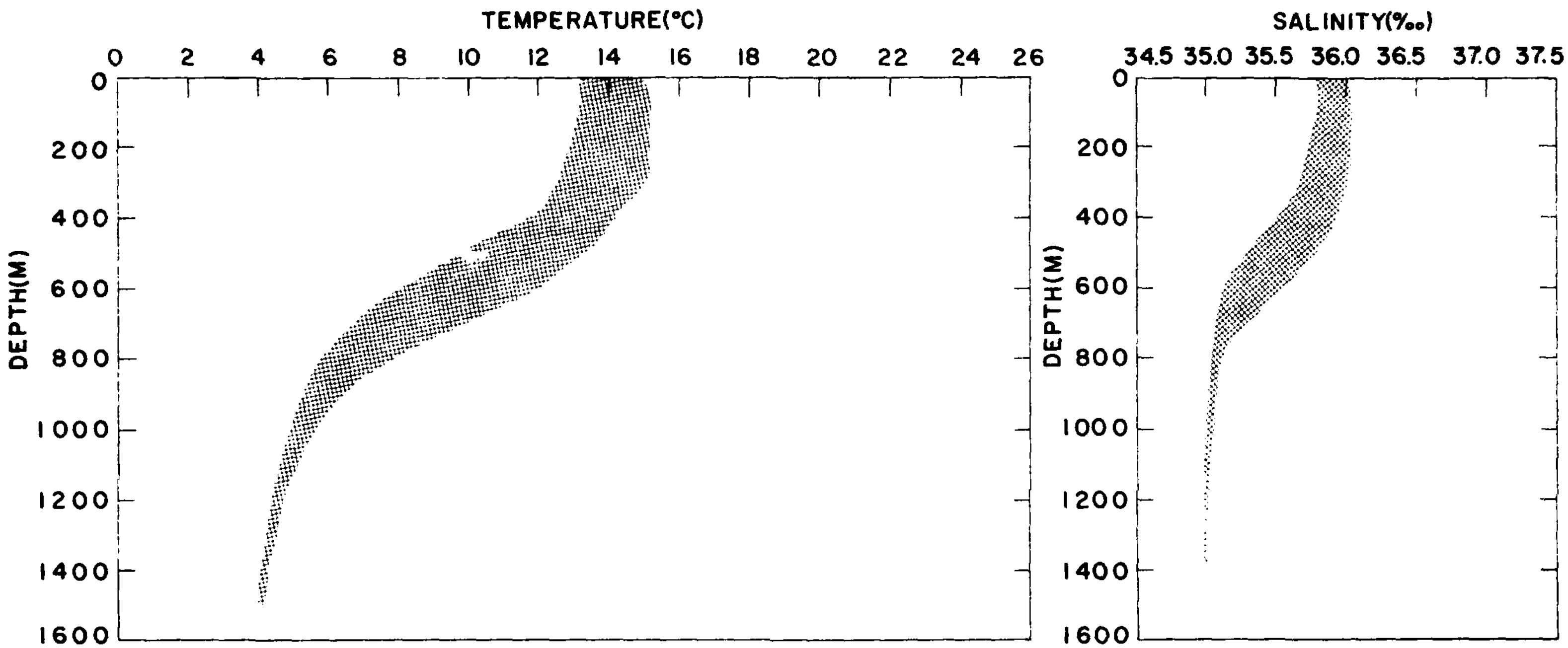

Figure 12.—February vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1968—1973.

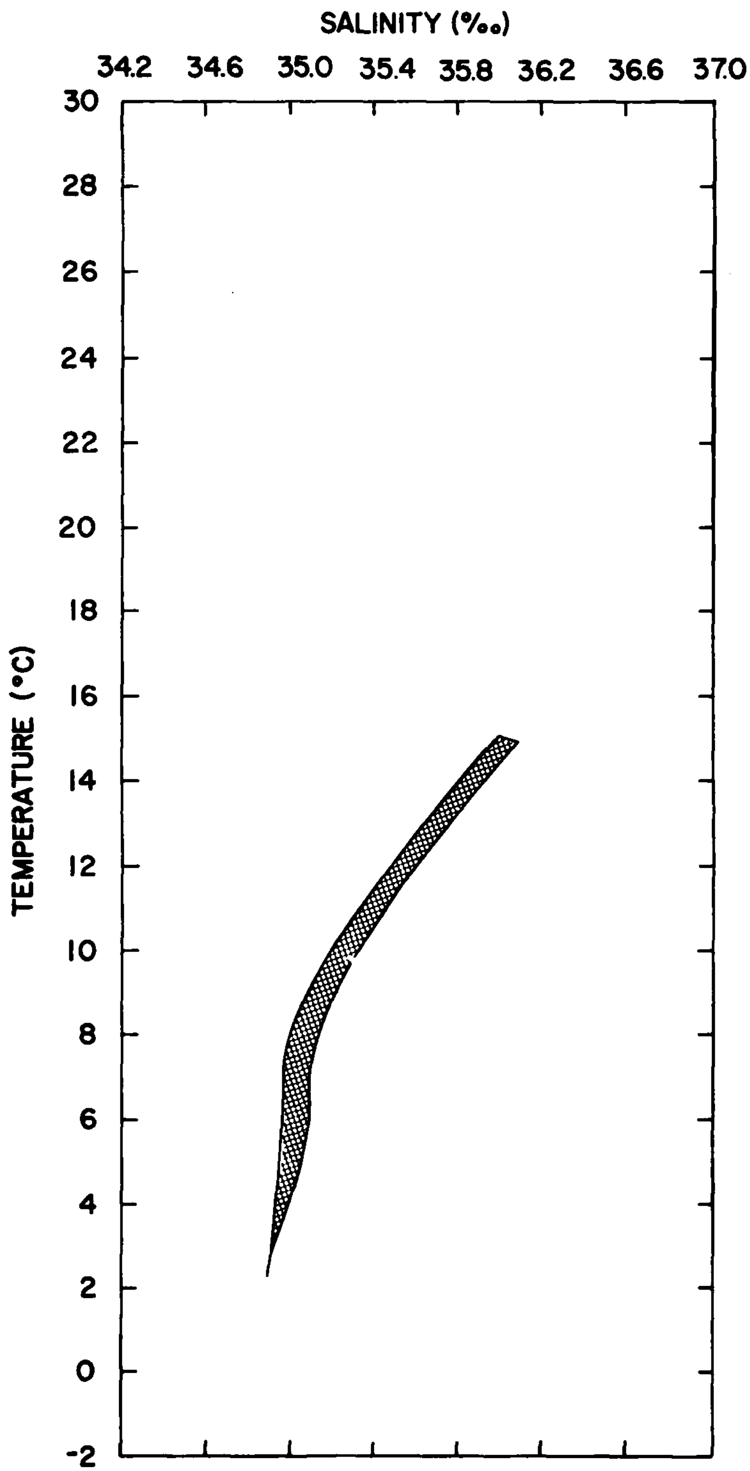

Figure 13.—February T-S envelope for Ocean Station DELTA (44°N, 41°W), 1968—1973.

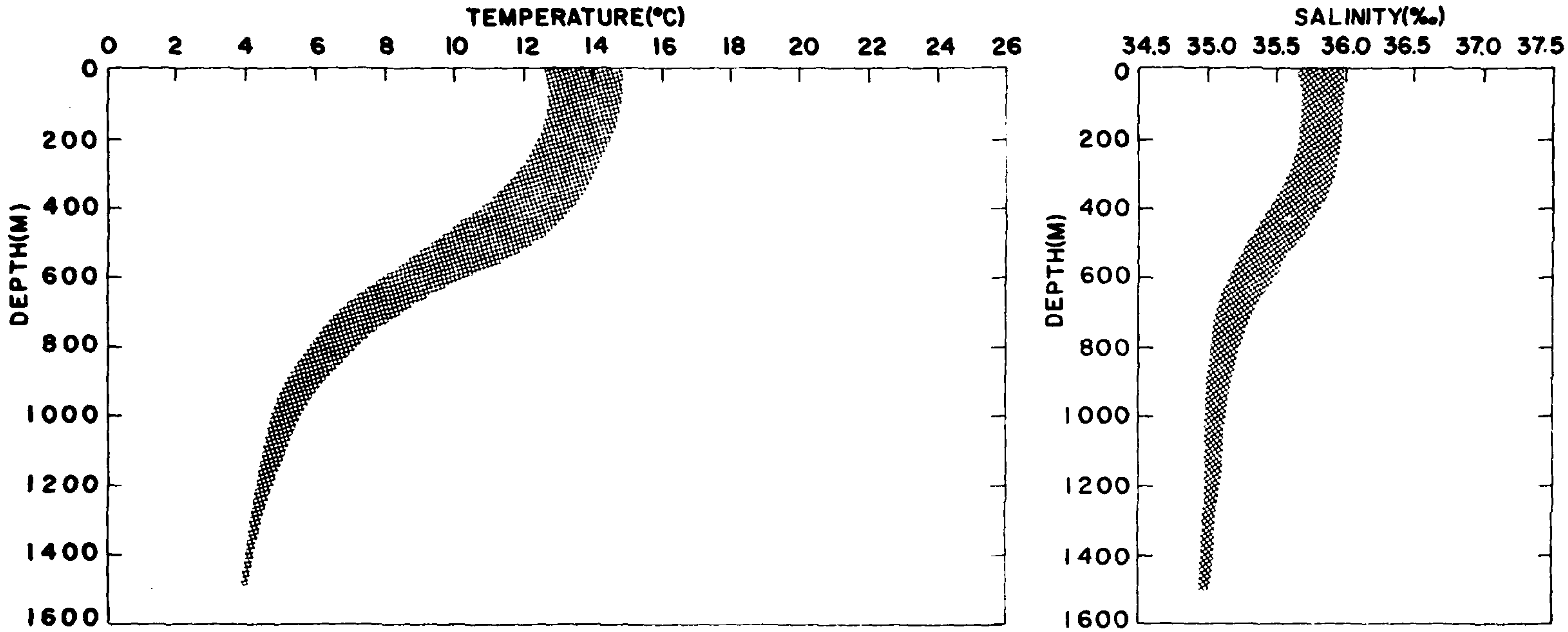

Figure 14.—March vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1967—1973.

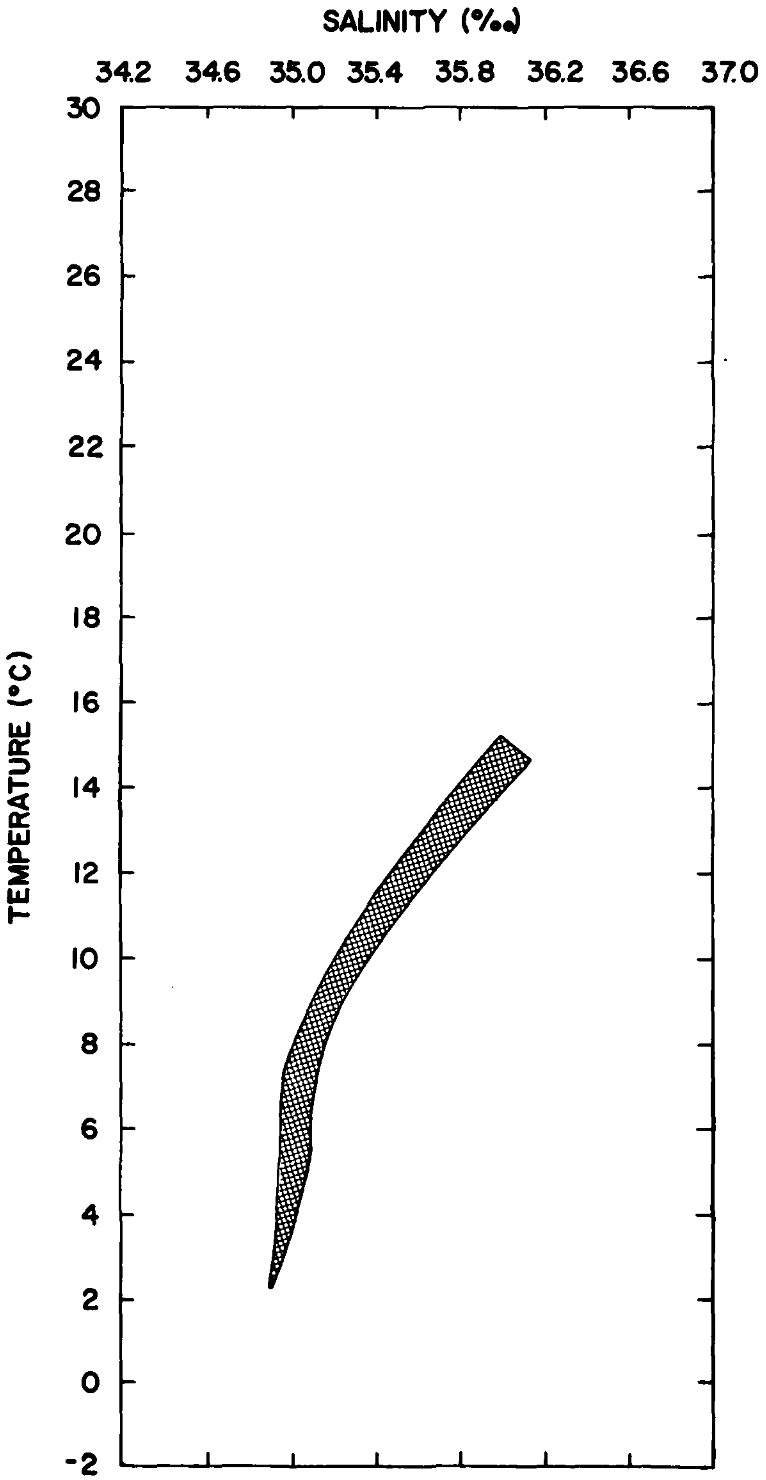

Figure 15.—March T-S envelope for Ocean Station DELTA (44°N, 41°W), 1967—1973.

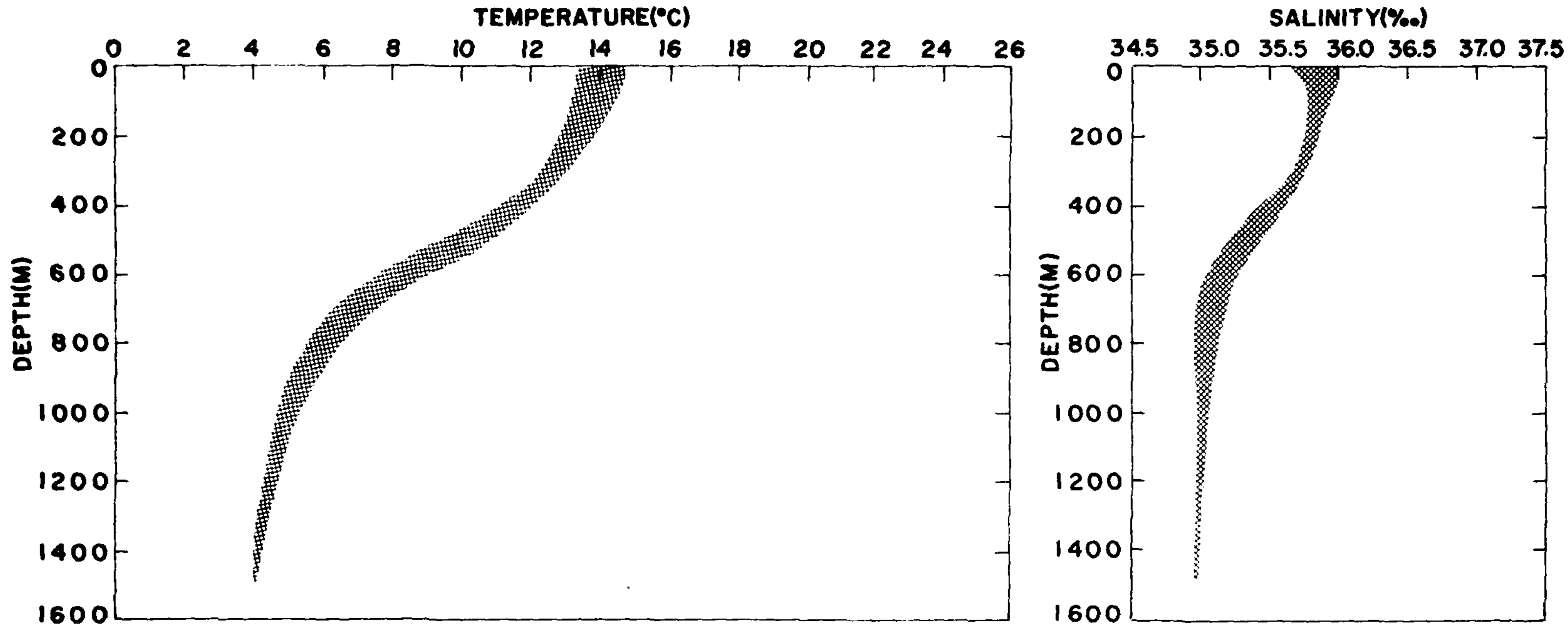

Figure 16.—April vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1967—1973.

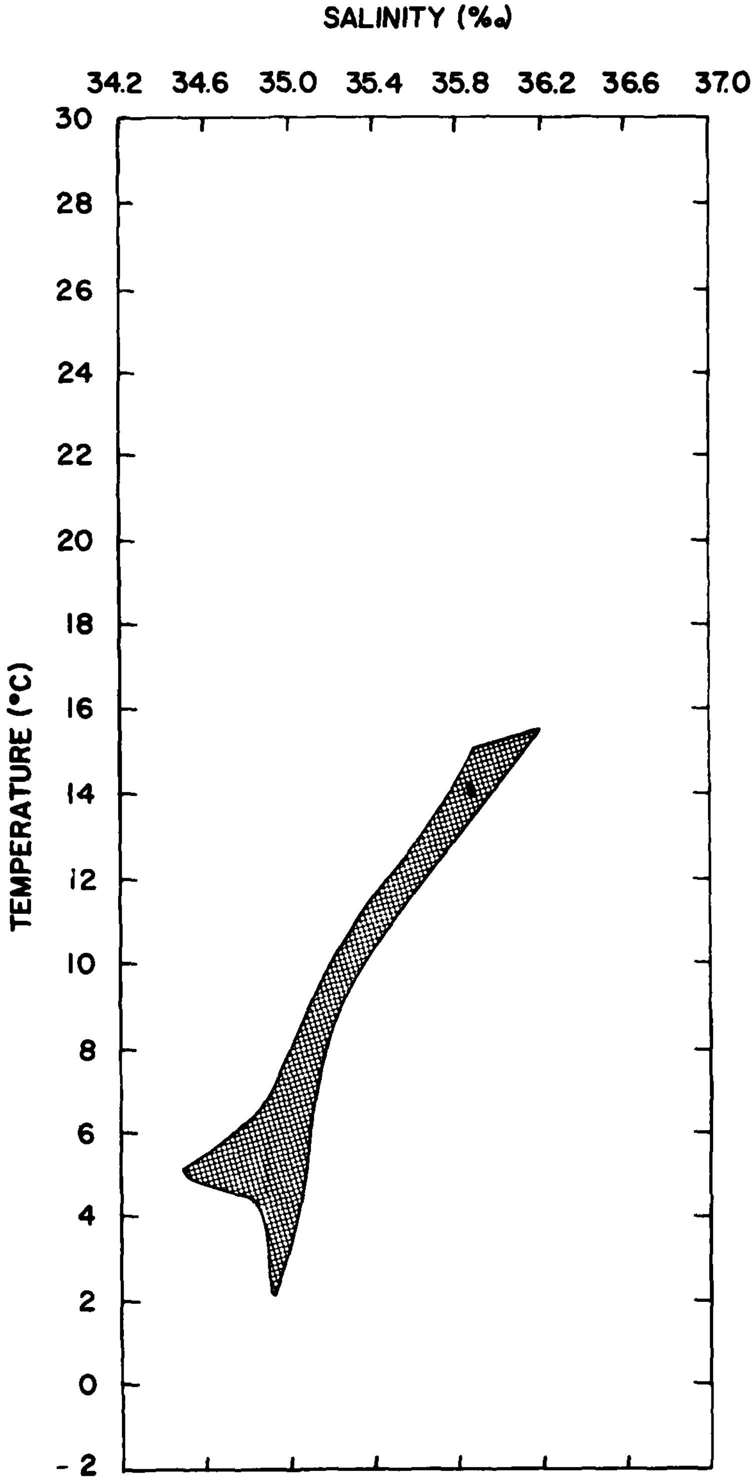

Figure 17.—April T-S envelope for Ocean Station DELTA (44°N, 41°W), 1967—1973.

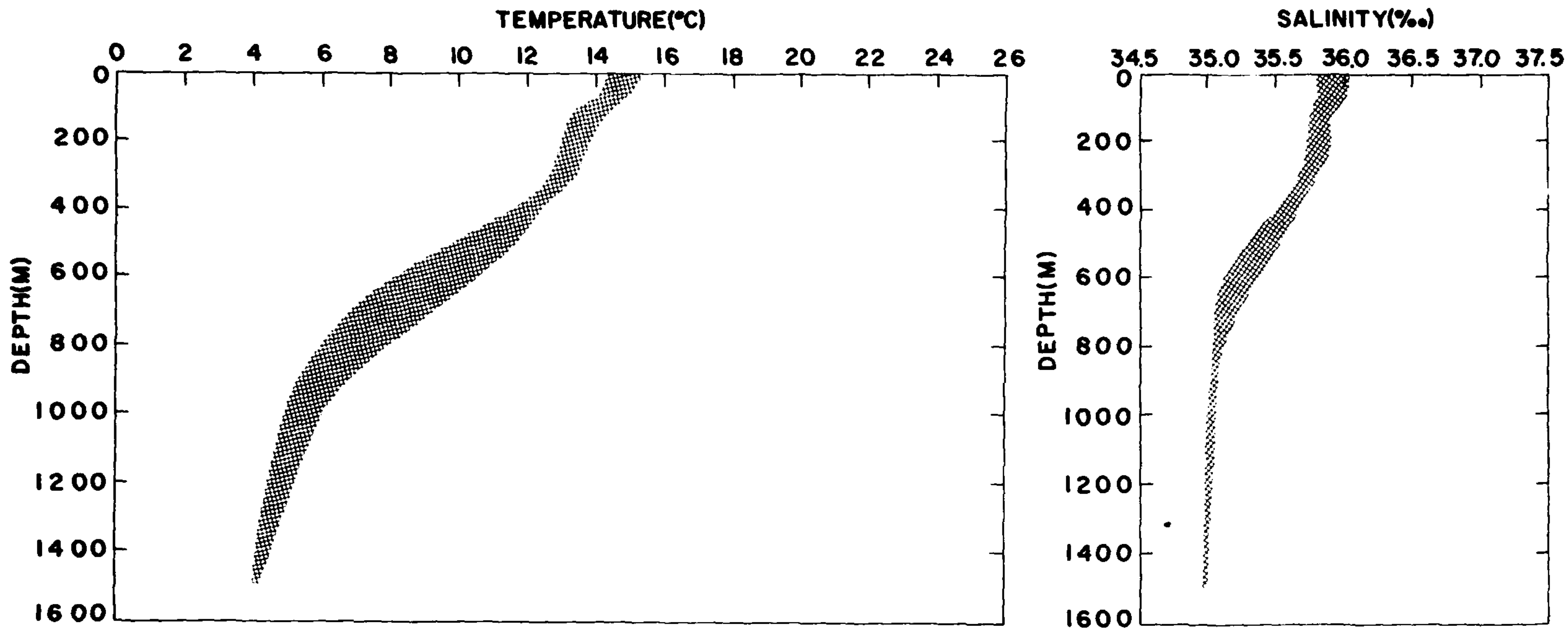

Figure 18.—May vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1967—1973.

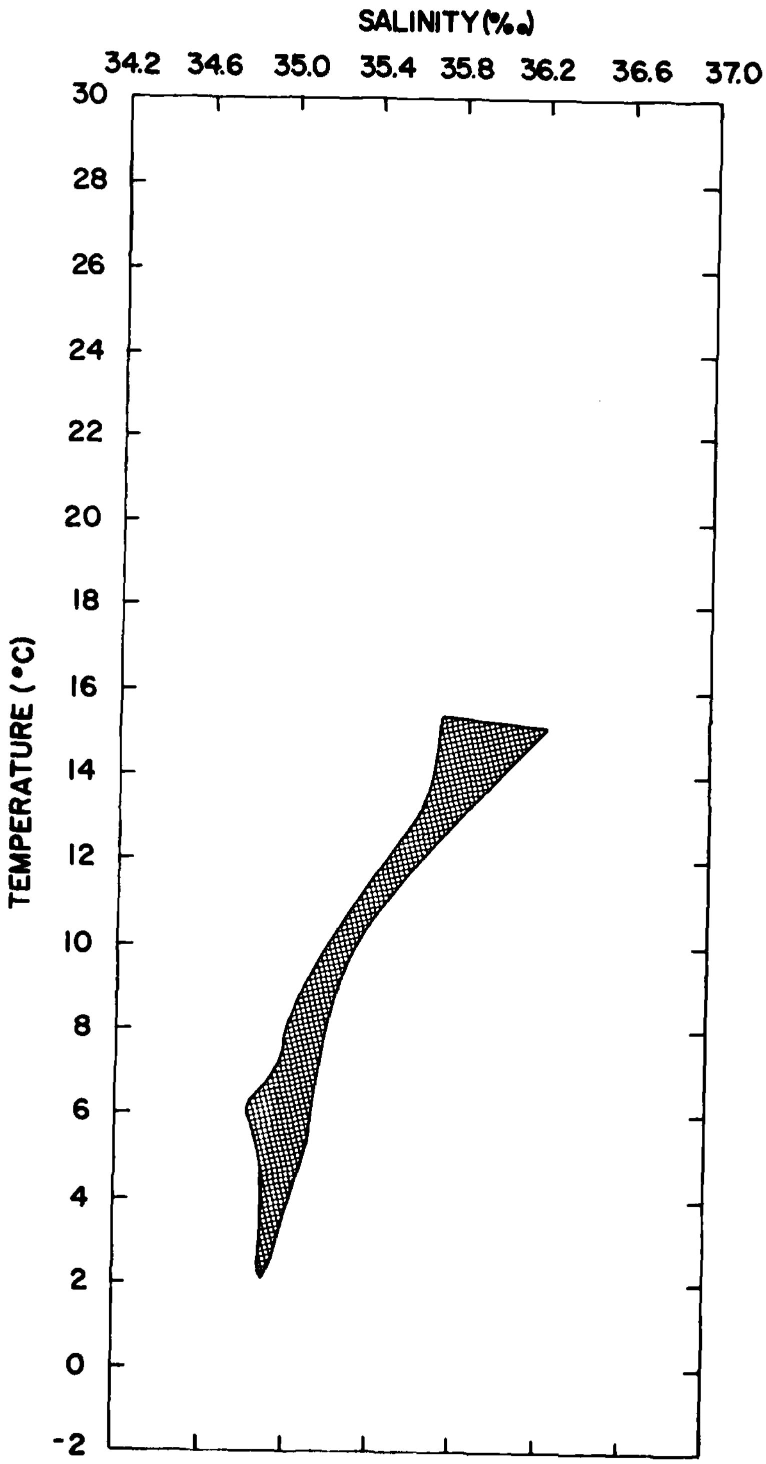

Figure 19.—May T-S envelope for Ocean Station DELTA (44°N, 41°W), 1967—1973.

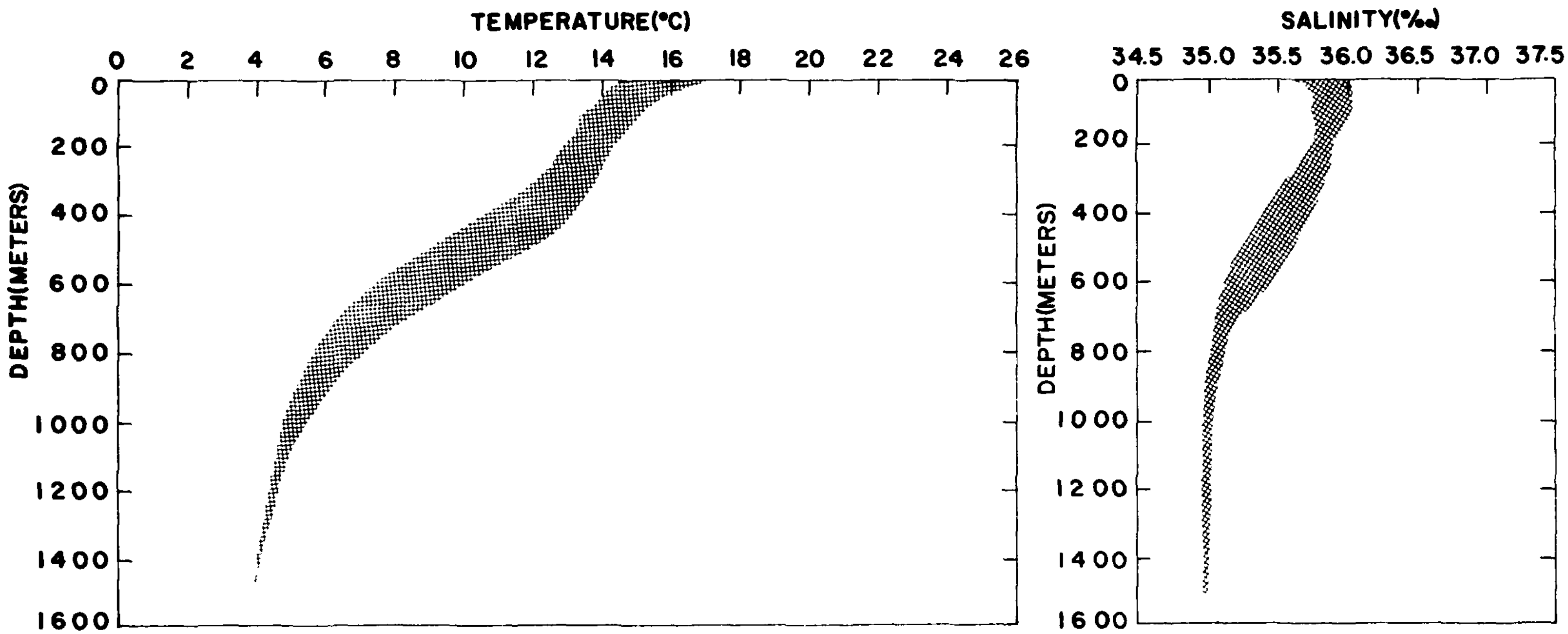

Figure 20.—June vertical envlopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1967—1973.

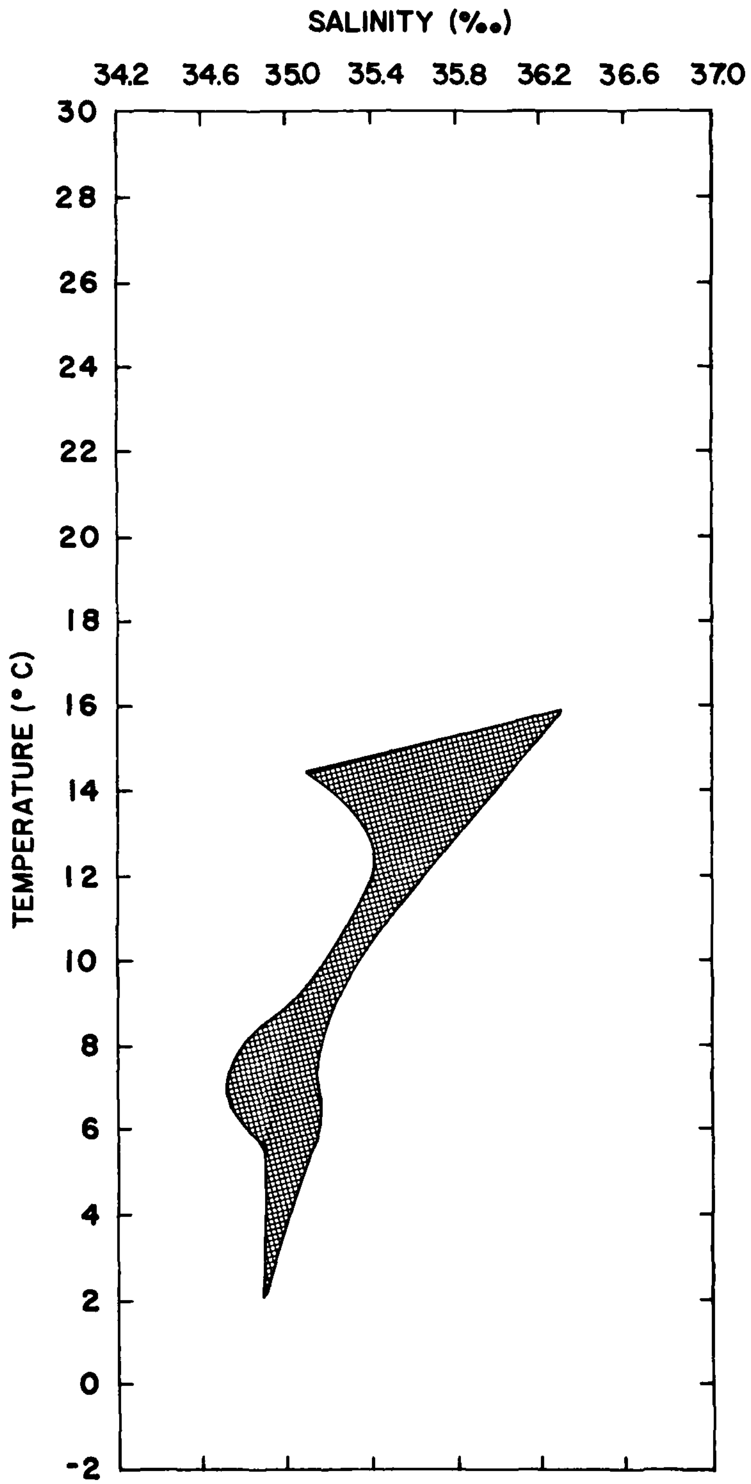

Figure 21.—June T-S envelope for Ocean Station DELTA (44°N, 41°W), 1967—1973.

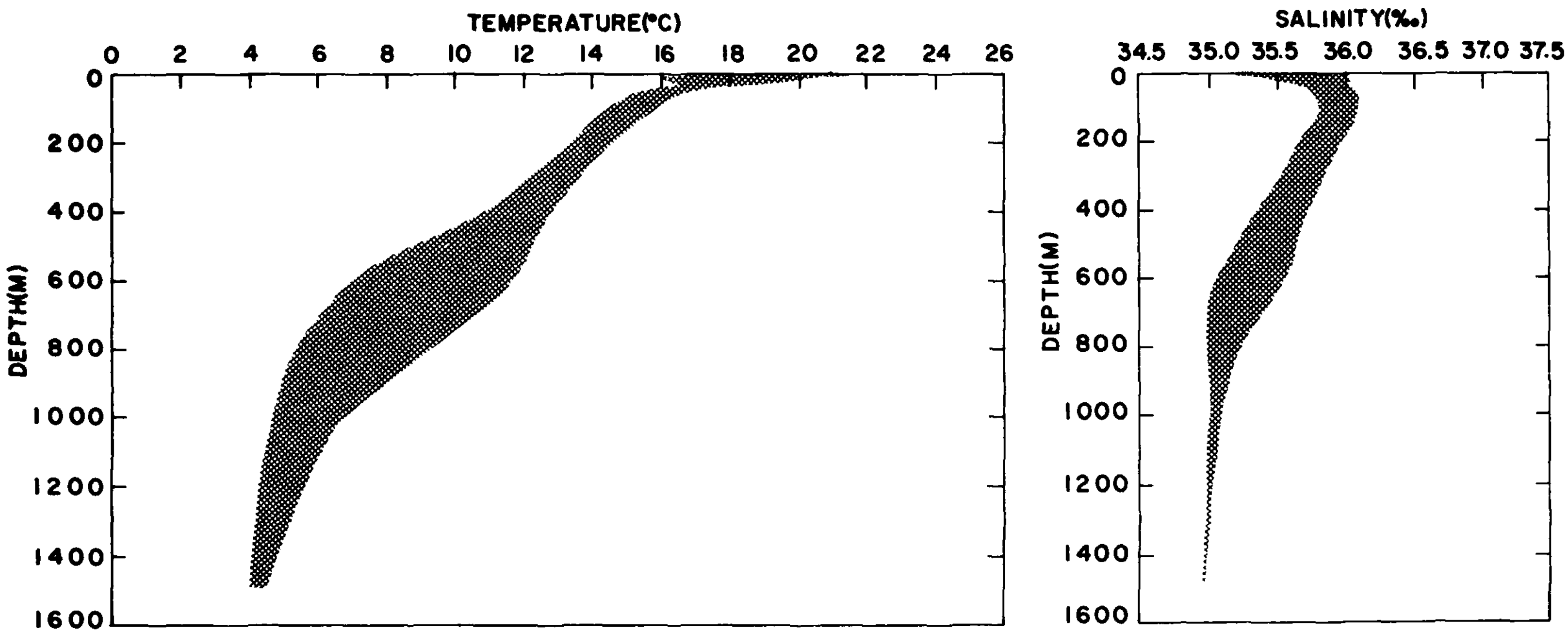

Figure 22.—July vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1966—1973.

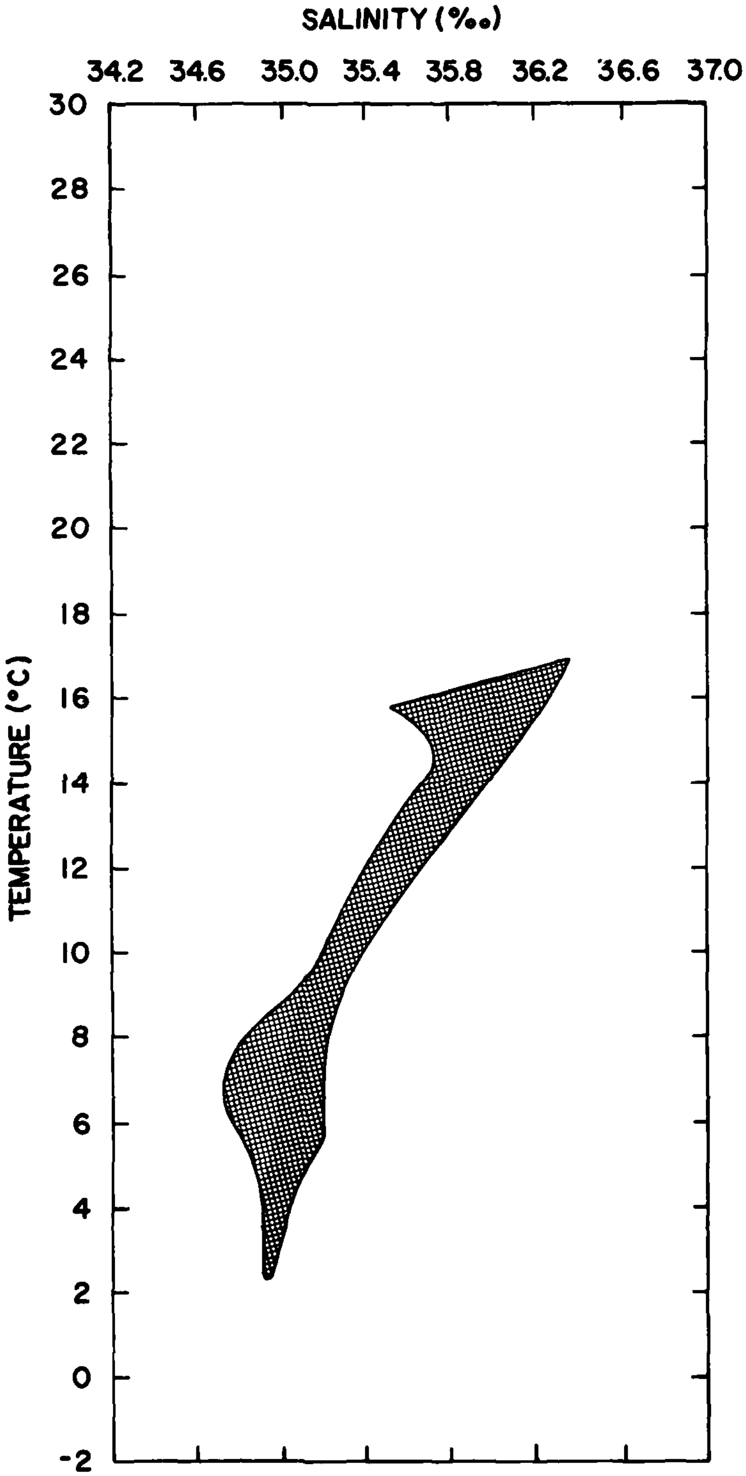

Figure 23.—July T-S envelope for Ocean Station DELTA (44°N, 41°W), 1966—1973.

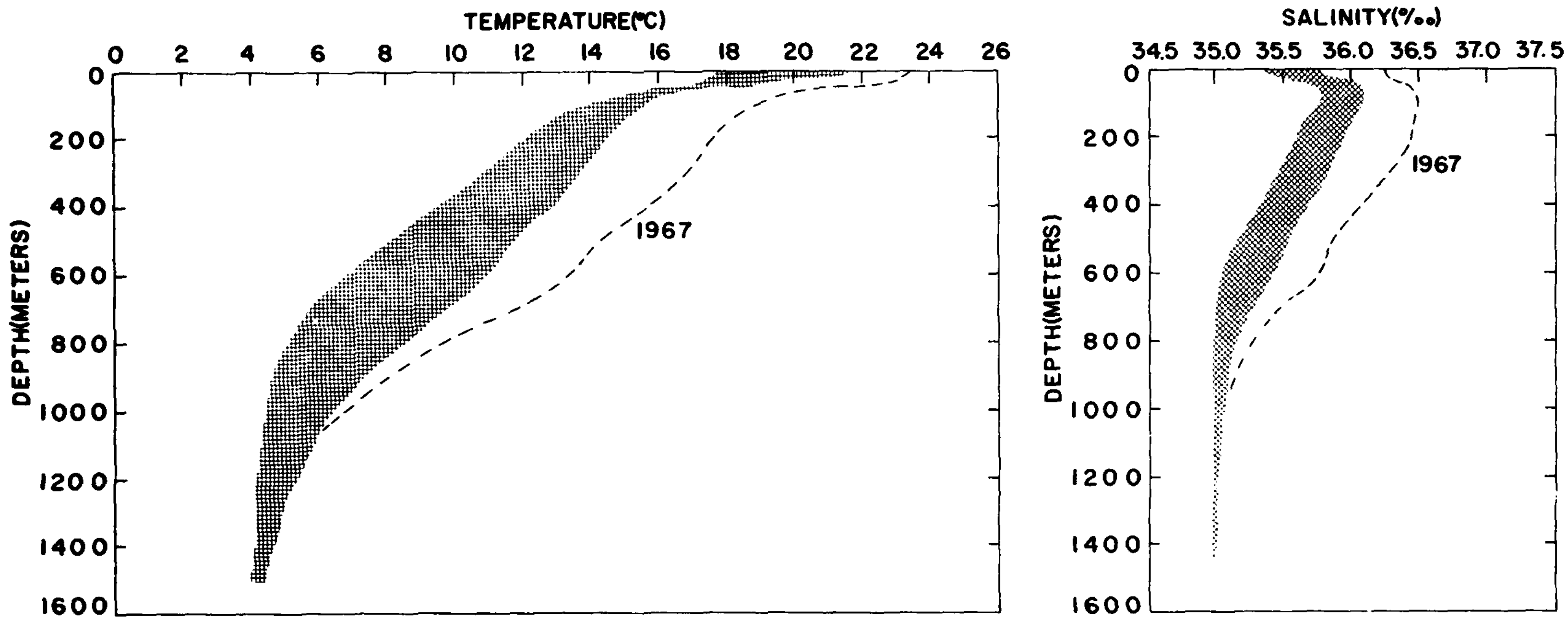

Figure 24.—August vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1966—1972.

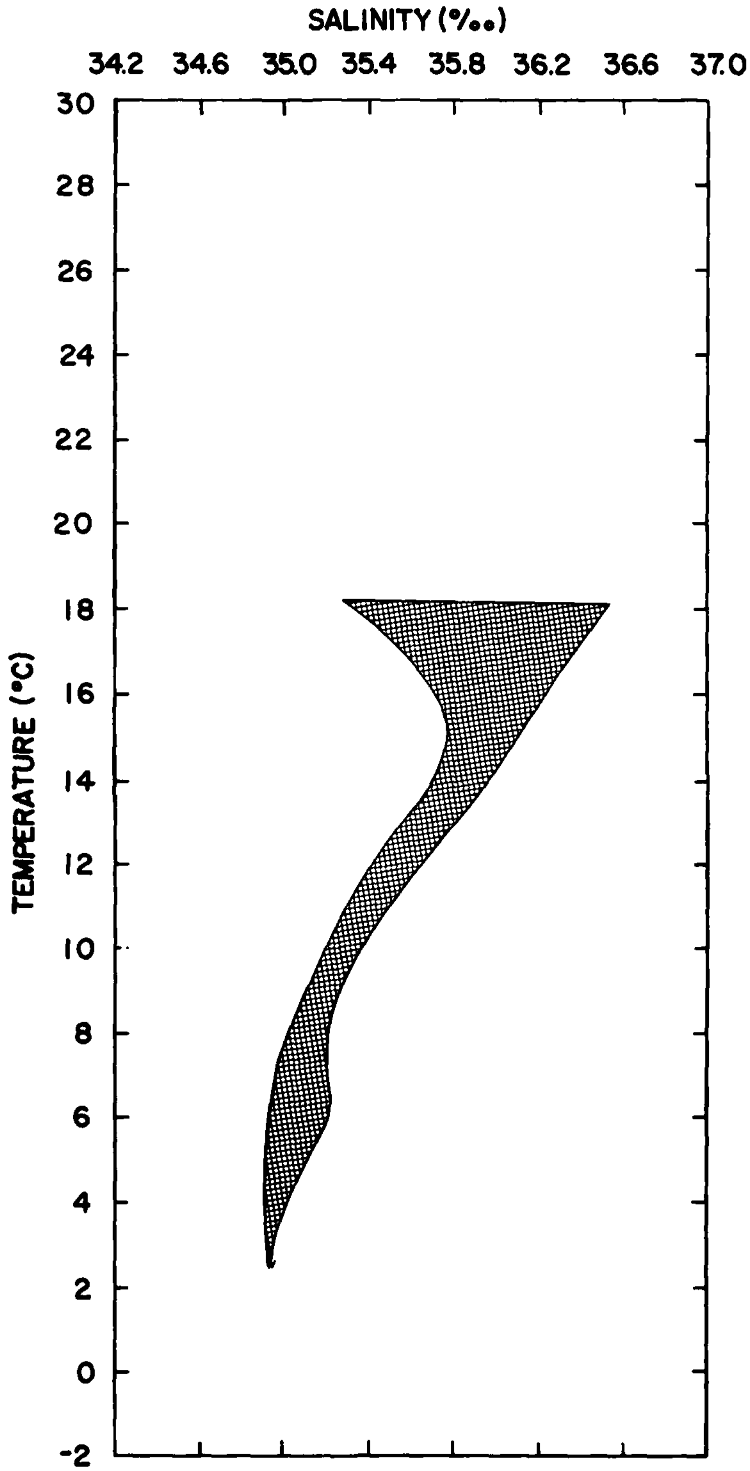

Figure 25.—August T-S envelope for Ocean Station DELTA (44°N, 41°W), 1966—1972.

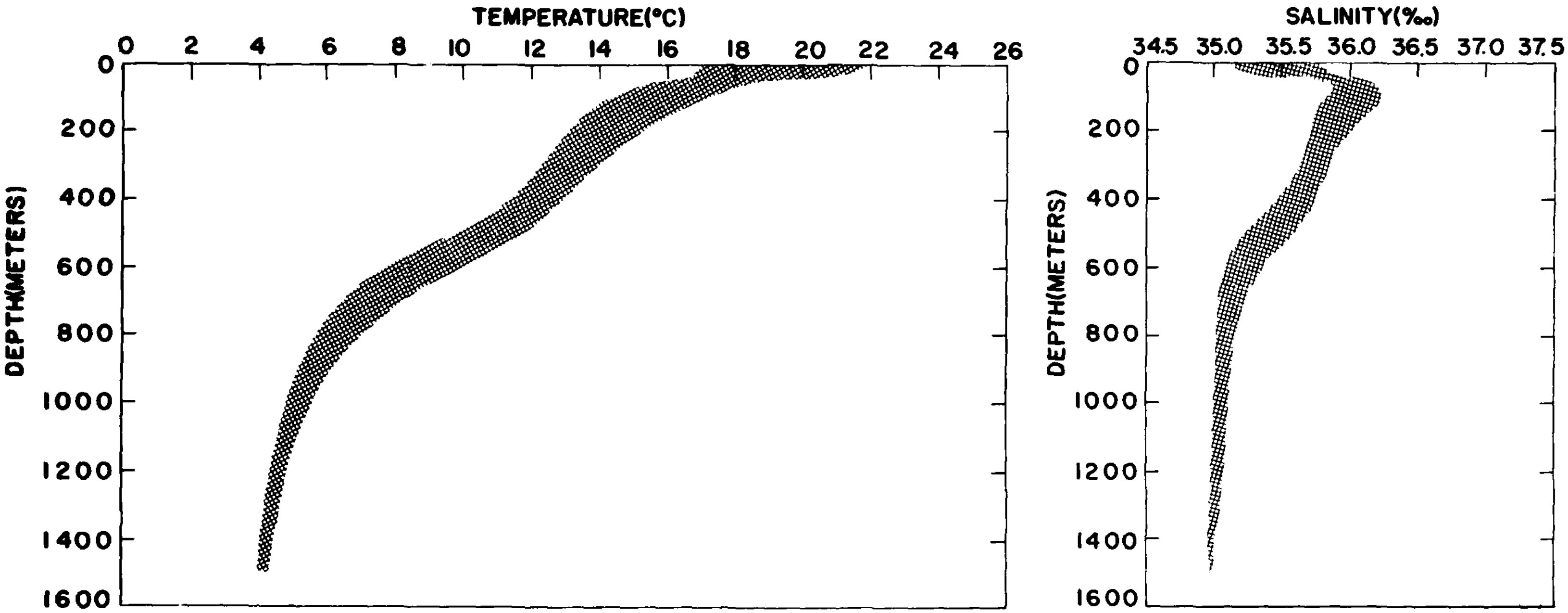

Figure 26.—September vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1966—1972.

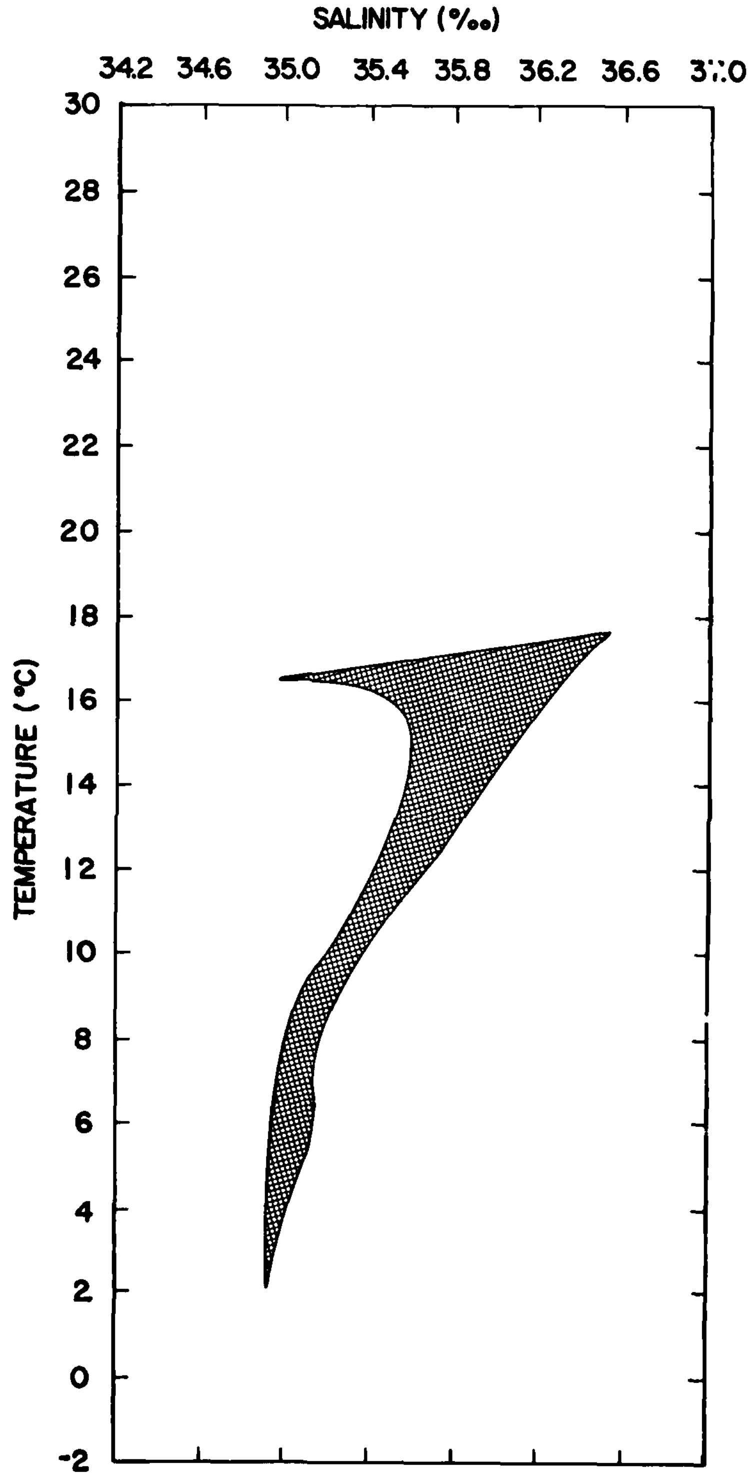

Figure 27.—September T-S envelope for Ocean Station DELTA (44°N, 41°W), 1966—1972.

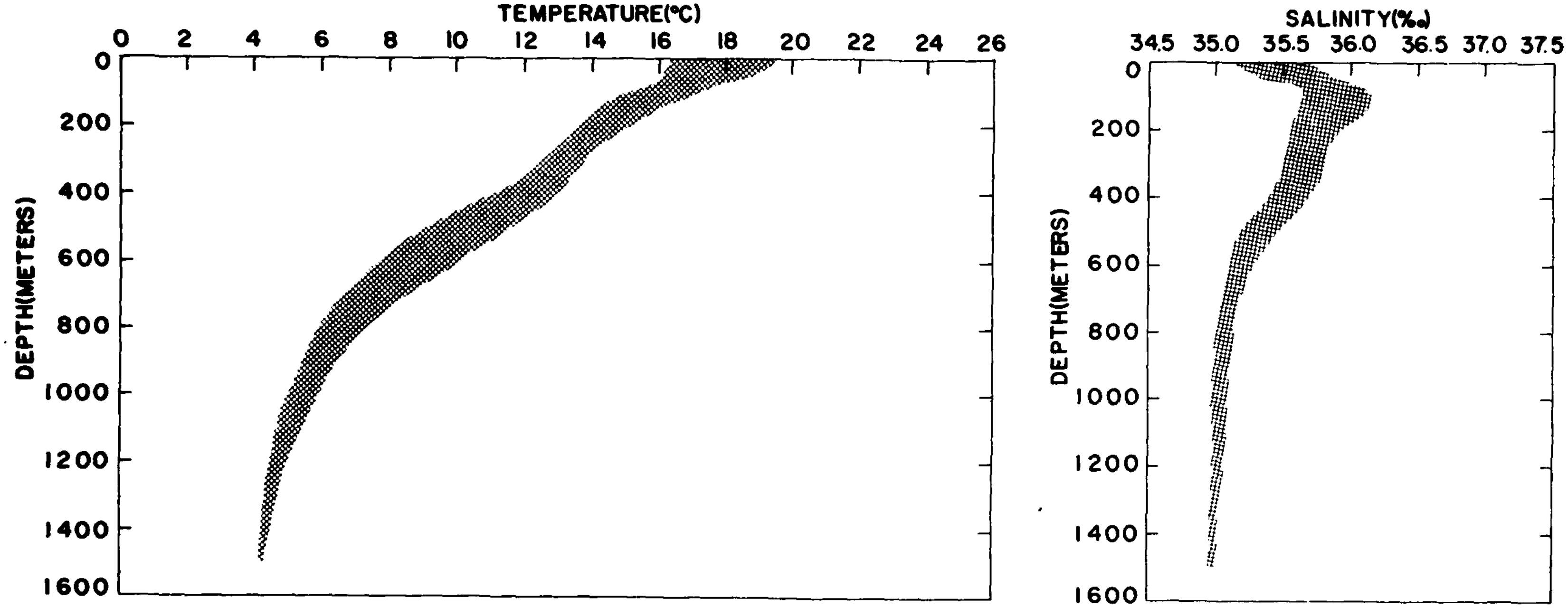

Figure 28.—October vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1966—1972.

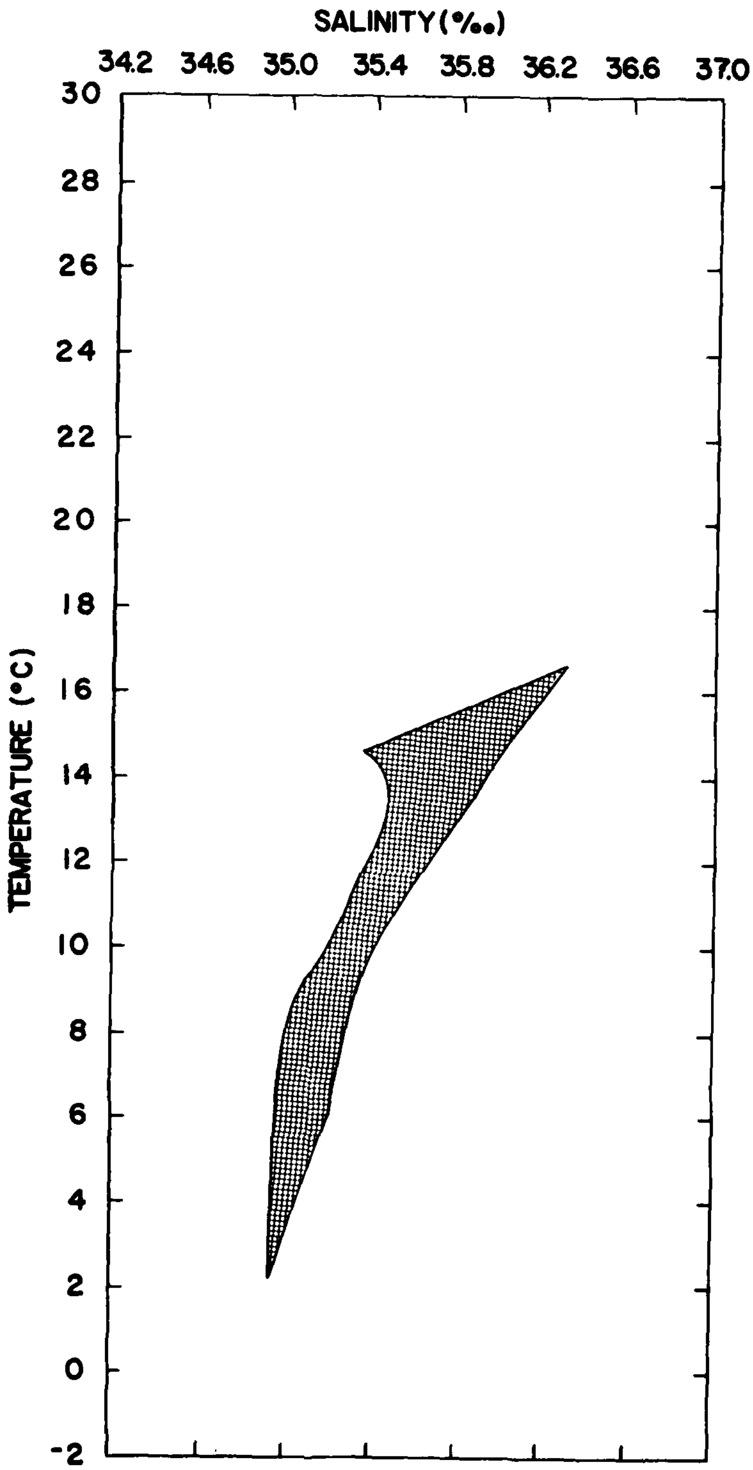

Figure 29.—October T-S envelope for Ocean Station DELTA (44°N, 41°W), 1966—1972.

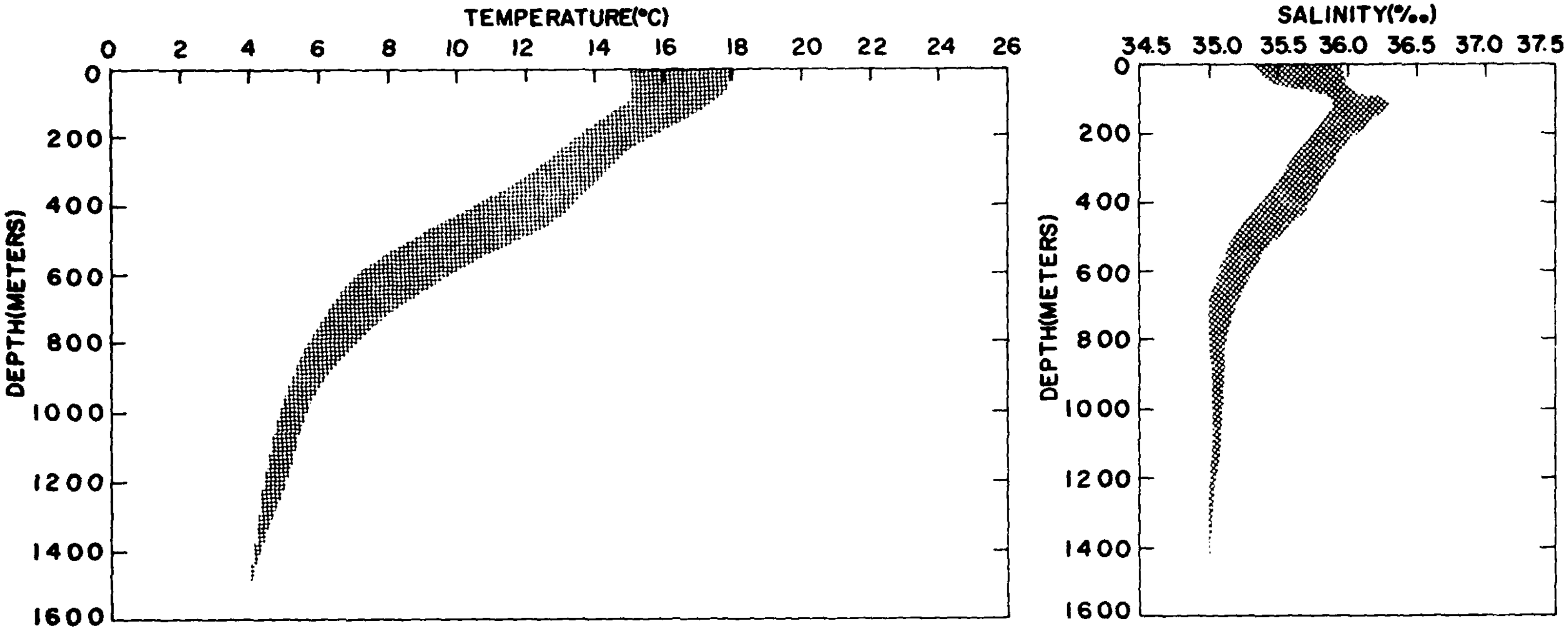

Figure 30.—November vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1966—1972.

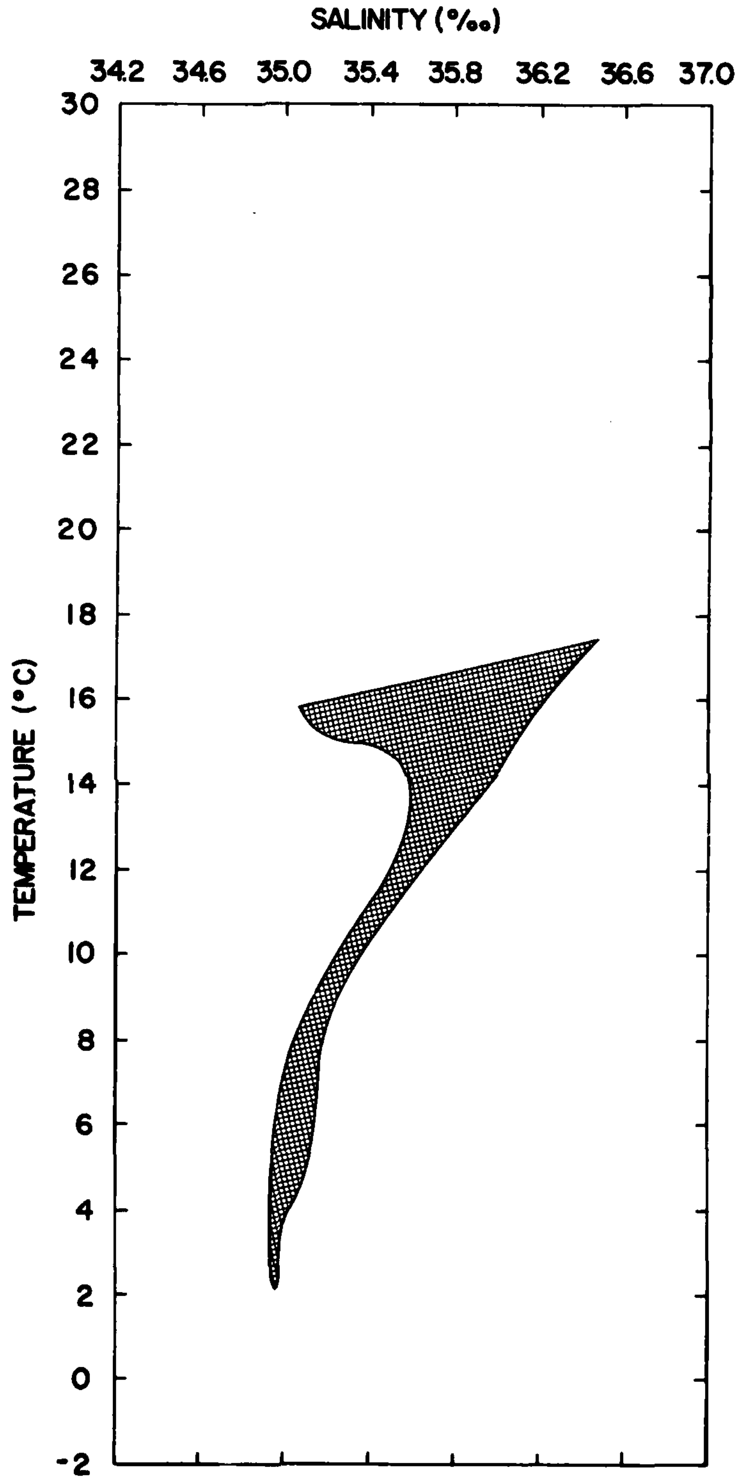

Figure 31.—November T-S envelope for Ocean Station DELTA (44°N, 41°W), 1966—1972.

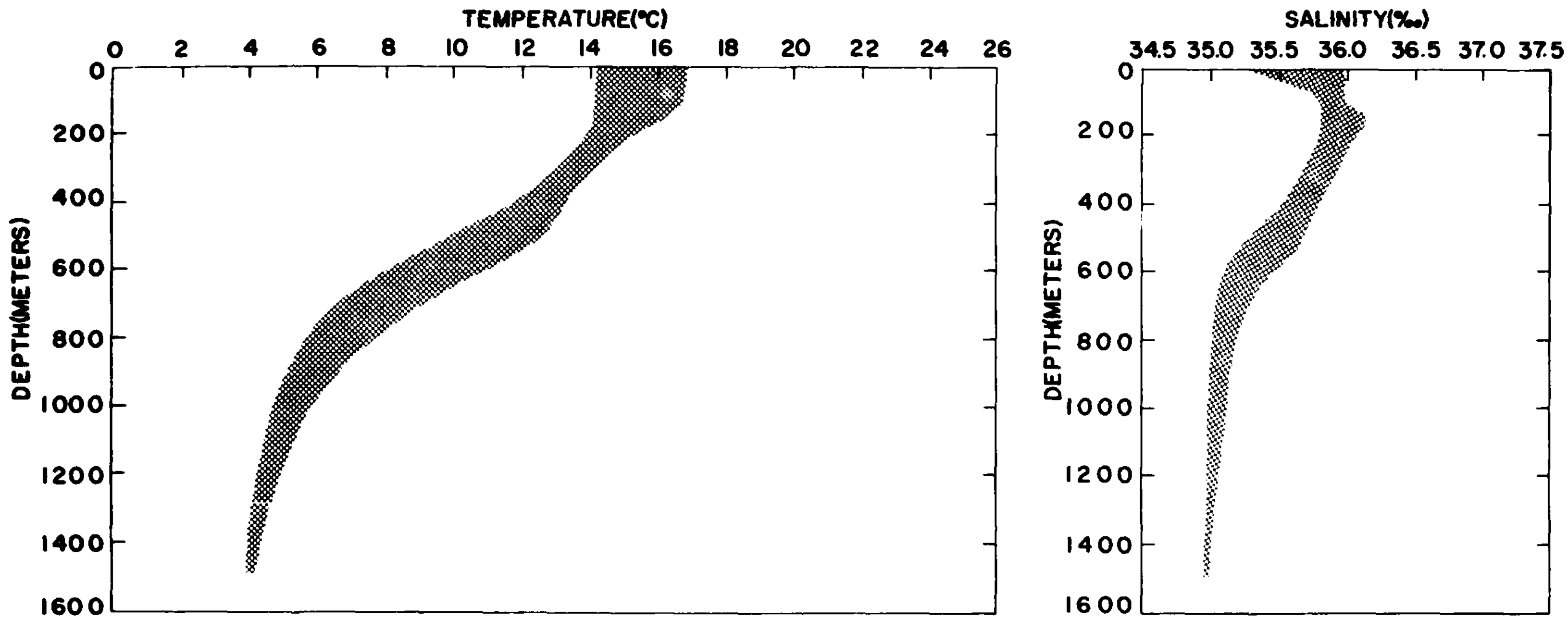

Figure 32.—December vertical envelopes of temperature and salinity for Ocean Station DELTA (44°N, 41°W), 1966—1972.

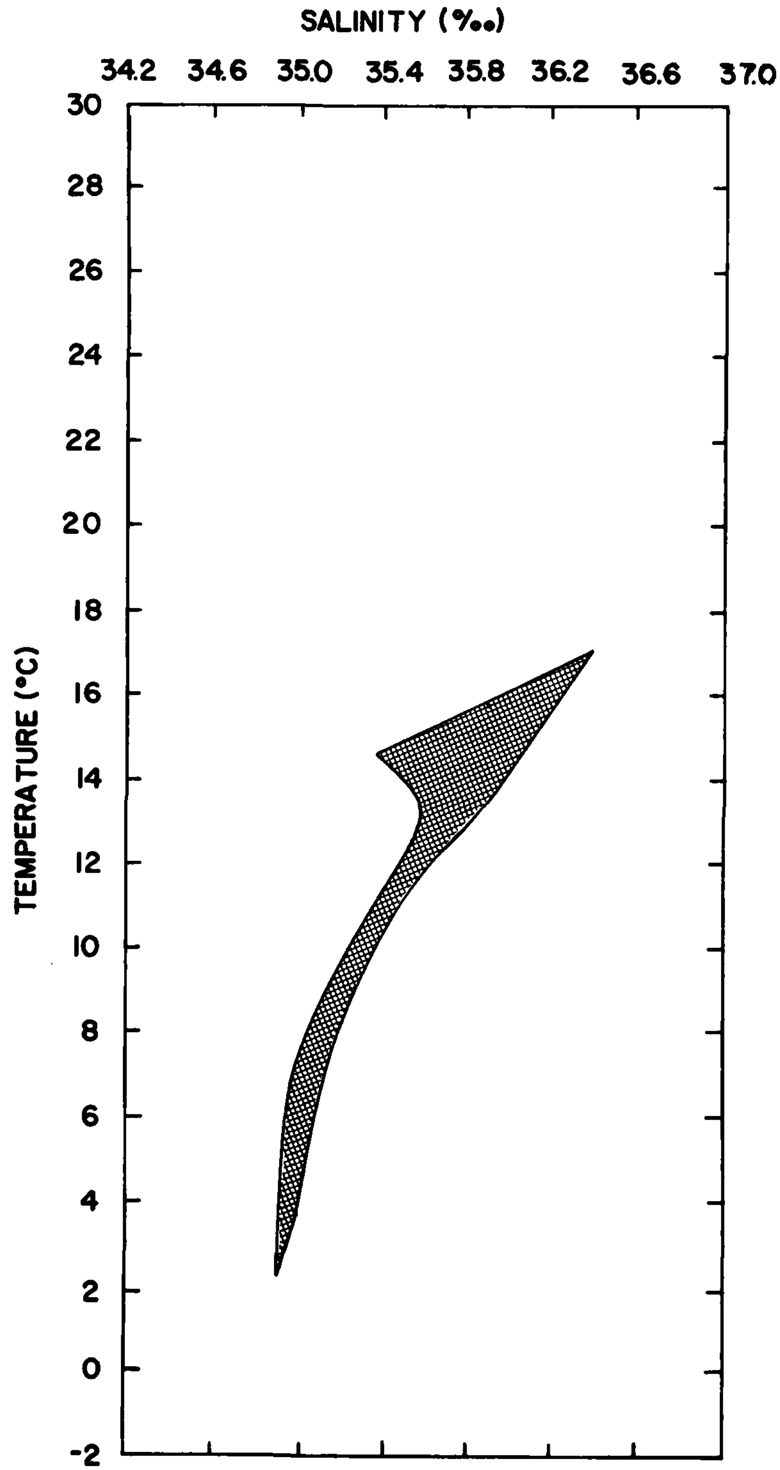

Figure 33.—December T-S envelope for Ocean Station DELTA (44°N, 41°W) 1966—1972.

APPENDIX A
OCEANOGRAPHIC DATA LISTINGS

Table I.—USCGC GALLATIN, 27 August 1969—19 September 1969, NODC Listing No. 31-1539.

Table II.—USCGC COOK INLET, 19 September 1969—12 October 1969, NODC Listing No. 31-8129.

Table III.—USCGC YAKUTAT, 12 October 1969—4 November 1969, NODC Listing No. 31-8147.

Table IV.—USCGC GALLATIN, 4 November 1969—27 November 1969, NODC Listing No. 31-8135.

Table V.—USCGC DUANE, 27 November 1969—20 December 1969, NODC Listing No. 31-1527.

Table VI.—USCGC McCULLOCH, 20 December 1969—12 January 1970, NODC Listing No. 31-1582.

Table VII.—USCGC MORGENTHAU, 12 January 1970—4 February 1970, NODC Listing No. 31-8152.

Table VIII.—USCGC COOK INLET, 4 February 1970—27 February 1970, NODC Listing No. 31-8156.

Table IX.—USCGC CASTLE ROCK, 27 February 1970—22 March 1970, NODC Listing No. 31-1610.

Table X.—USCGC OWASCO 22 March 1970—14 April 1970, NODC Listing No. 31-1616.

Table XI.—USCGC CHINCOTEAGUE, 14 April 1970—12 May 1970, NODC Listing No. 31-1625.

Table XII.—USCGC McCULLOCh, 12 May 1970—30 May 1970, NODC Listing No. 31-8163.

Table XIII.—USCGC MORGENTHAU, 30 May 1970—22 June 1970, NODC Listing No. 31-1641.

Table XIV.—USCGC INGHAM, 22 June 1970—15 July 1970, NODC Listing No. 31-1664.

Table XV.—USCGC ESCANABA, 15 July 1970—7 August 1970, NODC Listing No. 31-8181.

Table XVI.—USCGC OWASCO, 7 August 1970, NODC Listing No. 31-8176.

Table XVII.—USCGC DUANE, 30 August 1970—22 September 1970, NODC Listing No. 31-1688.

Table XVIII.—USCGC DALLAS, 22 September 1970—15 October 1970, NODC Listing No. 31-1687.

Table XIX.—USCGC McCULLOCH, 15 October 1970—7 November 1970, NODC Listing No. 31-1745.

Table XX.—USCGC BOUTWELL, 7 November 1970—30 November 1970, NODC Listing No. 31-8234.

Table XXI.—USCGC ANDROSCOGGIN, 30 November 1970—22 December 1970, NODC Listing No. 31-8236.

Table XXII.—USCGC OWASCO, 22 December 1970—14 January 1971, NODC Listing No. 31-1790.

Table XXIII.—USCGC SEBAGO, 14 January 1971—6 February 1971, NODC Listing No. 31-8250.

Table XXIV.—USCGC CHASE, 6 February 1971—1 March 1971, NODC Listing No. 31-8262.

Table XXV.—USCGC OWASCO, 1 March 1971—24 March 1971, NODC Listing No. 31-1810.

Table XXVI.—USCGC INGHAM, 24 March 1971—16 April 1971, NODC Listing No. 31-1826.

Table XXVII.—USCGC CHINCOTEAGUE, 18 April 1971—9 May 1971, NODC Listing No. 31-8266.

Table XXVIII.—USCGC ABSECON, 9 May 1971—1 June 1971, NODC Listing No. 31-1857.

Table XXIX.—USCGC GALLATIN, 1 June 1971—24 June 1971, NODC Listing No. 31-8268.

Table XXX.—USCGC SEBAGO, 24 June 1971—14 July 1971, NODC Listing No. 31-1882.

Table XXXI.—USCGC MENDOTA, 14 July 1971—4 August 1971, NODC Listing No. 31-1877.

Table XXXII.—USCGC McCULLOCH, 4 August 1971—27 August 1971, NODC Listing No. 31-1918.

Table XXXIII.—USCGC INGHAM, 27 August 1971—20 September 1971, NODC Listing No. 31-1912.

Table XXXIV.—USCGC ESCANABA, 20 September 1971—14 October 1971, NODC Listing No. 31-1926.

Table XXXV.—USCGC BIBB, 14 October 1971—7 November 1971, NODC Listing No. 31-1927.

Table XXXVI.—USCGC CAMPBELL, 7 November 1971—1 December 1971, NODC Listing No. 31-1928.

Table XXXVII.—USCGC SEBAGO, 1 December 1971—21 December 1971, NODC Listing No. 31-1929.

Table XXXVIII.—USCGC MENDOTA, 21 December 1971—31 December 1971, NODC Listing No. 31-1930.

Table XXXIX.—USCGC CAMPBELL, 12 January 1972—3 February 1972, NODC Listing No. 31-1970.

Table XL.—USCGC OWASCO, 3 February 1972—27 February 1972, NODC Listing No. 31-8301.

Table XLI.—USCGC ANDROSCOGGIN, 27 February 1972—24 March 1972, NODC Listing No. 31-2083.

Table XLII,—USCGC CHASE, 24 March 1972—19 April 1972, NODC Listing No. 31-8302.

Table XLIII.—USCGC DUANE, 19 April 1972—13 May 1972, NODC Listing No. 31-2076.

Table XLIV.—USCGC ANDROSCOGGIN, 13 May 1972—2 June 1972, NODC Listing No. 31-2078.

Table XLV.—USCGC CAMPBELL, 2 June 1972—26 June 1972, NODC Listing No. 31-2084.

Table XLVI.—USCGC ESCANABA, 26 June 1972—20 July 1972, NODC Listing No. 31-8314.

Table XLVII.—USCGC MUNRO, 20 July 1972—15 August 1972, NODC Listing No. 31-2114.

Table XLVIII.—USCGC HAMILTON, 17 August 1972—8 September 1972, NODC Listing No. 31-2128.

Table XLIX.—USCGC DUANE, 8 September 1972—2 October 1972, NODC Listing No. 31-2129.

Table L.—USCGC MUNRO, 2 October 1972—28 October 1972, NODC Listing no. 31-2130.

Table LI.—USCGC TANEY, 28 October 1972—17 November 1972, NODC Listing No. 31-2143.

Table LII.—USCGC CHAUTAUQUA, 14 December 1972—4 January 1973, NODC Listing No. 31-2122.

Table LIII.—USCGC ESCANABA, 4 January 1973—26 January 1973, NODC Listing No. 31-2120.

Table LIV.—USCGC BIBB, 26 January 1973—15 February 1973, NODC Listing No. 31-2164.

Table LV.—USCGC OWASCO, 15 February 1973—9 March 1973, NODC Listing No. 31-2184.

Table LVI.—USCGC INGHAM, 9 March 1973—27 March 1973, NODC Listing No. 31-2203.

Table LVII.—USCGC CAMPBELL, 27 March 1973—19 April 1973, NODC Listing No. 31-2178.

Table LVIII.—USCGC PONCHARTRAIN, 19 April 1973—11 May 1973, NODC Listign No. 31-2196.

Table LIX.—USCGC MORGENTHAU, 11 May 1973—6 June 1973, NODC Listing No. 31-2218.

Table LX.—USCGC CAMPBELL, 6 June 1973—30 June 1973, NODC Listing No. 31-2231.

Table LXI.—USCGC GALLATIN, Ocean Station JULIET to Ocean Station DELTA 8 December 1969—11 December 1969, NODC Listing No. 31-8136.

Table LXII.—USCGC ROCKAWAY, ROMEOS Cruise (Stations 104 to 144) 4 September 1970—13 September 1970, NODC Listing No. 31-8219.

Codes Utilized

A complete description of the codes utilized in the tabulation of oceanographic station data can be found in National Oceanographic Data Center publication M-2, Processing Physical and Chemical Data from Oceanographic Stations. (Rev. August 1964, supplement issued May 1966.)

To facilitate use of the oceanographic station data listing, entry headings which are not self-explanatory are described below.

REFID	NODC reference indentity number.
CONSEC	Consecutive station number.
BOTDP (B)	Uncorrected sounding depth in meters.
SHIP (B)	NODC assigned platform identity code.
DATA USE	Entry 1 identifies DNP data.
AREA	NODC ocean area code.
CLOUD T/A (B)	Cloud type according to WMO code 0500 and cloud amount according to WMO code 2700.
Wave observations	
DIR	Direction from which dominant waves are coming in tens of degrees according to WMO code 0885.
HGT	Height of dominant waves according to WMO code 1555.
PER	Period of dominant waves according to WMO code 3155.
SEA (B)	Sea state according to WMO code 3700.
CL/TR (B)	Water color according to forel-Ule code. Transparency in meters as determined by Secchi disc.
WIND DIR (B)	Direction from which wind is blowing in tens of degrees according to WMO code 0877.
WIND SPD (B)	Wind speed in knots.
WIND FOR (B)	Wind force in beaufort code.
WEATHER (B)	Weather code—If preceded by letter X is according to WMO code 4501. A numeric two digit entry indicates weather according to WMO code 4677.
INST	Instrument used for observation—"Nansen Cast" indicates station consists of Nansen cast data—"STD Recorder" indicates station consists of STD data or a mixture of STD and Nansen cast data.
TRACE DIR (B)	"Trace" indicator U (UP), D (DOWN), and A (AVERAGED)—used with STD casts, and specify that data were taken while hoisting or lowering respectively or that the two traces were averaged.
DURATION (B)	Time elapsed during raising or lowering of the STD recorder to tenths of hours.
ORIG (B)	Originator's reference number in two parts—cruise number or 3 characters (if year of cruise forms part of cruise number years digits may sometimes only be found in "Year" field), and station number.
TEN SQ	Ten-degree square—modified Canadian square number.
5 SQUARE	Five-degree squares—modified Canadian system.
2 SQUARE	Two-degree squares—modified Canadian system.
1 SQUARE	One-degree squares—modified Canadian system.
CASTNUM (B)	Number of cast on multicast stations (blank when messenger time is given).
TIME (B)	Time of release of messenger in hour and tenths for applicable observed levels. If multicast series extends past midnight, 24 hours are added to cast time of next day. Beginning time for STD is given at first obs depth.
LVLTYP	Type of record at depth indicated. "OBS"—observed values. For STD recorder = level of data read-out. "STD"—NODC standard interpolated values. "ORG"—Standard or other depths carrying non-NODC interpolated values. "LIT"—Interpolated standard depth values used as obs for computational purposes. Note—When an observed level coincides with a STD depth level, both "STD" and "OBS" lines will appear.
DEPTH	Depth of sample (or standard level) in whole meters. Prefix "T" indicates thermometrically determined depth (depth of unprotected thermometers). Subscript "Q" indicates that the value is marked doubtful by the originator. A value designated as implausible by NODC is marked with a "P". Postscript "Z" indicates uncorrected and inaccurate 'Wire-out' depths (high wire angle present).
TEMP (B)	Temperature in degrees celsius. For 'Q' and 'P' notation see depth field.
SAL (B)	Salinity in parts per thousand. For 'Q' and 'P' notation see depth field.
SIGMA-T (B)	Seawater density anomaly to 2 decimal places. When depth, temp, or salinity is doubtful, a 'Q' is suffixed. An asterisk indicates a decrease of 0.02 or more from the previous level.
DYNDPTH	Dynamic depth anomaly in dynamic meters to millimeters.
SND VEL (B)	Sound velocity in meters per second to decimeters according to Wilson's formula. (A standard depth-pressure term is used for stations not beginning at the surface).
OXYG (B)	Oxygen in ML/L to hundredths.

DATE

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