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NESDIS AISC 15

CHESAPEAKE BAY SURFACE SALINITIES 1951-88

Washington, D.C.
February 1989

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

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Michael J. Dowgiallo

Marine Environmental Assessment Division
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CHESAPEAKE BAY SURFACE SALINITIES 1951-88

Michael J. Dowgiallo[1]

Marine Environmental Assessment Division
Assessment and Information Services Center
National Environmental Satellite, Data, and
Information Service, Washington, DC 20235

ABSTRACT. Surface salinities for five National Ocean Service stations around Chesapeake Bay are summarized for the 38-year period 1951-88. Monthly average salinities and long-term monthly averages are presented graphically for each station. Departures from normal (1951-80 monthly average) salinities are color-coded to highlight the above- and below-normal periods. Salinities were predominantly above normal in the 1960's, below normal in the 1970's, and above normal in the 1980's. Monthly percent departures from normal were computed to allow for quantitative comparison of individual months or comparison between stations. The dataset shows such events as the greatly depressed salinities following Tropical Storm Agnes in 1972 and the above-normal salinities evident following the dry periods in the 1980's.

1. INTRODUCTION

Salinity distribution in Chesapeake Bay was mapped in detail by Stroup and Lynn (1963) in their atlas of Bay salinity and temperature from cruise data covering the years 1949-61. Other studies, such as those done by Beaven (1960) and Ritchie and Genys (1975), have presented data from a single station. The purpose of this study is to supplement studies of Bay salinities by providing a long-term, multiple-station record in a format for convenient reference to monthly salinity fluctuations during the period 1951-88.

Lippson and Lippson (1984) and Lippson (1973) provide summaries

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[1]Presently a staff member of the NOAA Estuarine Programs Office, Office of Chief Scientist, Washington, DC 20235.

of the seasonal variation of salinities in the Bay and discuss factors that influence the salinity structure of Bay waters. Salinities in Chesapeake Bay range from near zero at the head of the Bay to about 30 ppt at the Bay mouth, averaging about 15 parts per thousand (ppt) in the middle Bay. Minimum salinities typically occur in the spring, and maximum salinities typically occur in the autumn.

The salt content of the water throughout Chesapeake Bay and its tributaries is an important physical factor affecting the distributional patterns of animal and plant species whose adaptation to any area is regulated by the range of salinity they can tolerate (Lippson, 1973). Beaven (1960) in his analysis of salinities at Solomons Island, MD, for the years 1938-57, noted that the knowledge of variations in salinities at given points offers a useful means of relating certain biological and physical phenomena to salinities. Although the salinity data are presented in a format similar to that used in Beaven's 1960 study, they cover a longer period, 1951-88, and are for multiple stations. The format allows for ready comparison between the salinity record and biological occurrences, such as oyster disease, whose presence and distribution appear to be influenced by salinity.

2. METHODS AND MATERIALS

Surface salinity data were analyzed for five National Ocean Service (NOS) stations in Chesapeake Bay (Figure 1). The stations were selected because of their length of record, continuity of data collection, and activity through 1988. These five stations are the only temperature and density stations in the NOS network on or near the main Bay which were active through 1988. Four of these stations have data available to compute a long-term mean of 30 years. The Chesapeake Bay Bridge-Tunnel station record begins in 1981. One other active NOS station, Washington, DC, is not included in this analysis because of its location far up the Potomac River close to fresh water and is not representative of Bay salinities.

Monthly averages are computed from daily surface densities provided to NOS by individual observers at each station. Densities are obtained by means of a hydrometer from a sample of water drawn by bucket from a foot or two below the surface. Observations are usually made once each weekday. There are occasional omissions in station records when no data are reported over holidays, during periods of severe ice cover, or when equipment was inoperable. No attempt was made in this study to interpolate values for any missing values, thus where a large portion of daily values were not available in a given month for any of the above reasons, a monthly average was not computed.

Monthly mean densities reduced to 15.0°C (59.0°F) were available in handwritten form from NOS for each station through 1983. Densities were converted to salinities (parts per thousand) using the corresponding density and salinity table in NOS Publication 31-1, Surface Water Temperature and Density (NOAA, 1972). Data after 1979 were computerized by NOS with the data available in parts per thousand. All data in the present study were loaded onto and analyzed on a personal computer.

Monthly averages for the period 1951-80 were assumed to represent an approximation of normal conditions. The 1951-80 period coincides with the period presently used by the National Weather Service to derive climatological means. These long-term monthly salinity averages are used as reference points to show departures from normal for observed monthly average salinities.

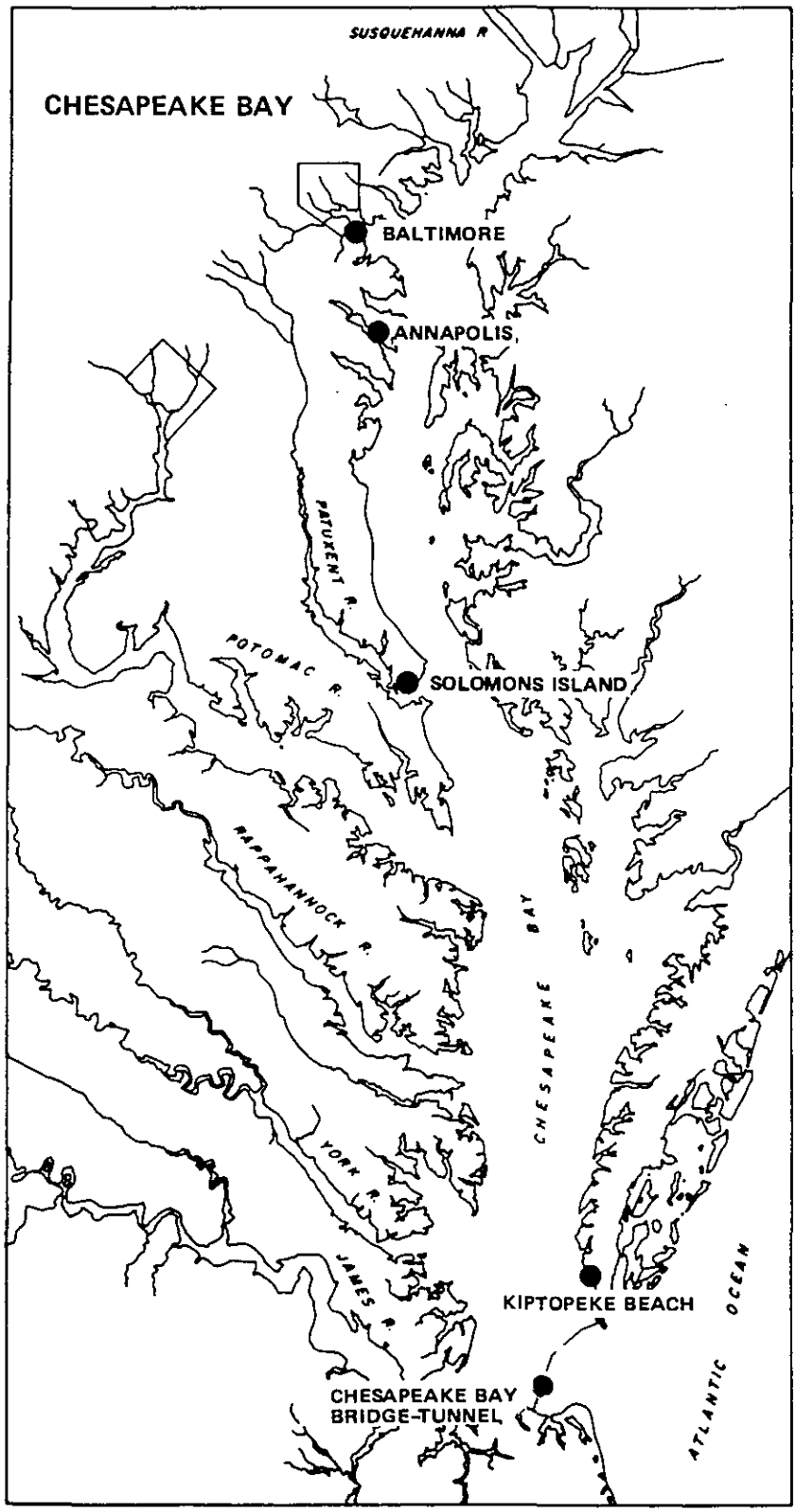

Figure 1. Locations of National Ocean Service temperature and density stations, Chesapeake Bay.

3. RESULTS

3.1 Monthly Salinities, 1951-88

Monthly salinities are presented graphically for each station as the 1951-80 average or "normal" monthly values and the observed individual monthly average values for the 1951-88 period (Figures 2, 4, 6, 8, and 10). To see more clearly the high and low salinity periods, areas between the average and observed lines that were below normal are shaded red and above-normal areas are shaded black. Salinities are scaled to cover the range of values reported for individual stations. In Figures 3, 5, 7, 9, and 11, the percent departures from normal are also presented for each station. For comparison purposes, the same scale is used for all stations in the graphs depicting percent departures from normal. The monthly salinity numerical values and computed monthly averages for each station are presented in Appendix A (Tables 1 through 5).

3.2.1 Baltimore, MD

Baltimore, MD, is the northernmost NOS Bay station that had salinity data available for the study period. Being close to the mouth of the Susquehanna River, Baltimore salinities are low and greatly influenced by periods of dry weather. Some of the data from 1980-88 showed unreasonably large changes in the daily values. These daily values were apparently transcription errors and were corrected, when possible, after consultation with NOS. When it was not possible to determine if a questionable daily value was a transcription error, the value was not included in the monthly average. Since some errors in the daily values were detected in Baltimore data examined after 1980, it is possible that some unreliable daily values may be included in some of the older Baltimore monthly data. However, the above- and below- normal periods seen in the monthly data for Baltimore and the other two closest stations, Annapolis and Solomons Island, are similar.

A salinity minimum occurs in May at Baltimore, as seen in the monthly average (Figure 2). A salinity maximum occurs in November. Baltimore in the 1950's showed mixed above- and below-normal salinities. The 1960's was a decade of strongly above-normal salinities, reaching nearly 75 percent above normal in March 1969 (Figure 3). Salinities in the 1970's at Baltimore were mostly below normal, in striking contrast to the 1960's decade. In the 1981-83 period, salinities were much above normal, followed by below-normal salinities in 1983 and 1984, returning to mostly above normal through 1988.

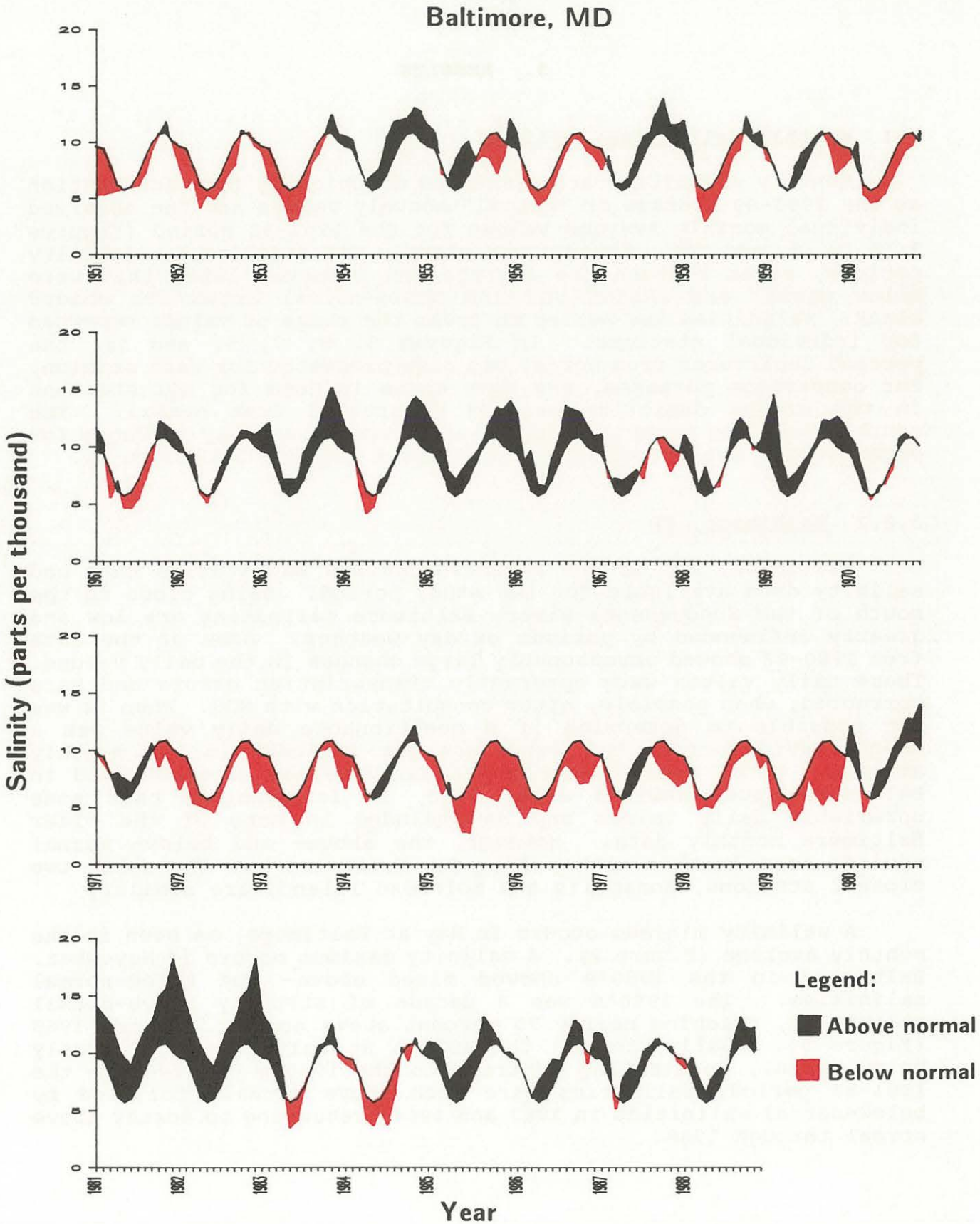

Figure 2. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Baltimore, MD, 1951-88. Data from NOAA, National Ocean Service.

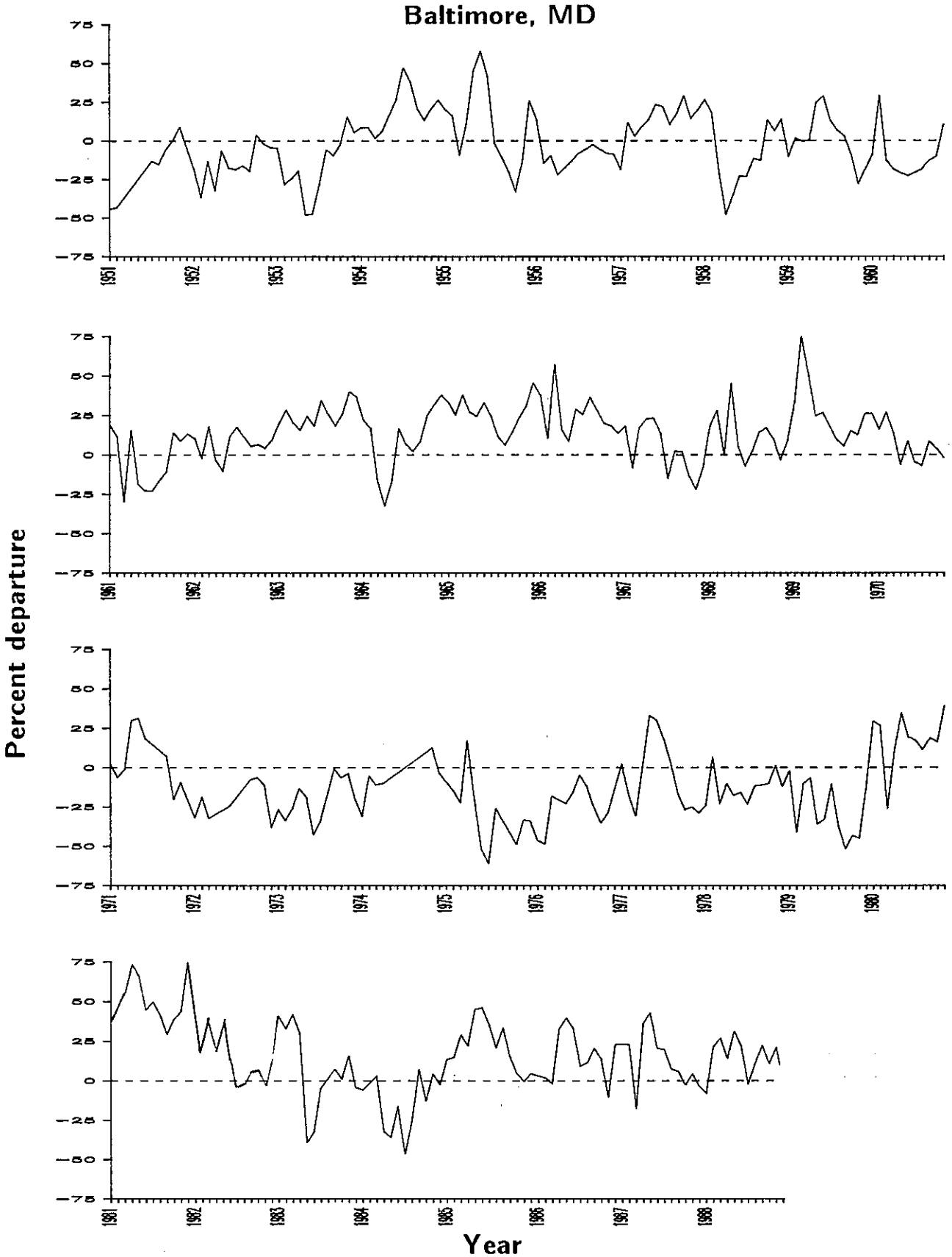

Figure 3. Monthly percent deviation from normal for 1951-88 surface salinities, Baltimore, MD. Data from NOAA, National Ocean Service.

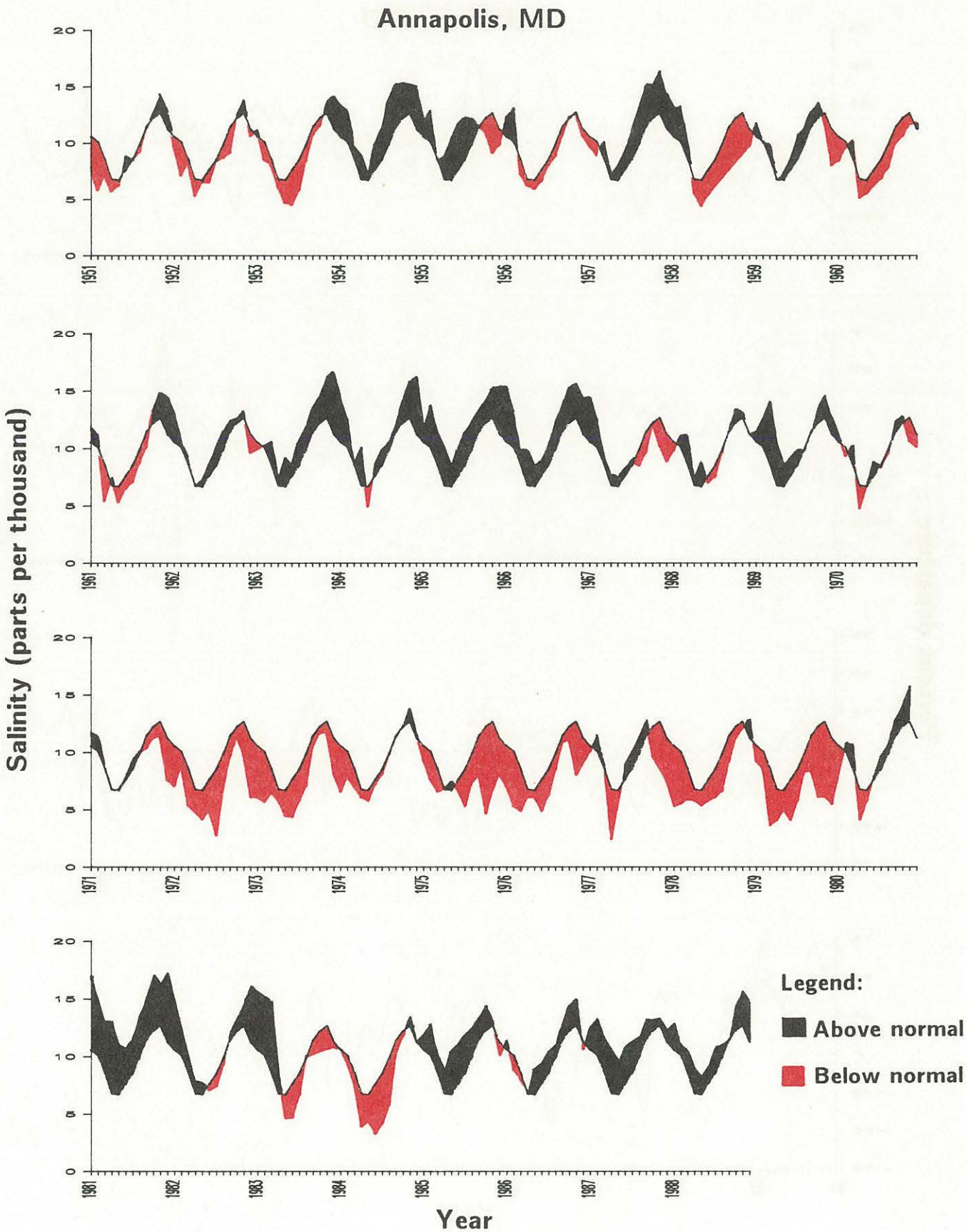

Figure 4. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Annapolis, MD, 1951-88. Data from NOAA, National Ocean Service.

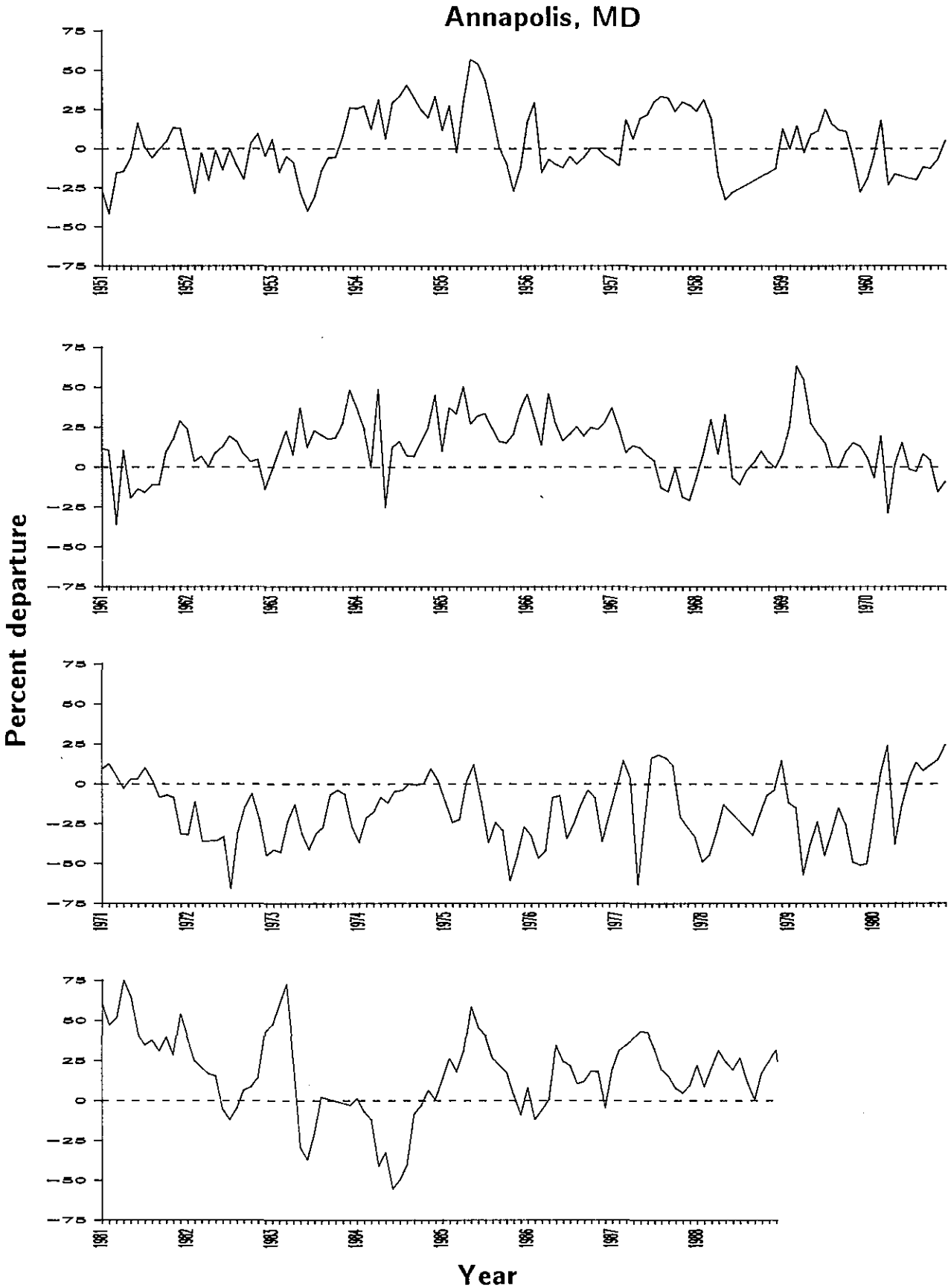

Figure 5. Monthly percent deviation from normal for 1951-88 surface salinities, Annapolis, MD. Data from NOAA, National Ocean Service.

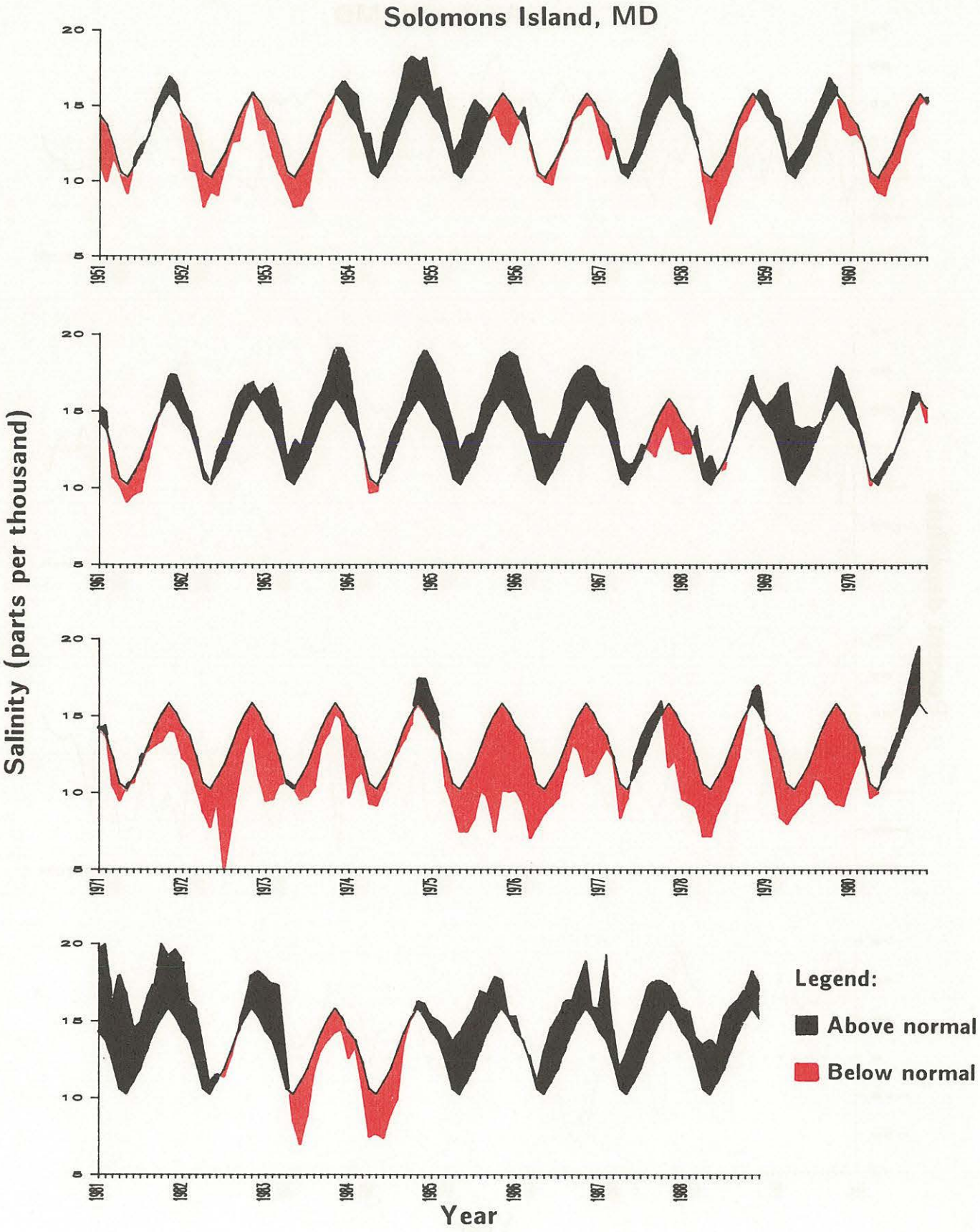

Figure 6. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Solomons Island, MD, 1951-88. Data from NOAA, National Ocean Service.

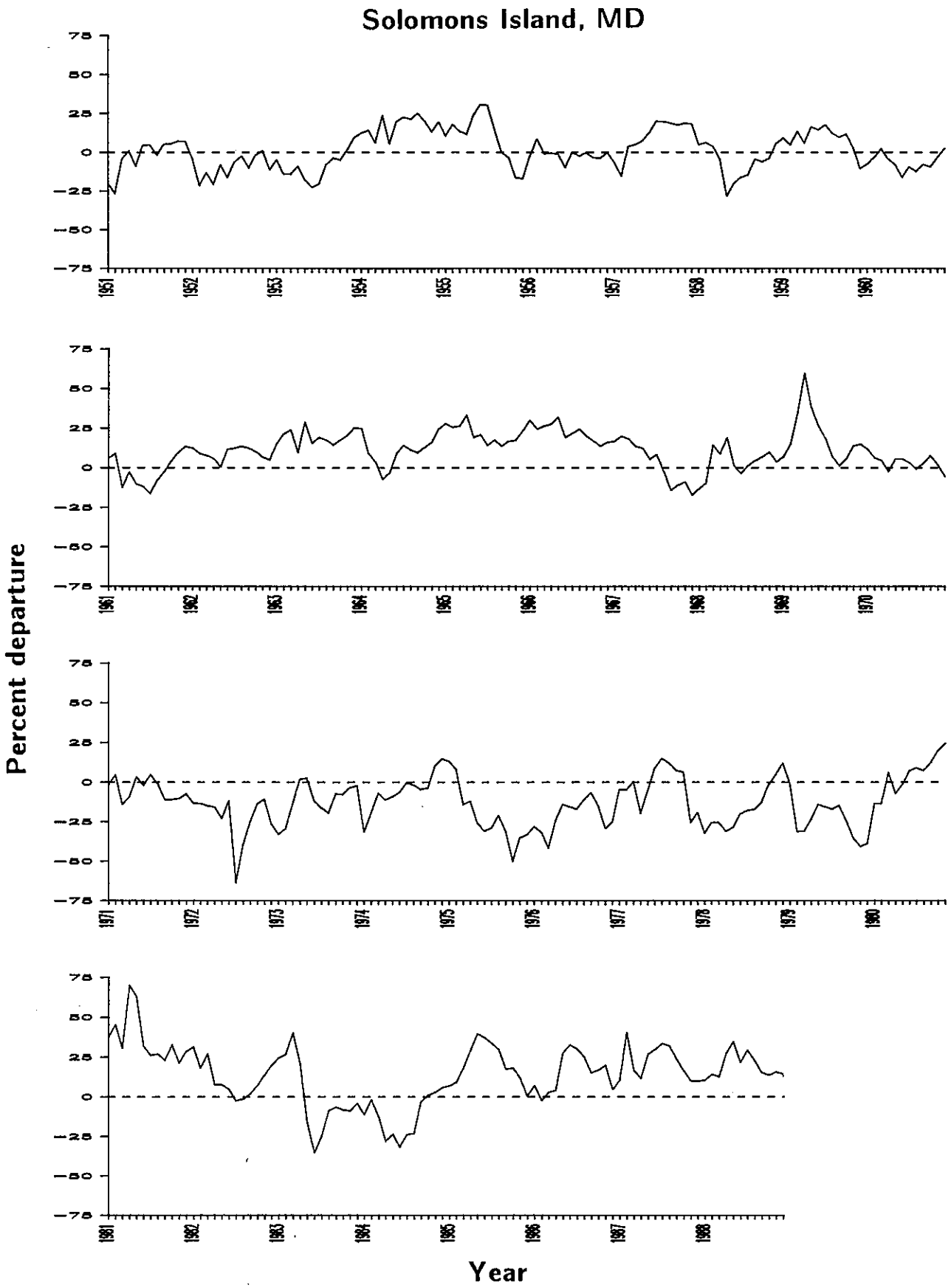

Figure 7. Monthly percent deviation from normal for 1951-88 surface salinities, Solomons Island, MD. Data from NOAA, National Ocean Service.

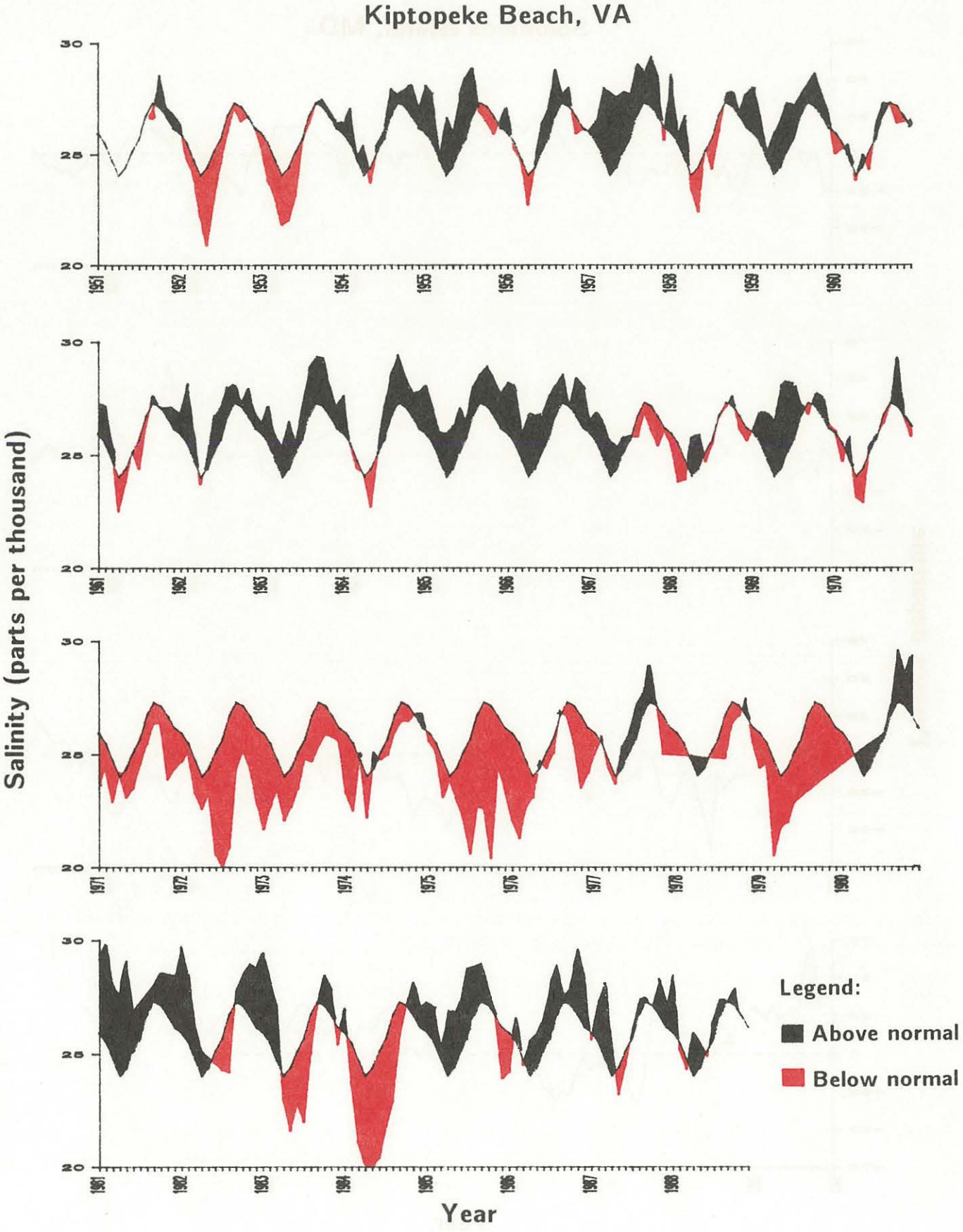

Figure 8. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Kiptopeke Beach, VA, 1951-88. Data from NOAA, National Ocean Service.

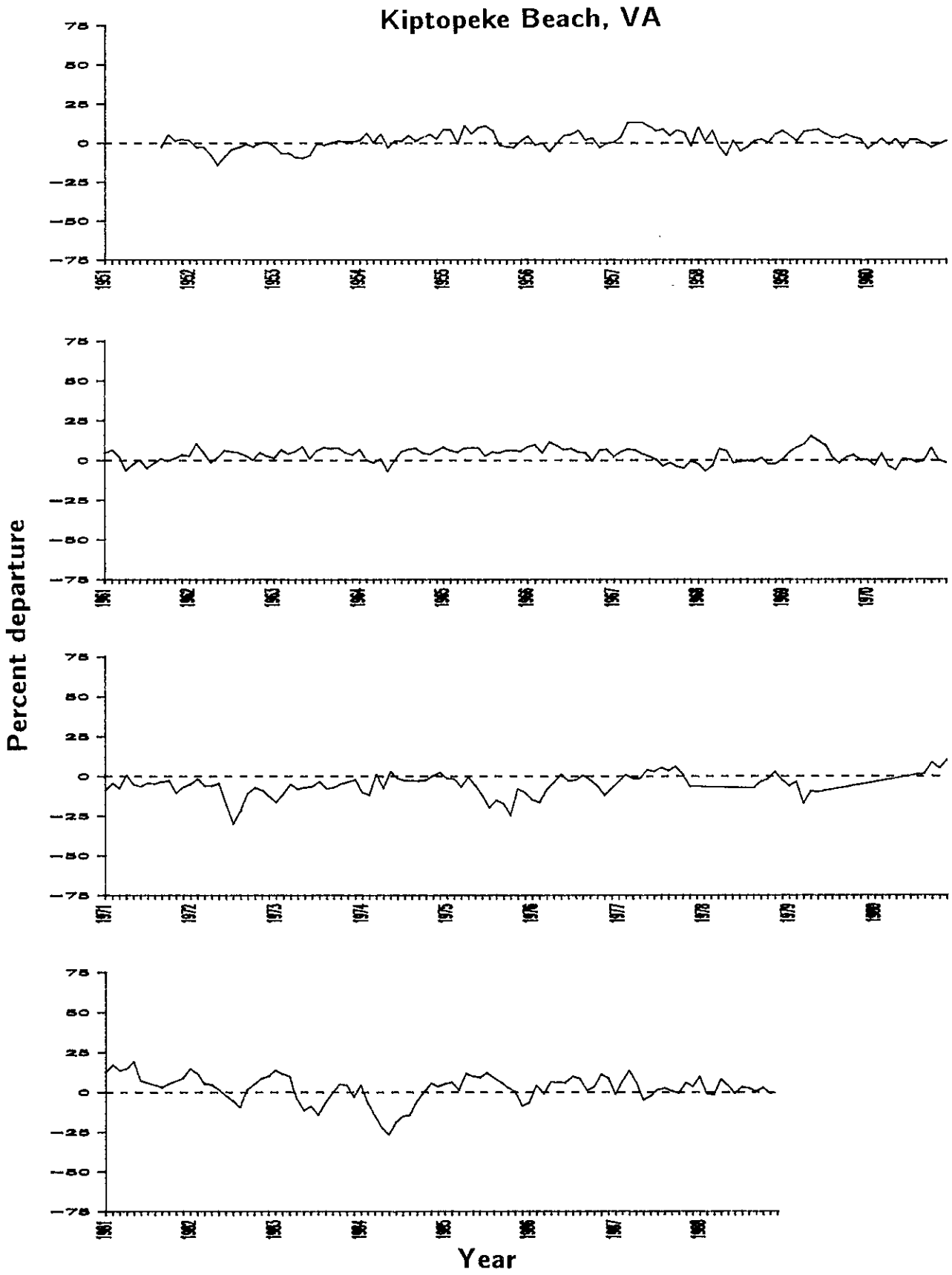

Figure 9. Monthly percent deviation from normal for 1951-88 surface salinities, Kiptopeke Beach, VA. Data from NOAA, National Ocean Service.

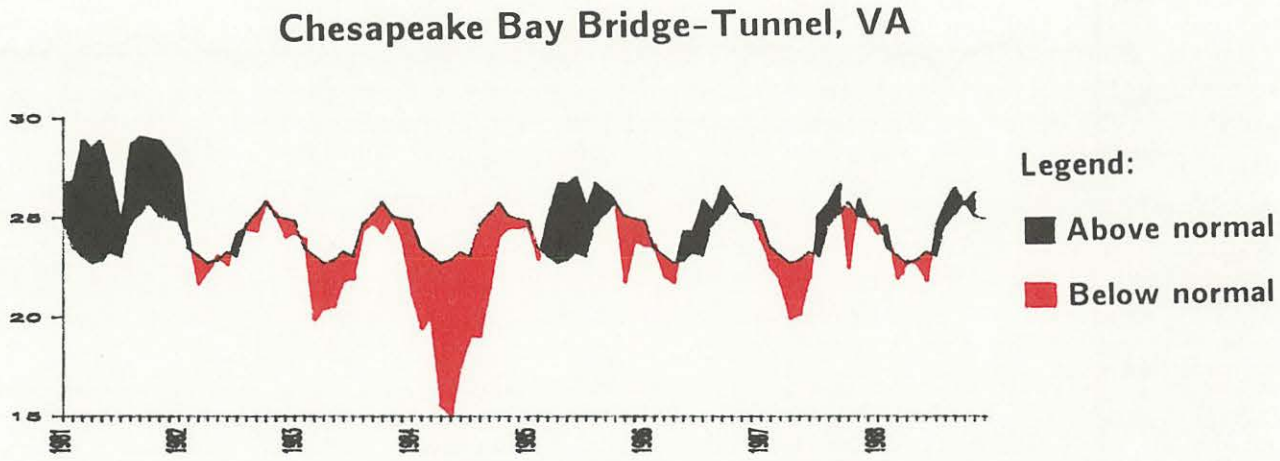

Figure 10. Monthly average surface salinities (parts per thousand) with monthly averages (1981-85) for Chesapeake Bay Bridge-Tunnel, VA, 1981-88. Data from NOAA, National Ocean Service.

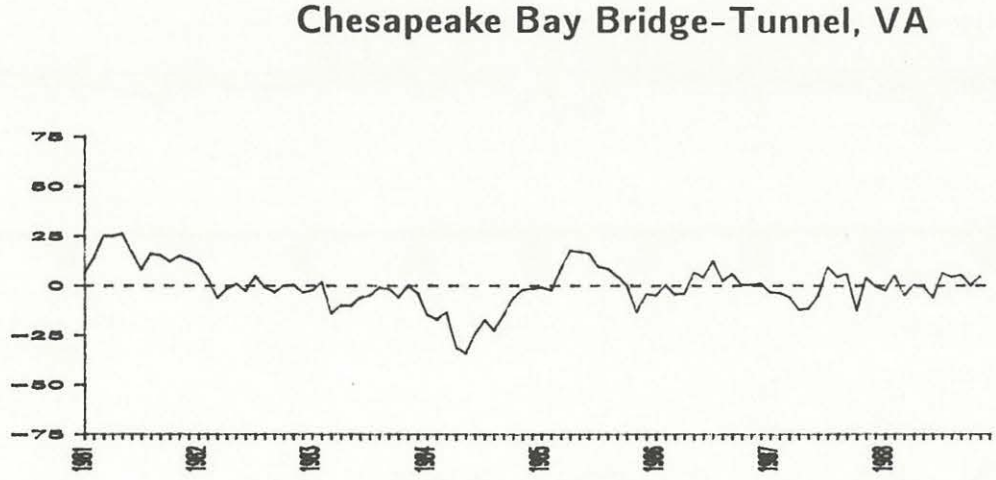

Figure 11. Monthly percent deviation from normal for 1981-88 surface salinities, Chesapeake Bay Bridge-Tunnel, VA. Data from NOAA, National Ocean Service.

3.2.2 Annapolis, MD

Annapolis, MD, salinities are very close to the range of salinities that occurred at Baltimore from 1951-88. A salinity minimum occurs in May at Annapolis, as seen in the monthly averages (Figure 4). A salinity maximum occurs in November.

Above- and below-normal salinity periods for Annapolis are similar to those at Baltimore. The differences between stations during these periods can be seen by comparing Figures 2 and 4. Quantitatively, these differences in salinities between the two stations can be seen by comparing the percent departures from normal in Figures 3 and 5.

3.2.3 Solomons Island, MD

Solomons Island, MD, has a mid-Bay location and is a station that represents salinity conditions over a major portion of the middle Bay. A seasonal salinity minimum occurs in May, and a maximum is reached in November.

Figure 6 shows a mixed appearance of above- and below-normal salinities in the 1950's, and mostly above-normal salinities in the 1960's. High streamflow throughout most of the 1970's lead to below-normal salinities over most of the decade. Seasonal differences in the streamflow from the Susquehanna (contributing nearly half of the annual freshwater inflow to the Bay), fall vertical mixing, upwellings, and other mass water movements in the Bay appear to constitute the major causes of salinity changes at Solomons Island (Beaven, 1960). The lowered salinities in summer 1972 had a profound effect on the Bay's biota, notably oysters, which suffered extensive mortalities (Chesapeake Research Consortium, Inc., 1976).

Following the mostly below-normal salinities of the 1970's, the 1980's began with drought conditions that led to strongly above-normal salinities in 1980 and 1981. Salinities dipped below normal in 1983 and 1984 and returned to predominantly above-normal values in 1985 through 1988.

In Figure 7, the above- and below-normal salinity periods can be more clearly seen as percent deviations from the 1951-80 monthly normals. Percent departures from normal were strongly positive in the mid-1960's, but dipped below normal from August 1967 through February 1968 and in July 1968. Following the nearly 60 percent above-normal peak in March 1969, percentages were well below normal throughout the 1970's. The percentage departures from normal highlight the years 1980-87 as having mostly above-normal salinities, except for the below-normal values from May 1983 through September 1984.

3.2.4 Kiptopeke Beach, VA

Salinities at the lower Bay stations are influenced by both the exchange of shelf and Bay waters and by local hydrological conditions. Kiptopeke Beach, VA, shows, as do the upper Bay stations, mixed above- and below-normal periods in the 1950's, followed by mostly above-normal salinities in the 1960's, followed by mostly below-normal salinities in the 1970's, followed by mostly above-normal salinities in the 1980's (Figure 8). There was a notable drop in salinity in spring and summer 1984 at Kiptopeke. Precipitation and streamflow records showed this to be an unusually wet period in the lower Bay compared to the upper Bay (Dowgiallo, et al. 1985). The percent departures from normal are shown in Figure 9.

3.2.5 Chesapeake Bay Bridge-Tunnel, VA

Salinity records at the Chesapeake Bay Bridge-Tunnel, VA, station were available since 1981 and are included primarily because of the station's activity through 1988. A five-year monthly average was computed for the period of 1981-85. The monthly observed salinities and averages are shown in Figure 10. The 1980's began with above-normal salinities at the Chesapeake Bay Bridge-Tunnel station. In 1982, salinities were close to normal, followed by dips to below normal in 1983 and 1984. Salinities from 1985 through 1988 showed mixed above- and below-normal periods at this station. Percent departures from normal are shown in Figure 11.

4. SUMMARY AND CONCLUSIONS

Surface salinity data for five National Ocean Service (NOS) stations are provided for the period 1951-88. Monthly averages were computed for 1951-80, coinciding with the period used to derive climatological means used by the National Weather Service. Percent departures from normal were computed for quantitative comparison of fluctuations of salinities between individual months and stations.

Salinities in Chesapeake Bay were mostly above normal in the 1960's, mostly below normal in the 1970's, and, with the exception of 1983-84, mostly above normal in the 1980's. The presentation of this long-term dataset supplements earlier studies of Bay salinities with the multiple stations active in the NOS network through 1988. This analysis lends itself readily to a comparison between salinity and biological phenomena such as oyster diseases whose distribution in the Bay appear to be strongly influenced by year-to-year salinity changes.

5. LITERATURE CITED

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APPENDIX A

Table 1. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Baltimore, MD, 1951-88.

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1951	5.4	5.4					6.2	7.3	9.4	10.8	11.9	
1952	7.9	6.0	6.9	4.2	5.4	5.0	5.8	7.2	8.0	11.2	10.7	9.7
1953	9.2	6.8	6.0	5.0	3.0	3.2	5.1	8.1	9.0	10.5	12.6	10.7
1954	10.5	10.3	8.1	6.6		7.7	10.5	11.9	12.0	12.2	13.2	12.8
1955	11.6	11.0	7.2	6.9	8.4	9.6	10.1	8.4	8.9	8.6	7.3	8.8
1956	12.2	10.8	6.8	5.6	4.5	5.0	6.2	7.9	9.4	10.5	10.3	9.3
1957	8.8	7.7	8.9	6.4	6.3	6.9	8.8	10.5	11.0	12.7	14.1	11.6
1958	11.6	12.0	9.4	5.0	3.0	3.9	5.5	6.6	8.8	9.4	12.4	10.8
1959	11.0	8.5	8.1	6.2	5.8	7.6	9.2	9.7	10.6	11.1	9.9	7.3
1960	7.9	8.6	10.3	5.4	4.7	4.8	5.5	6.8	8.1	9.4	9.8	11.2
1961	11.5	10.6	5.6	7.2	4.7	4.7	5.5	7.2	8.9	12.3	11.9	11.5
1962	10.7	9.3	9.4	6.0	5.2	6.8	8.4	9.6	10.5	11.5	11.4	11.1
1963	11.6	12.2	9.6	7.2	7.2	7.2	9.6	10.8	11.8	13.6	15.3	13.9
1964	11.8	11.1	6.6	4.2	4.8	7.1	7.6	8.8	10.8	13.5	14.4	14.0
1965	12.9	11.9	11.0	7.9	7.2	8.1	8.9	9.6	10.6	12.3	13.5	13.3
1966	14.1	13.1	8.8	9.8	6.7	6.6	9.2	10.8	13.6		13.1	12.0
1967	11.0	11.2	7.3	7.3	7.1	7.5	8.1	7.3	10.2	11.0	9.4	7.9
1968	8.9	11.2	10.2	6.2	8.4	6.4	6.6	8.8	11.4	12.6	12.0	9.8
1969	10.5	12.6	14.5	9.4	7.2	7.7		9.4	10.5	12.4	12.3	12.8
1970	12.2	11.0	10.1	7.1	5.4	6.6	6.8	8.0	10.8	11.2	10.7	
1971	9.9	8.9	7.9	8.1	7.6	7.2			10.7	8.6	9.9	
1972	6.6	7.7	5.4			4.6			9.2	10.1	9.7	6.3
1973	7.1	6.3	5.9	5.4	4.7	3.5	4.7		9.9	10.1	10.5	8.1
1974	6.7	9.0	7.1	5.6							12.3	9.8
1975	8.8	8.1	6.2	7.3	4.6	2.9	2.8	6.4			5.6	6.8
1976	6.4	5.1	4.1	5.1		4.7	6.0	8.2	8.8	8.1	7.1	7.2
1977		9.7	6.6	4.3		8.1	9.3	10.2	10.3	9.0	8.0	7.6
1978	6.9	7.2	8.5	4.8	5.2	5.0	6.0	6.6	8.8		9.8	10.3
1979	8.5	9.3	4.7	5.6	5.4	3.9	4.8	7.7	6.2	5.2	6.2	5.6
1980	8.6	12.3	10.1	4.6	6.4	8.2	8.5	10.1	11.1	12.8	12.7	14.1
1981			12.4	10.8	9.6	8.8	10.7	12.2	12.9	15.0	15.7	18.3
1982		11.0	11.1	7.3	8.0	6.9	6.8	8.5	10.5	11.6	10.8	11.4
1983	13.6	12.6	11.3	8.1	3.5	4.1	6.8		10.7	10.9	12.7	9.7
1984	9.1		8.2	4.2	3.7	5.1	3.8	6.4	10.7	9.4	11.4	9.9
1985	11.0	10.9	10.3	7.6	8.4	8.9	9.7	10.4	13.3	12.4	11.4	10.1
1986	10.1		8.1	6.1	7.7	8.5	9.5	9.4	11.1	13.0	12.4	9.1
1987	11.9	11.7	9.8	5.1	7.9	8.7	8.6	10.3	10.7	11.4	10.6	10.6
1988	9.3	8.7	9.7	7.9	6.6	8.0	8.7	8.4	11.1	13.2	12.1	12.3
'51-80 AVG.	9.7	9.5	8.0	6.2	5.8	6.1	7.1	8.6	10.0	10.8	10.9	10.2

(Blank entries indicate monthly average not available.)

Table 2. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Annapolis, MD, 1951-88.

	Month											
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1951	7.7	5.9	7.3	5.8	6.3	8.9	8.6	9.3	11.4	12.8	14.4	12.7
1952	9.8	7.2	8.4	5.4	6.6	6.6	8.5	8.8	9.2	12.7	13.9	10.7
1953	11.2	8.6	8.2	6.2	4.8	4.6	5.9	8.5	10.8	11.6	13.7	14.2
1954	13.3	12.9	9.7	8.9	7.1	9.9	11.4	13.9	15.2	15.3	15.2	15.0
1955	11.8	12.9	8.4	8.8	10.5	11.8	12.3	12.2	11.5	11.1	9.2	9.9
1956	12.4	13.1	7.3	6.3	6.0	6.7	8.1	8.9	10.8	12.3	12.7	10.7
1957	9.8	9.0	10.2	7.2	8.0	9.3	11.1	13.2	15.2	15.2	16.5	14.4
1958	13.1	13.3	10.3	5.6	4.5	5.5						9.8
1959	11.9	10.1	9.9	6.6	7.3	8.5	10.7	11.4	12.8	13.6	11.9	8.1
1960	8.5	9.7	10.2	5.2	5.6		6.9	7.9	10.1	10.7	11.8	11.8
1961	11.8	11.2	5.5	7.5	5.4	6.6	7.2	8.8	10.2	13.5	14.9	14.5
1962	13.1	10.5	9.2	6.8	7.3	8.6	10.2	11.5	12.4	12.7	13.3	9.7
1963			10.6	7.3	9.2	8.6	10.5	11.9	13.5	14.5	16.2	16.7
1964	14.5	12.6	8.6	10.1	5.0	8.6	9.9	10.6	12.2	14.2	15.8	16.3
1965	11.6	13.9	11.5	10.2	8.5	10.1	11.4	12.3	13.3	14.1	15.3	15.3
1966	15.4	13.2	9.8	9.9	8.5	8.9	10.3	12.4	13.7	15.3	15.7	14.4
1967	14.5	12.6	9.4	7.7	7.5	8.2	8.9	8.6	9.7	12.2	10.3	8.9
1968	9.9	11.1	11.2	7.3	8.9	7.1	7.6	9.7	11.8	13.5	13.1	11.2
1969	11.5	12.7	14.1	10.5	8.5	9.2	9.8	9.9	11.4	13.5	14.6	12.7
1970	11.2	9.4	10.3	4.8	6.8	8.8	8.4	9.6	12.4	12.8	10.7	10.2
1971	11.6	11.4		6.6	6.9	7.9	9.4	10.1	10.5	11.4	11.6	7.7
1972	7.2	9.0	5.5		4.3	5.1	2.9	6.9	9.8	11.5	9.9	6.2
1973	6.2	5.8	6.6	5.9	4.6	4.5	5.9	7.2	10.7	11.8	11.9	8.2
1974	6.7	8.0	7.1	6.2	5.9	7.3	8.2	9.9	11.4	12.3	13.9	11.5
1975	9.4	7.7	6.7	6.9	7.5	6.8	5.4	7.5	8.1	4.8	6.9	8.2
1976	7.1	5.4	5.0	6.2	6.2	5.0	6.4	8.6	11.0	11.2	8.1	
1977	10.2	11.6	8.9	2.5		8.9	10.1	11.5	12.8	9.7		7.5
1978	5.4	5.6	6.0	5.9	5.5		6.2	6.7	9.3	11.4	12.2	12.9
1979	9.3	8.6	3.7	4.2	5.1	4.2	5.9	8.4	8.5	6.2	6.2	5.6
1980		10.8	10.7	4.2	5.8	7.9	9.7	10.7	12.8	14.1	15.8	
1981	16.9	14.9	13.1	13.1	11.0	10.8	11.5	13.6	15.0	17.1	16.3	17.3
1982		12.6		7.9	7.7	7.2	7.5	9.4	12.2	13.3	14.5	16.1
1983	15.6		14.9	8.5	4.7	4.8	6.8	10.1				10.9
1984	10.7	9.4	7.6	4.0	4.5	3.4	4.3	5.9	10.5	11.9	13.5	11.3
1985	12.0	12.8	10.2	8.9	10.6	11.1	12.0	12.5		14.4	13.1	10.2
1986	11.4	8.9	8.1	6.8	9.0	9.5	10.4	10.9	12.8	14.5	15.0	10.7
1987	12.6	13.3	11.6		9.6	10.9	11.3	11.8	13.2	13.2	13.3	12.3
1988	12.9	11.0	10.4	8.9	8.3	9.1	10.8	11.0	11.5	14.4	15.8	14.8
'51-80 AVG.	10.6	10.1	8.6	6.8	6.7	7.6	8.5	9.9	11.5	12.3	12.7	11.3

(Blank entries indicate monthly average not available.)

Table 3. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Solomons Island, MD, 1951-88.

	Month											
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1951	11.4	10.1	11.8	10.7	9.3	11.5	12.4	12.8	15.0	16.0	17.0	16.3
1952	13.7	10.8	10.7	8.4	9.4	9.2	11.1	12.7	12.8	14.9	16.0	13.5
1953	13.6	11.8	10.6	9.6	8.4	8.5	9.4	12.0	13.7	14.4	16.1	16.7
1954	16.1	15.7	13.1	13.1	10.8	13.2	14.5	15.8	17.8	18.2	17.9	18.2
1955	15.8	16.2	14.0	11.8	12.7	14.4	15.4	14.9	14.2	14.6	13.2	12.6
1956	13.9	14.9	12.2	10.5	10.1	9.9	11.8	12.7	14.2	14.6	15.2	15.2
1957	13.3	11.6	12.8	11.1	11.0	12.4	14.2	15.6	16.9	17.8	18.8	18.0
1958	15.0	14.6	12.8	10.1	7.3	8.8	9.9	11.1	13.6	14.2	15.2	16.1
1959	15.6	14.4	14.0	11.2	11.9	12.6	13.9	14.6	15.6	16.9	16.3	13.6
1960	13.2	13.3	12.6	10.1	9.4	9.2	10.7	11.4	13.1	13.7	15.3	15.6
1961	15.2	15.0	10.8	10.3	9.2	9.7	9.9	12.0	13.9	15.8	17.4	17.3
1962	16.1	15.0	13.3	11.2	10.3	12.3	13.3	14.8	16.0	16.7	16.9	16.0
1963	16.5	16.7	15.3	11.6	13.2	12.7	14.1	15.3	16.3	17.8	19.1	19.1
1964	17.9	15.0	12.8	9.8	9.9	12.0	13.5	14.5	15.6	17.1	18.4	19.0
1965	18.3	17.3	15.6	14.1	12.2	13.3	13.5	15.3	16.2	17.7	18.6	18.8
1966	18.6	17.1	15.6	13.5	13.5	13.1	14.4	16.2	17.1	17.7	18.0	17.7
1967	16.7	16.5	14.6	12.0	11.5	11.6	12.8	12.7	12.2	13.5	14.4	12.6
1968	12.4	12.4	14.1	11.5	12.2	11.1	11.4	13.2	14.9	16.2	17.4	15.8
1969	15.3	15.8	16.6	16.9	14.1	13.9	14.0	13.9	14.4	16.0	18.0	17.5
1970	16.0	14.6	12.9	10.3		11.6	12.2	12.9	14.6	16.3	16.1	14.4
1971	14.1	14.4	10.6	9.6	10.6	10.8	12.4	12.9		13.5	14.2	14.1
1972	12.4	11.9	10.5	8.9	7.9	9.7	4.3	7.9	10.7	13.1	14.1	11.2
1973	9.6	9.7	10.7	10.8	10.5	9.7	9.9	10.5	13.2	14.0	15.3	14.9
1974	9.8	11.1	11.5	9.4	9.3	10.3	11.8	12.8	13.6	14.6	17.5	17.5
1975	16.2	14.9	10.6	9.3	7.6	7.6	8.4	10.3	9.8	7.6	10.3	10.2
1976	10.3	9.4	7.2	8.0	8.8	9.3	9.8	11.6	13.3	12.9	11.2	11.4
1977		13.1	12.4	8.5	9.7	12.0	13.6	14.6	15.3	16.1	11.8	12.3
1978	9.7		9.2	7.3	7.3	8.8	9.7	10.8	12.4	14.9	16.6	17.1
1979	14.2		8.5	8.1	8.8	9.3	9.8	11.1	10.8	9.8	9.4	9.3
1980		11.9	13.1	9.8	10.1	11.8	12.9	14.0	16.0	18.2	19.7	
1981	19.7	20.0	16.1	18.0	16.7	14.5	14.9	16.5	17.5	20.1	19.2	19.6
1982	18.8	16.2	15.7		11.0	11.5	11.5	12.8	14.5	16.2	18.0	18.2
1983	17.8	17.4	17.3	12.8	8.6	7.1	8.9	11.9	13.3	13.9	14.4	14.6
1984	12.7	13.5	10.8	7.6	7.8	7.5	9.0	10.0	13.8	15.3	16.3	16.1
1985	15.3	15.0	14.6	13.7	14.3	15.1	15.8	16.9	16.7	17.9	17.7	15.3
1986	15.3	13.4	12.7	11.0	13.1	14.6	15.4	16.3	16.4	17.7	19.0	15.9
1987	15.8	19.3	14.4	11.8	13.0	14.3	15.8	17.2	17.6	17.6	17.4	16.7
1988	15.8	15.7	13.9	13.5	13.8	13.4	15.3	16.0	16.4	17.2	18.3	17.4
'51-80 AVG.	14.3	13.8	12.4	10.6	10.2	11.0	11.8	13.0	14.2	15.2	15.8	15.2

(Blank entries indicate monthly average not available.)

Table 4. Monthly average surface salinities (parts per thousand) with monthly averages (1951-80) for Kiptopeke Beach, VA, 1951-88.

	Month											
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1951									26.7	28.6	27.1	26.8
1952	26.4	24.8	24.1	22.2	20.9	22.9	24.6	26.0	27.1	26.5	26.7	26.3
1953	25.4	23.8	23.1	21.8	22.0	23.1	25.6	26.4	27.3	27.5	26.9	26.4
1954	26.4	27.1	24.8	25.4	23.7	25.4	26.0	28.0	27.7		28.2	26.9
1955	28.2	27.7	24.7	26.7	25.8	27.6	28.5	28.9	26.9	26.5	25.9	26.5
1956	27.1	25.2	24.7	22.7		26.3	27.1	28.9	27.8	28.0	25.9	26.1
1957	26.1	26.5	28.0		27.6	27.8	27.7	29.1	28.6	29.4	28.5	25.6
1958	28.6	25.8	26.7	23.4	22.4	25.5	24.3	26.0	27.7	27.8	26.8	27.7
1959	28.0		25.1	25.8		27.3	27.2	27.7	28.2	28.6	27.7	26.8
1960	25.0		25.4	23.8	25.0	24.3	26.3	27.3	27.3	26.4		26.5
1961	27.2	27.2	25.4	22.5	23.8	25.2	24.4	26.3	27.6	27.1	27.1	27.1
1962	26.7	28.2	26.0	23.7	24.8	26.7	27.1	28.0	28.1	27.2	28.0	26.9
1963	26.3	27.2	25.8	25.4	26.5	25.4	27.3	28.9	29.3	29.3	28.0	27.1
1964	27.7	25.5	24.4	24.2	22.7	25.1	27.1	28.6	29.4	28.4	27.7	27.8
1965	28.1	27.1	26.0	25.9	26.3	27.1	26.4	28.1	28.6	28.9	28.4	27.7
1966	28.2	28.0	25.9	26.8	26.7	26.8	27.6	28.1	28.6	27.1	28.4	28.0
1967	26.5	26.9	26.5	25.6	25.4	25.8	25.8	25.8	26.9	26.1	25.4	26.1
1968	25.4	23.8	23.9	25.8	25.9	24.7	25.5	26.7	27.1	27.6	26.1	25.6
1969	26.1	26.9	26.8	26.5	28.1	28.2	28.1	27.2	26.8	27.7	27.6	26.3
1970	26.0	24.7	25.8	23.1	22.9	25.4	25.8	26.4	27.2	29.3	26.7	25.8
1971	23.7	24.4	22.9	24.2	23.1	23.5	24.6	25.5	26.4	26.4	23.9	24.4
1972	24.7	25.1	23.3	22.6	23.3	20.6	18.0	20.9	24.4	25.2	24.4	22.9
1973	21.7	22.7	23.5	22.1	22.7	23.5	24.8	24.7	25.4	25.9	25.8	25.6
1974	23.3	22.5	25.1	22.2	25.1	24.8	25.0	26.0	26.5	26.5	26.8	26.8
1975	25.6	25.1	23.1	23.9	23.0	22.1	20.6	22.7	22.6	20.4	24.6	23.5
1976	22.1	21.3	22.7	23.1	24.7	24.4	25.1	26.9	26.7	25.5	23.5	24.2
1977		25.8	24.4	23.7	25.4	25.9	27.1	27.7	29.0	27.5	25.0	
1978								24.8	26.4	26.7	27.5	25.5
1979	24.4	24.6	20.5	21.8	22.0	22.9						
1980							26.0	27.2	29.7	28.5	29.4	
1981	29.3	29.9	28.1	27.6	29.1	26.9			28.1	28.6		28.5
1982	29.8	28.5	26.1	25.1	24.8	24.6	24.3	24.2	27.7	28.5	29.0	28.8
1983	29.5	28.4	27.2	23.0	21.6	22.9	22.0	25.0	27.2	28.5	27.9	25.4
1984	27.1	23.7	21.1	18.6	17.9	20.4	21.8	22.9	25.8	27.2	28.2	27.1
1985	27.3	27.1	25.1	26.8	26.8	27.4	28.8		29.0	27.9	26.8	23.9
1986	24.2	26.6	24.5	25.6	25.9	26.6	28.2	29.0	27.6	28.0	29.7	28.5
1987	25.6	27.3	28.1	25.5	23.2	24.5	26.1	27.4	27.5	27.0	28.3	27.1
1988	28.5	25.2	24.3	26.0	25.4	24.9	26.5	27.4	27.4	27.9	26.5	
'51-80 AVG.	26.0	25.5	24.8	24.0	24.4	25.1	25.7	26.7	27.3	27.2	26.7	26.2

(Blank entries indicate monthly average not available.)

Table 5. Monthly average surface salinities (parts per thousand) with monthly averages (1981-85) for Chesapeake Bay Bridge-Tunnel, VA, 1981-88.

	Month											
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1981	26.7	26.9	29.0	28.5	28.9	27.2	25.0	28.7	29.1	29.0	28.9	28.3
1982	27.6	24.3	21.7	22.4	23.1	22.7	24.2	24.5	24.4	25.8	25.2	24.1
1983	24.3	23.9	19.9	20.5	20.6	21.9	22.0	24.5	24.8	24.3	25.1	24.0
1984	21.2	19.5	20.0	15.6	15.1	17.7	19.1	19.1	21.5	24.2	24.6	24.6
1985	24.7	23.0	25.1	26.8	26.8	27.1	25.3	26.8	26.4	25.8	21.8	23.9
1986	23.7	23.6	22.1	21.8	24.4	24.3	26.0	25.3	26.7	25.9	25.2	25.2
1987	24.0	22.6	21.8	20.0	20.2	22.1	25.3	25.8	26.7	22.5	26.1	24.9
1988	24.3	24.7	22.0	22.8	22.8	21.9	24.6	25.8	26.6	25.8	26.3	
'81-85 AVG.	24.9	23.5	23.1	22.8	22.9	23.3	23.1	24.7	25.2	25.8	25.1	25.0

(Blank entries indicate monthly average not available.)