HYDROGRAPHY

OF THE

PAMLICO RIVER ESTUARY, N. C.

By

John E. Hobbie

Associate Professor of Zoology

N. C. State University

Raleigh, N. C.

The work upon which this publication is based was supported in part by funds provided by The Office of Water Resources Research, Department of Interior, through The Water Resources Research Institute, The University of North Carolina as authorized under The Water Resources Research Act of 1964. Matching funds and other support were provided by the Texas Gulf Sulphur Company.

Project No. B-004-NC

Agreement No. 14-01-0001-1038, F. Y. 1967-69

August 1970

ABSTRACT

The Pamlico River Estuary extends some 35 miles from Washington, N. C. to Pamlico Sound. It is shallow, from 2 to 6 miles wide, naturally productive, and has from 0.5 to 15 or 20 ppt salinity. The salinity regime is determined chiefly by the quantity of inflowing freshwater and changes in salinity of up to 10 ppt are common at any station. Lunar tides are small (less than 0.5 ft) but wind and wind tides can have important effects on the salinity distribution. In addition, the Coriolis Force causes much of the freshwater to flow along the south side of the estuary.

The temperatures range from 3°C (37°F) to 34°C (93°F), although temperatures above 31°C (89°F) are unusual. On any given day, there could be horizontal temperature differences of up to 4 degrees (C) or 7 fahrenheit degrees.

The estuary stratifies irregularly; when this happens in the summer complete deoxygenation may occur. This condition may last for only a week and then be destroyed by wind. The benthic animals (bottom dwelling) are completely eliminated from large stretches of the river by the low concentrations of oxygen.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This report covers salinity, temperature and dissolved oxygen measurements made in the Pamlico River Estuary of North Carolina in 1965, 1967, 1968 and 1969. The estuary is shallow and naturally productive with a salinity range of 0.5 to 15 or 20 ppt. The lunar tide is damped out by the Outer Banks so that there is only a 6 inch change in water level. Wind tides are more important and may raise or lower the water level more than 3 ft.

Changes in salinity were closely related to the amount of inflowing freshwater. This produced changes at one station, some 10 miles from the mouth of the estuary, of 13 ppt. Upstream dams on the Tar River would certainly reduce much of this flushing of freshwater and would thereby change the character of the estuary. It is recommended that studies be made of the effect of these changes on the animals and plants of the estuary so that accurate predictions can be made.

There were also changes in the salinity distribution due to the wind speed and direction and also to the Coriolis Force. In general, the estuary had lower salinities along the south shore as a result of these factors.

Temperatures ranged from close to freezing up to 93°F, although temperatures above 89°F were unusual. There are no industrial effluents adding heat so the temperatures found were the natural condition of the estuary. It is also important to note that the temperature varied by as much as 7°F within the estuary so that average temperatures or natural conditions of the water are extremely difficult to define. These facts become important when standards are being set for thermal additions to estuaries. It is recommended that 93°F would be a logical upper limit for an absolute standard for this estuary instead of the 90°F proposed Federal Standard.

The estuary stratifies irregularly, but the waters are so rich that the bottom waters lose all their dissolved oxygen within a week or so after stratification. As a result, benthic animals (bottom dwelling) are killed throughout large areas of this estuary. Although the estuary still has its natural flora and fauna, it is being enriched by sewage and farm runoff. If this could be reduced, then the occurance of these low oxygen levels would be reduced or halted entirely. The estuary would then become an even better environment. It is recommended, therefore, that every effort be made to reduce nutrient addition to this estuary from urban and farm wastes as well as from fertilizers.

INTRODUCTION

The estuaries of North Carolina are a valuable resource of the state that must be preserved. Obviously, research must be carried out to determine what the present-day conditions are in these estuaries, what changes are taking place, and what is the probable result of any added industrial wastes, increased domestic wastes, fertilizer runoff from farms, and dam and channel construction. Because of this need for research on estuaries, a laboratory was established in 1965 on the Pamlico River Estuary, near Aurora, N. C.

This publication includes data on salinity, temperature and dissolved oxygen collected between 1965 and 1969 by workers at the Pamlico Marine Laboratory of the Department of Zoology, North Carolina State University. The information will be valuable for planning future sampling, for explaining the distribution of organisms, and for delineating the basic estuarine environment. For example, R. Miller (1) has used the salinity and temperature data to help explain the distribution of ctenophores (comb-jellyfish) in the river and K. Tenore (2) used the oxygen data to explain seasonal changes in the benthic (bottom dwelling) animal populations. The temperature data should be useful to the N. C. Department of Water and Air Resources in setting and enforcing temperature standards. Some of the same data were also used in the chapter on oligohaline estuarine systems (low salt estuaries) in a forthcoming book (3).

This publication follows one on the phosphorus concentrations (4) and covers the same time span and stations. Other information on this estuary may be found in theses (5), (6), (7), (8), (1), (9) and in published papers (10),(11),(12).

A number of persons have helped in the planning and data collection for this project. D. B. Horton set up the laboratory and was principal investigator for some projects. E. Carpenter, H. L. Davis, D. Peters, J. Berry, W. Daniels,

D. Gossett, L. Wood and N. Scobie helped collect and reduce the data.

The Pamlico River Estuary

The Tar River flows through northeastern North Carolina and becomes an estuary at Washington, N. C.; at this point it becomes the Pamlico River. It then flows east for some 35 miles to enter Pamlico Sound directly west of Cape Hatteras. The maximum width is about 8 miles and the average depth about 10 feet. Most important for the current and the salinity regimes is the damping effect the outer banks have on the lunar tide. As a result, this tide is about 6 inches and is greatly overshadowed by wind tides of up to 3 feet. Because of the shallowness, the water is well stirred and there is little or no stratification in large parts of the estuary. The stirring also keeps large amounts of particulate matter in suspension with the result that the estuary is quite turbid most of the time.

The salinity range in this estuary, from 0 to 15 ppt, is very difficult for organisms to adapt to; as a result, the number of different kinds of animals is small compared with the freshwaters, oceans or even Pamlico Sound (salinity around 20 ppt). The phytoplankton is dominated by an extensive algal bloom that occurs in January to March of every year. The dominant organisms in this bloom, the dinoflagellate Peridinium triquetrum, attains "red tide" numbers. The dominant zooplankter is the copepod, Acartia tonsa, which is fed upon by larval fish and by the ctenophore (comb-jellyfish), Mnemiopsis leydii (1). The fish are mostly salt water forms, although freshwater forms do occur near Washington, N. C. The permanent resident fish include mummichog, the rainwater killifish, the naked goby, white perch, the striped anchovy, American eel, and the hogchoker. Another group of fish is present year-round except in the winter. These include the tidewater silverside, the rough silverside, the common silverside, spot, atlantic croaker, pinfish, atlantic menhaden, summer flounder, and the northern pipefish. Other fish are found only during their migrations through the estuary. These include hickory shad, the alewife, glut herring, American shad, gizzard shad, striped bass, and the common sturgeon.

The benthic animals (bottom dwelling) are dominated in the fresher parts of the estuary by the clam, Rangia cuneata, and in the saltier parts by the bivalve, Macoma balthica. In contrast to many estuaries, there is a pronounced seasonal change in benthic animal species in the Pamlico River Estuary (2). This is probably due to changes in oxygen in the deeper waters.

The blue crab, shrimp, clam and oyster are commercially harvested from the estuary in sizeable quantities. In addition, the young of many saltwater commercial fish may spend part of their lives in this estuary.

Although there are salt marshes in several places along the estuary, these are high marsh (Juncus sp.) areas and do not contribute organic material to the estuary. This contrasts with other areas of North Carolina coast where the greater tidal range allows Spartina marshes to grow (low salt marsh). However, this missing organic matter is compensated for in the Pamlico River by dense beds of widgeon grass, Ruppia maritima, and Potamogeton (rooted aquatic plants). These are eaten directly by wintering geese and ducks and also furnish great quantities of nutritious particulate matter when they break up and decay in the fall.

One of the reasons for the establishment of the Aurora laboratory was to study the expected changes caused by the Texas Gulf Sulfur Company phosphate mine and fertilizer plant. The data on phosphorus concentrations in the estuary are given in detail in (4). Briefly, while phosphorus does enter the estuary, it appears to have little effect on the expected target site, the photosynthesis and growth of the algae. This is undoubtedly caused by the low levels of nitrogen found in the estuary. In fact, the nitrogen is probably limiting photosynthesis and algae are not able to utilize all the phosphorus. Another conclusion of the study was that the concentration of phosphorus entering the estuary from upstream (above the TGS site) is increasing rapidly.

METHODS

At least four different series of stations have been used during the study. Maps of the station numbers for March 1967 through February 1967 and for June 1968 through July 1969 are given as Figure 1 in (4).

During the sampling period reported here, from June 1965 to July 1969, samples were usually taken at two-week intervals. A conductivity bridge with built-in thermistor (Beckman RS5-3 induction salinometer) was used except for a few times when hydrometers were used. The samples for oxygen were fixed in the field and titrated in the laboratory (13). In order to calculate the saturation value for the oxygen in the waters of various salinities, the formula developed by (14) was used. This formula, as modified by Armstrong (personal communication), is:

$$C_S = \frac{475-2.65S}{33.3 + T};$$

where C_S is the saturation value for oxygen (mg/liter) at the given temperature and salinity, S is salinity (ppt), and T is temperature (^{o}C). The mg O_2/liter times 0.7 equals the ml/liter used in this report.

RESULTS

River Flow

The only river flow data from the Pamlico River area are those of the U. S. Geological Survey (Annual Reports of the Water Resource Division, U.S.G.S., Raleigh). One station is on the Tar River, 49.2 miles upstream from Washington, N. C. (the western end of the estuary). This has a watershed of 2,140 square miles. The other station is on Durham Creek, near Edward, N. C., about 6.7 miles south of the estuary. This creek has a drainage basin of only 21 square miles and enters the estuary just to the west of the Texas Gulf Sulphur Company plant (see later Figures for location).

The water flow in the two bodies of water was generally alike in basic characteristics, but differed at many particular points (Fig. 1). These differences result from local storms at these widely separated stations, plus the lag effects of a large versus a small watershed.

The water flow, reflecting directly the rainfall pattern, was irregular at both stations; there was, however, more flow during the winter. High flow periods in the Tar River were: 1967 in late February, end of August, early September, December; and in 1968 in January and at the end of March. For Durham Creek high flow occurred in: 1967 in mid-February, July, August, September, and December; and in 1968 in January, mid-March and the beginning of June.

Wind

The wind speed and direction for the period covered in this report are provided by Texas Gulf Sulfur Company observations. The data available include hourly wind speed and direction measurements as well as other standard meteorological observations. For the purpose of this report, the total wind movement per day (miles) and the prevailing direction of that wind have been abstracted (Fig. 2). The direction is given in degrees where 0° is a wind from the North, 90° is from the East, etc. Unfortunately, the wind direction recording equipment was not operating during the first five months of 1967.

The average wind speed, based upon total elapsed miles per day, appears to be much less than the 10 mph suggested as an average for the main coast line (15). If the average were 10 mph, then the total per day would be 240 miles and this is certainly much higher than the values in Figure 2. Of course, the

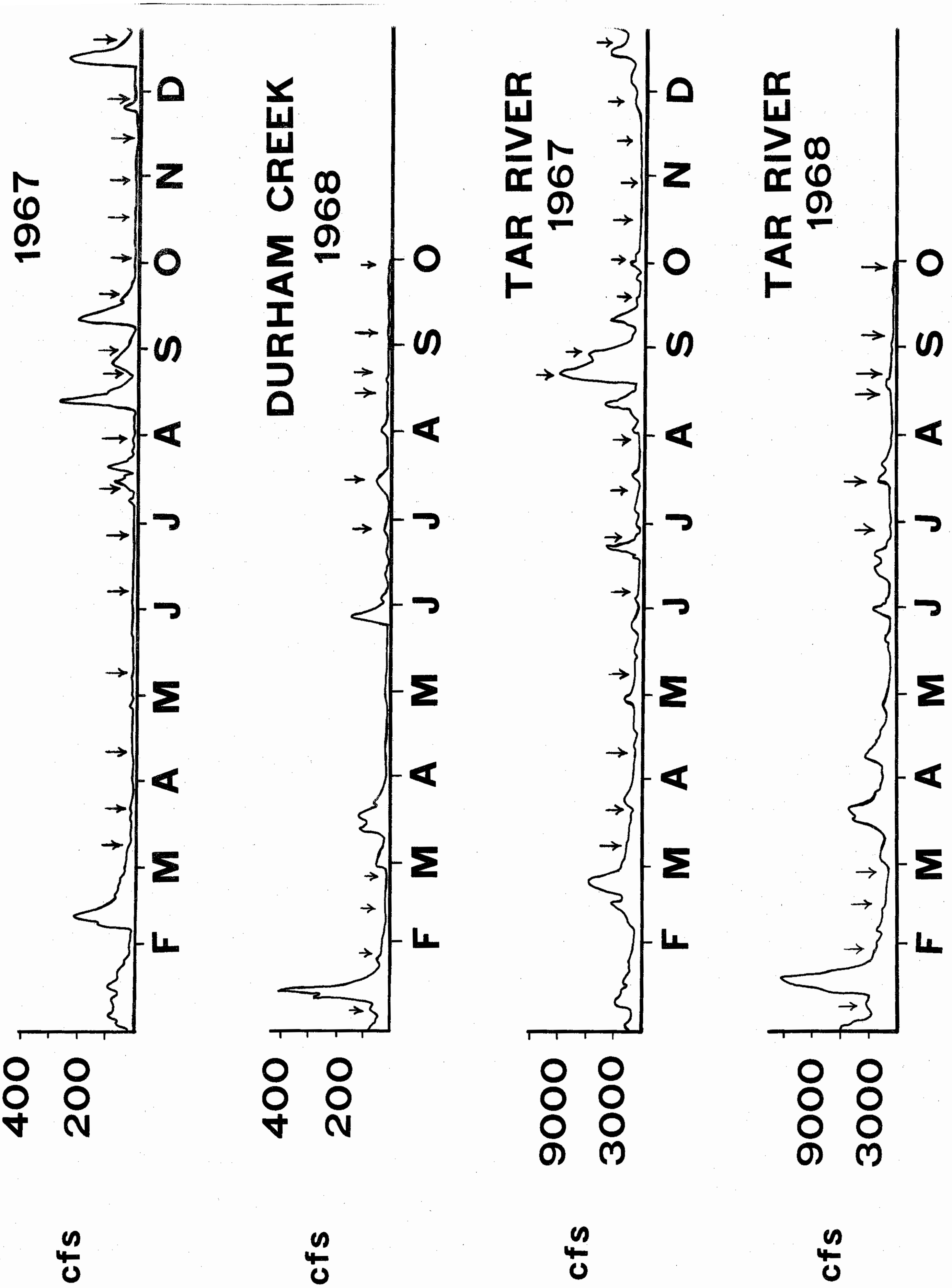


Figure 1. Water flow (cubic feet per second) in the Tar River at Tarboro, N. C. and in Durham Creek near Edward, N. C. Arrows indicate sampling dates.

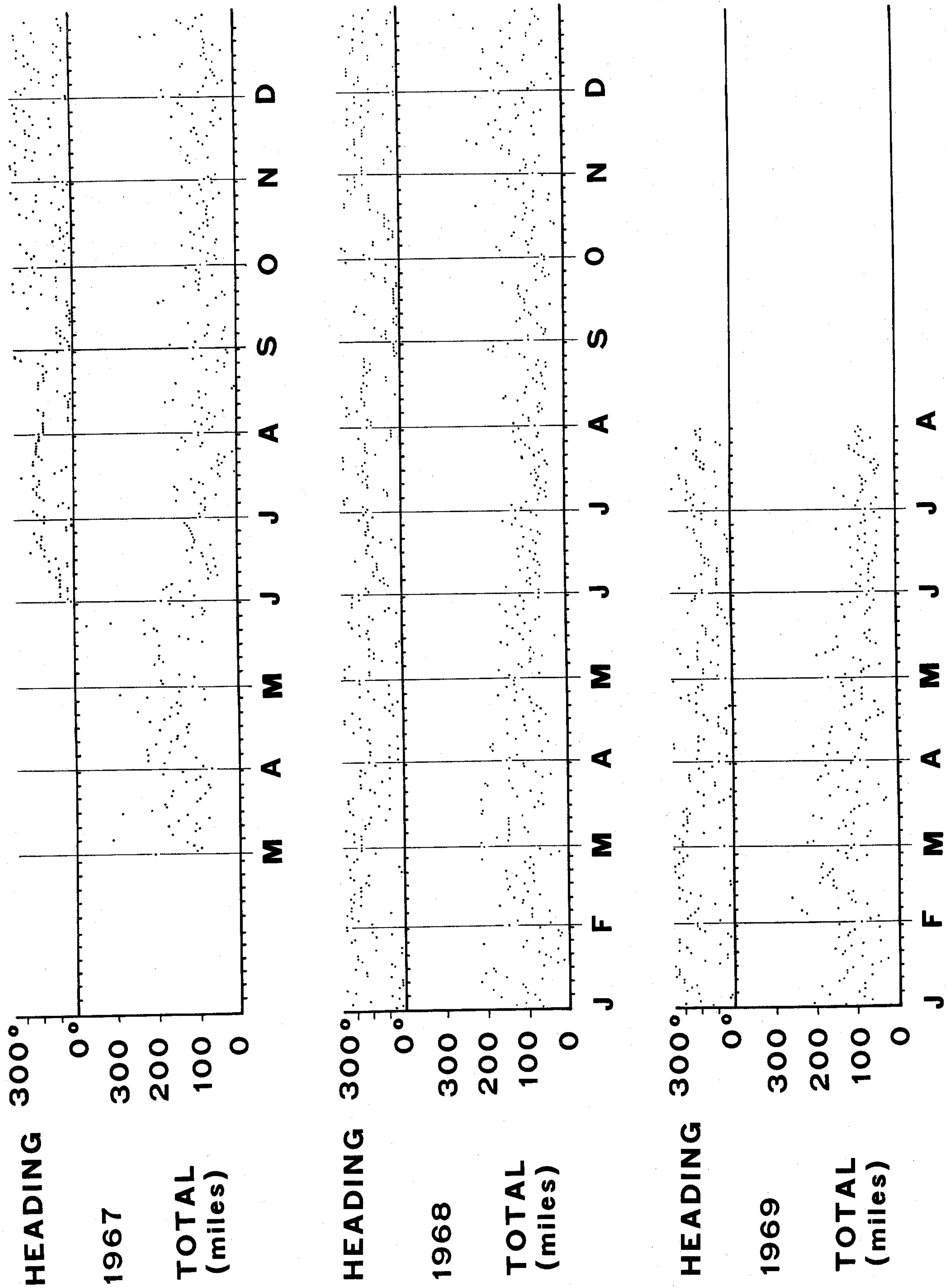


Figure 2. Wind speed and direction at the Texas Gulf Sulfur Company near Aurora, N. C.

two different methods of measuring as well as the methods of averaging may not be at all comparable. For this report, I am concerned only with the strong winds that would be capable of disturbing the stratification in the estuarine waters, and these would appear high in a relative sense even if there were errors. It is obvious, however, that the periods during the year of high winds were the winter and spring months. Only once during the ten summer months observed were there any winds greater than a total of 190 miles. Stronger winds began appearing in November and December and continued through May. However, during this period of observation there were no severe summer or fall hurricanes. The wind direction is much more difficult to describe accurately in a report, but it appears that the strong winds were out of the NE and NW. The prevailing winds for the whole of North Carolina are SW, except that in September and October, the prevailing winds are NE (15). This change of direction in the autumn results from persistant high pressure over the northern states and a greater number of low pressure storms passing off North Carolina. The effect of these strong winds will be discussed later in the section on salinity changes.

Salinity

The vertical and horizontal distribution of the salinity in 1965 is given in Table 1 and graphically in Figs. 3 to 6. In the figures the polygon along the base of each graph represents the bottom of the estuary. The lines above this are isohalines or lines connecting points of equal salinity. Thus, both the vertical depth distribution and the distribution of the salinity along the estuary are given.

The next notable feature of this 1965 series is the changeability of the stratification and of the salinity. For example, in the surface waters salinity of 2 ppt was found as near as 14 miles to the mouth of the estuary (Fig. 4) and as far as 30 miles from it (Fig. 5) (estimated). Moderate salinity water, around

Table 1. Salinity (ppt) at five stations in the Pamlico River Estuary, 1965. Station 2 (downstream) is the same as H1, 1 as H4, 3 as H6, 4 as H8, and 5 as H11 given in (4) Fig. 1).

Dates:	Depth (m)	June 10	June 29	July 21	Aug. 4	Aug. 18	Sept.9	Sept.23	Oct. 6	Nov. 12	Dec.16
Sta. 1	0.0	8.50	6.06	7.62	3.90	5.26	7.10	9.46	13.07	13.82	12.91
	0.5	8.43	6.14	7.66	3.92	5.38	7.17	9.43	13.22	13.77	12.85
	1.0	8.53	6.36	7.63	4.13	5.36	7.15	9.34	13.35	13.83	12.89
	2.0	8.47	7.00	7.68	4.89	5.52	7.41	9.69	13.50	13.84	15.32
	3.0	8.56	7.57	7.66	5.87	6.30	7.81	9.81	13.37	13.87	17.73
	4.0	11.66	11.80	7.72	8.91	11.88	12.00	13.64	14.85	13.83	17.79
				7.75*							
Sta. 2	0.0	10.92	9.30	12.73	7.91	8.60	8.21	12.04	20.43	18.25	--
	0.5	10.90	9.10	12.65	7.90	8.64	8.73	12.38	21.43	18.46	--
	1.0	10.92	9.20	12.62	9.33	8.68	9.64	12.87	22.26	18.63	--
	2.0	11.10	9.38	12.67	10.15	9.26	13.49	13.01	22.40	18.77	--
	3.0	11.28	10.01	12.75	10.74	11.00	13.91	14.77	22.78	18.77	--
	4.0	11.80	10.23	12.72	14.35	13.76	14.41	16.88	22.80	18.76	--
			0.61*								
	5.0	13.35	12.10	12.83	15.28	14.14	14.40	18.67	23.06	18.79	--
	6.0	13.40	12.80	13.19	15.29	14.42	14.40	18.80	23.76**	18.87	--
Sta. 3	0.0	5.47	4.62	3.84	.94	4.00	6.46	7.05	10.32	12.47	12.32
	0.5	5.46	4.68	3.90	1.02	4.02	6.43	7.05	10.23	12.53	12.60
	1.0	5.48	4.84	3.94	1.03	4.08	6.56	7.05	10.25	12.57	12.70
	2.0	5.44	5.35	4.10	1.42	4.34	6.52	7.13	12.50	12.60	15.33
	3.0	5.43	5.72	4.90	6.37	11.54	6.87	--	13.60	12.69	16.22
	4.0	5.48	5.88	8.66	6.03	11.48	7.01	--	--	12.69	17.53
Sta. 4	0.0	3.29	2.18	3.42	0.64	2.80	4.46	5.74	8.87	10.50	11.34
	0.5	3.28	2.24	3.42	0.60	2.86	4.49	5.70	9.18	10.57	11.62
	1.0	3.22	2.63	3.44	0.60	2.96	4.57	5.77	9.20	10.61	11.82
	2.0	3.26	2.77	3.42	0.73	3.56	5.78	5.78	10.60	10.76	14.57
	3.0	3.25	3.20	3.42	1.86	10.20	6.02	7.10	11.39	10.88	14.99
	3.5	3.25	--	--	--	--	--	--	--	--	--
	4.0	--	--	3.58	4.43	--	--	--	--	--	--
Sta. 5	0.0	1.06	0.78	1.82	0.28	2.04	2.40	3.83	7.41	9.07	9.14
	0.5	1.06	0.88	1.85	0.30	1.96	2.46	3.69	7.61	9.43	9.60
	1.0	1.09	0.85	1.85	0.37	1.94	2.70	3.76	7.69	9.51	9.85
	2.0	1.02	1.18	1.90	0.23	1.90	3.15	4.05	7.66	9.61	12.77
	3.0	1.03	1.80	1.90	0.27	4.30	3.70	5.04	8.31	9.86	13.39
	4.0	1.04	3.47	3.07	0.25	6.44	3.80	6.56	8.84	9.92	13.85
	5.0	1.04	3.98*	--	0.26	6.84*	3.80	6.70	9.23	10.10	13.87

*These Samples taken at 4.5 m.

** This Sample taken at 5.5 m.

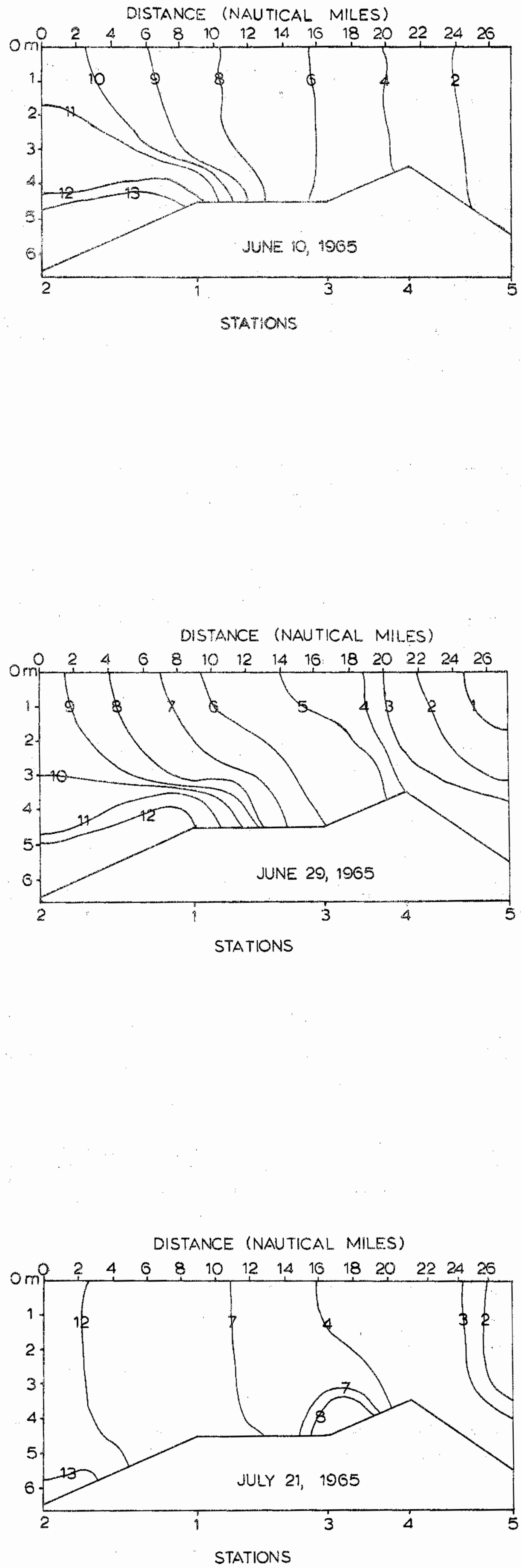


Figure 3. Salinity profiles (in ppt) in the Pamlico River Estuary for 10 June, 29 June, and 21 July 1965. Distances are from the mouth.

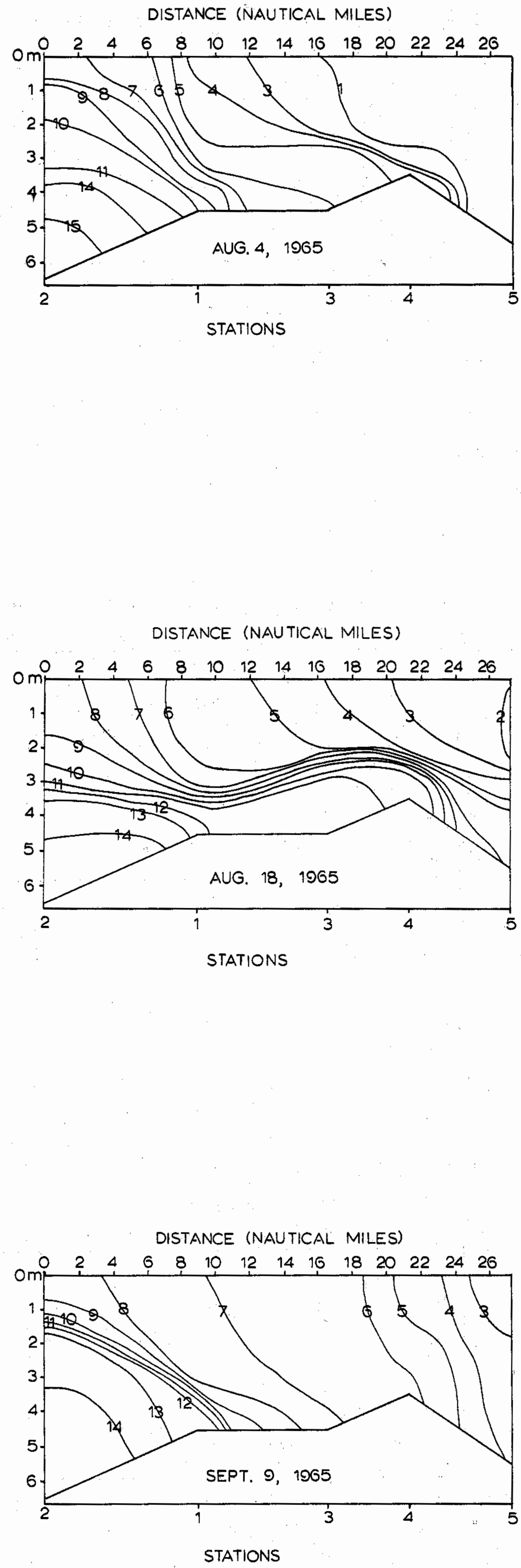
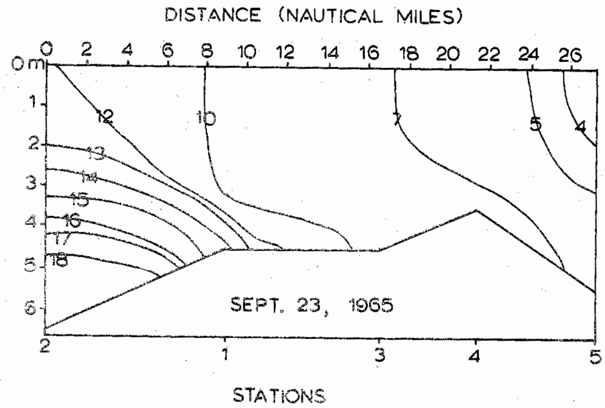
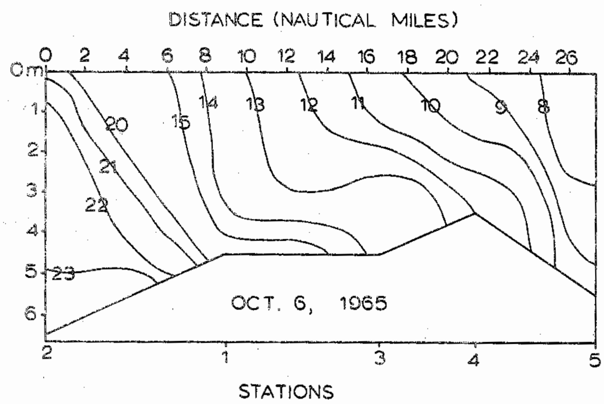


Figure 4. Salinity profiles (in ppt) in the Pamlico River Estuary for 4 August, 19 August, and 9 September 1965.





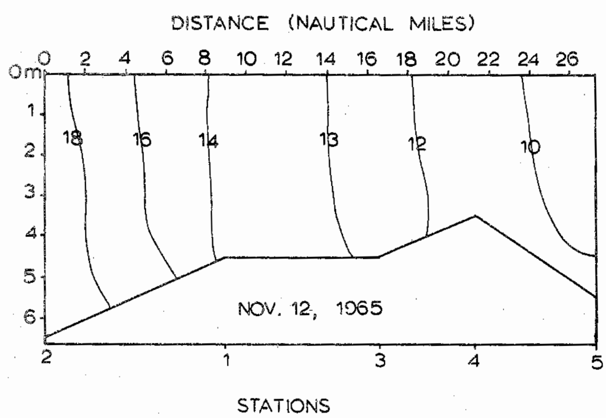


Figure 5. Salinity profiles (in ppt) in the Pamlico River Estuary for 23 September, 6 October, and 12 November 1965.

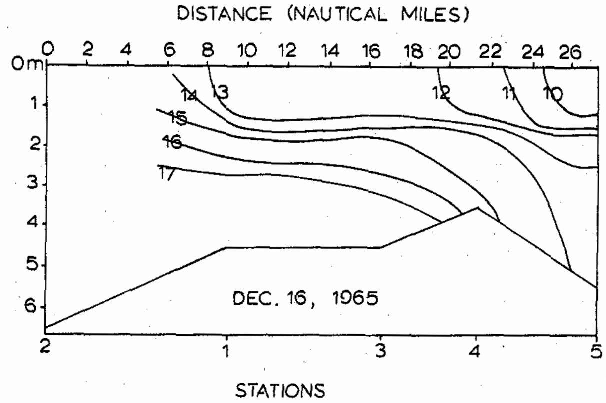


Figure 6. Salinity profiles (in ppt) in the Pamlico River Estuary for 16 December 1965.

10 ppt, moves from out in the sound (beyond Station 2 in Fig. 4) to 25 miles up in the estuary (Fig. 6). Finally, the bottom waters can change even more drastically as is seen at Station 4 (range of 4(Fig. 3) to 17 ppt (Fig. 6). This tremendous change would have a strong influence on the benthic animals, eliminating all but the most adaptable.

Stratification is irregular in the river with no permanent salt wedge present. The salt wedge refers to the high salinity water (more dense) that lies below the fresher river water. Thus, the stratification visible on 29 June (Fig.3) was largely destroyed by 21 July. The stratification returned in August (Fig.4) and was again destroyed by early November (Fig. 5). The destruction of the stratification undoubtedly occurred because of the water movements and turbulance caused by the wind.

When the surface salinities are measured at stations across the estuary (Table 2), it is seen that there is often a gradient across the river as well as along it. This is noted to some extent in Fig. 7 (March 22) and Fig. 8, but is especially strong on July 31 (Fig. 9) where higher salinity water was found along the south shore than along the north shore.

Table 2. Temperature (C) and Salinity (ppt) in the Pamlico River Estuary, 9 Mar. 1967 to 26 Feb. 1968. Stations are the same as those given in (4), Fig. 1).

Stations:		1	2	3	4	5	6	7	8	9	10	11	12	13
9 Mar.	Temp	15.57	15.57	15.57	15.62	15.62	15.62	13.35	13.35	13.35	13.35	13.91	13.91	13.91
1967	Sal	6.21	6.21	6.21	7.40	7.40	7.40	10.34	10.34	10.34	10.34	10.51	10.51	10.51
22 Mar.	Temp	19.70	11.50	10.70	9.60	16.80	17.30	9.40	12.20	12.70	14.60	14.70	12.40	16.60
1967	Sal	6.00	5.00	5.00	8.00	9.00	7.00	13.00	9.00	9.00	10.00	11.00	11.00	10.00
11 Apr.	Temp	No Data												
1967	Sal	6.00	5.00	5.00	7.00	7.00	7.00	8.00	9.00	9.00	9.00	10.00	10.00	10.00
9 May	Temp	No Data												
1967	Sal	8.60	8.60	8.00	8.80	9.80	10.40	11.20	11.80	11.30	11.20	11.00	12.30	13.10
7 June	Temp	21.05	21.16	21.45	21.37	20.83	20.90	21.03	21.05	21.14	21.26	21.34	21.14	21.04
1967	Sal	8.70	8.50	8.80	9.10	8.90	9.10	11.30	11.00	11.20	10.60	12.30	11.50	11.40
27 June	Temp	25.52	25.76	25.52	25.78	27.70	25.40	25.05	25.57	25.69	25.86	26.15	25.70	25.60
1967	Sal	7.44	7.58	6.92	7.55	7.56	7.98	10.35	10.58	9.79	9.54	10.85	10.62	11.32
13 Jul	Temp	28.26	27.98	27.50	27.60	27.82	28.18	27.98	27.84	27.90	27.56	27.98	27.96	28.22
1967	Sal	7.25	7.42	8.26	9.18	9.34	9.89	10.68	10.30	10.15	10.20	10.98	11.68	11.62
31 Jul	Temp	No Data												
1967	Sal	9.50	8.50	8.20	8.70	8.70	9.70	10.50	10.40	9.20	9.20	10.70	10.50	11.90
23 Aug	Temp	27.34	27.58	27.54	27.60	27.50	27.58	27.50	27.62	28.04	28.11	24.04	27.99	27.85
1967	Sal	2.84	2.44	2.37	3.58	3.86	3.32	5.39	5.26	4.94	4.84	7.21	6.52	7.24
30 Aug	Temp	26.24	26.02	26.23	26.26	25.82	27.10	27.62	27.60	26.90	26.93	27.82	27.73	27.15
1967	Sal	--	--	1.50	1.08	0.98	0.13	0.58	0.53	0.47	1.53	4.10	4.27	1.56
20 Sept	Temp	24.55	24.54	24.78	25.34	23.68	23.80	23.40	23.79	24.78	25.69	25.48	24.90	24.75
1967	Sal	2.05	1.90	2.12	3.22	2.70	2.56	2.91	3.29	4.06	4.07	6.32	4.41	3.98
3 Oct	Temp	20.94	21.41	21.57	21.44	21.91	22.11	21.92	22.22	21.76	22.23	21.55	22.02	23.01
1967	Sal	7.10	7.23	7.96	9.18	8.88	8.62	9.48	9.54	9.73	9.86	10.44	10.36	10.37
17 Oct	Temp	20.67	20.48	20.80	20.93	20.44	20.29	20.89	26.67	20.74	20.90	21.08	21.08	20.84
1967	Sal	7.61	7.22	7.64	8.40	8.33	8.45	9.42	9.64	9.82	9.75	10.68	10.47	10.22

Table 2. Continued (9 Mar. - 17 Oct.1967)

Stations:		14	15	16	17	18	19	20	21	22	23	24	25	26
9 Mar 1967	Temp	13.91	13.21	13.21	13.21	13.21	13.21	12.90	12.90	17.90	12.90	12.58	12.58	13.64
	Sal	10.51	10.47	10.47	10.47	10.47	10.47	11.24	11.24	11.24	11.24	12.24	12.24	12.01
22 Mar 1967	Temp	16.90	17.30	17.00	9.30	16.10	12.30	11.20	12.20	12.20	11.80	12.50	12.90	13.40
	Sal	10.00	11.00	10.00	11.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
11 Apr 1967	Temp	No Data												
	Sal	10.00	10.60	11.00	12.00	12.20	11.00	13.00	13.00	13.00	12.80	13.20	11.60	12.00
9 May 1967	Temp	No Data												
	Sal	12.00	14.20	14.20	14.00	13.30	12.30	12.00	13.80	14.70	13.40	14.30	13.80	13.30
7 June 1967	Temp	21.75	21.90	21.32	21.14	20.84	20.70	21.44	21.21	22.20	--	--	--	--
	Sal	12.60	13.90	13.40	12.40	11.90	12.10	12.80	13.40	13.70	--	--	--	--
27 June 1967	Temp	24.95	25.25	25.85	25.85	25.75	26.35	26.35	25.95	25.80	25.30	24.70	--	--
	Sal	11.35	12.92	13.15	11.85	11.55	11.55	13.80	13.80	13.60	13.60	14.05	--	13.85
13 Jul 1967	Temp	28.52	28.40	28.22	27.85	27.90	28.00	28.50	28.43	--	--	--	--	--
	Sal	11.98	13.03	13.05	13.01	12.85	12.62	--	--	--	--	14.25	--	--
31 Jul 1967	Temp	No Data												
	Sal	12.50	14.10	13.90	11.90	11.00	10.50	12.30	11.60	12.30	15.10	15.10	15.60	14.90
23 Aug 1967	Temp	27.88	28.31	28.74	28.91	29.26	31.24	29.14	28.98	28.58	28.81	29.32	28.42	28.43
	Sal	6.70	8.44	8.30	8.15	8.12	7.86	8.99	9.00	8.86	9.82	8.90	9.86	9.21
30 Aug 1967	Temp	27.17	27.45	27.81	27.40	27.10	27.42	28.20	28.16	28.04	28.11	27.35	27.85	27.72
	Sal	1.08	1.27	2.11	2.38	2.52	4.01	6.92	6.22	5.73	4.43	--	3.58	3.00
20 Sept 1967	Temp	24.73	25.11	25.19	25.65	26.79	26.62	25.76	25.75	26.42	25.12	24.81	25.13	25.02
	Sal	4.42	4.75	5.30	6.05	6.54	6.77	8.48	7.00	7.32	6.55	5.74	25.20	4.87
3 Oct 1967	Temp	22.82	22.13	23.06	22.57	22.55	22.74	22.73	22.60	23.29	22.54	21.80	23.43	22.89
	Sal	10.00	10.67	10.74	11.05	10.99	11.16	11.68	11.48	11.70	11.32	11.02	10.93	10.42
17 Oct 1967	Temp	21.43	21.12	21.00	20.98	21.02	21.20	21.67	21.08	21.00	21.27	21.17	21.22	21.79
	Sal	9.12	11.72	11.38	11.25	11.08	11.49	12.08	11.96	11.70	11.70	11.71	12.12	12.32

Table 2. Continued (9 Mar - 17 Oct. 1967)

Stations:		27	28	29	30	31	32	33	34	35	36	37	38	39
9 Mar	Temp	13.64	13.64	14.12	14.73	--	--	--	--	--	--	--	--	--
1967	Sal	12.01	12.01	11.39	10.67	--	--	--	--	--	--	--	--	--
22 Mar	Temp	13.50	14.20	14.30	15.20	--	--	--	--	--	--	--	--	--
1967	Sal	12.00	11.00	11.00	11.00	--	--	--	--	--	--	--	--	--
11 Apr	Temp	--	--	--	--	--	--	--	--	--	--	--	--	--
1967		11.60	11.20	11.00	11.00	--	--	--	--	--	--	--	--	--
9 May	Temp	No Data												
1967	Sal	13.70	13.50	--	--	--	--	--	--	--	--	--	--	--
7 June	Temp	No Data												
1967	Sal	No Data												
27 June	Temp	No Data												
1967	Sal	--	14.00	--	--	--	--	--	--	--	--	--	--	--
13 Jul	Temp	No Data												
1967	Sal	No Data												
31 Jul	Temp	No Data												
1967	Sal	15.40	14.80	15.70	14.90	13.40	14.40	14.80	15.40	15.80	15.70	--	--	--
23 Aug	Temp	29.13	28.83	29.31	29.48	24.53	29.54	29.53	29.15	28.90	--	--	--	--
1967	Sal	10.46	10.04	10.02	9.00	9.15	9.12	9.10	9.40	10.25	--	--	--	--
30 Aug	Temp	28.38	27.43	28.21	27.43	28.34	28.98	26.62	28.14	27.98	--	--	--	--
1967	Sal	3.18	--	3.35	4.30	7.27	6.79	5.93	5.65	4.40	--	--	--	--
20 Sept	Temp	25.73	26.10	25.77	26.16	25.54	27.20	25.34	25.47	25.84	25.18	24.15	26.34	26.96
1967	Sal	5.44	5.67	5.68	13.26	7.69	7.59	6.35	5.86	5.67	7.69	7.90	10.83	11.43
30 Oct	Temp	23.70	23.30	22.97	23.93	24.51	24.90	25.70	24.68	25.63	22.72	24.59	23.61	23.81
1967	Sal	9.61	9.45	9.06	12.05	11.96	11.91	11.97	11.94	11.98	13.80	14.13	13.90	13.94
16 Oct	Temp	21.29	22.12	22.88	22.17	21.96	22.04	21.74	21.86	21.97	22.60	22.35	22.15	22.30
1967	Sal	10.55	10.50	10.28	13.08	12.72	12.51	12.58	12.71	13.02	14.57	14.31	14.40	14.75

Table 2. Continued (30 Oct. 1967 - 26 Feb. 1968)

Stations:		1	2	3	4	5	6	7	8	9	10	11	12	13
30 Oct	Temp	15.33	15.07	15.07	15.96	15.57	15.04	15.49	15.54	15.60	15.64	15.81	16.37	15.76
1967	Sal	7.42	6.73	6.92	8.65	8.06	7.77	9.46	9.38	9.10	9.16	10.81	10.52	9.84
14 Nov	Temp	11.92	12.07	12.12	12.10	11.73	11.77	11.52	11.79	11.96	12.12	12.02	11.90	11.84
1967	Sal	8.48	8.93	10.58	10.78	9.42	8.04	9.44	9.38	9.90	11.09	12.02	10.94	10.33
28 Nov	Temp	10.68	10.93	10.76	10.46	10.94	10.84	10.79	10.93	10.80	10.36	10.31	10.66	10.78
1967	Sal	10.50	10.80	11.24	12.30	11.30	11.05	12.46	12.50	13.37	12.90	13.51	13.69	13.11
19 Dec	Temp	9.21	8.90	8.90	8.93	9.03	8.76	9.10	9.04	9.02	9.19	9.12	9.38	9.53
1967	Sal	5.05	4.72	4.99	4.78	4.78	4.00	6.00	6.00	6.00	7.00	8.00	7.00	8.00
8 Jan	Temp	4.00	5.00	5.10	4.30	4.10	6.50	4.00	4.50	6.20	4.00	3.30	6.20	3.80
1968	Sal	2.50	3.00	2.00	4.00	4.50	4.50	5.50	6.00	6.00	5.50	7.00	7.00	7.00
29 Jan	Temp	4.91	5.04	5.52	5.50	4.57	5.29	4.61	5.09	5.71	6.56	6.44	6.48	6.32
1968	Sal	0.87	0.84	0.88	1.13	1.06	1.06	1.38	1.74	1.74	1.87	5.02	2.69	1.90
13 Feb	Temp	--	--	--	--	--	--	3.34	3.32	3.38	3.28	3.56	3.60	3.40
1968	Sal	--	--	--	--	--	--	8.53	8.82	9.11	9.09	9.78	9.28	9.00
26 Feb	Temp	2.09	2.50	3.43	2.90	2.24	2.08	2.30	2.44	2.50	2.90	3.10	2.91	2.86
1968	Sal	6.32	7.78	9.66	9.18	7.20	6.90	9.00	9.00	9.44	10.30	10.21	10.76	10.58

Table 2. Continued (30 Oct. 1967 - 26 Feb. 1968)

Stations:		14	15	16	17	18	19	20	21	22	23	24	25	26
30 Oct	Temp	15.80	15.34	15.97	15.93	16.22	16.04	15.57	16.82	16.61	16.37	16.10	15.65	15.79
1967	Sal	10.94	11.52	11.70	11.60	11.50	11.20	12.42	12.23	12.28	12.00	11.37	12.00	11.84
14 Nov	Temp	11.89	12.14	12.02	12.10	12.18	12.06	13.52	12.92	12.71	12.43	12.51	12.01	12.07
1967	Sal	10.00	10.91	11.70	11.66	12.09	12.24	12.80	12.24	12.08	11.36	11.18	11.29	11.10
28 Nov	Temp	10.70	11.01	10.62	10.57	10.61	10.68	10.89	10.79	10.76	10.91	10.84	10.78	10.20
1967	Sal	12.57	13.13	13.74	14.24	14.41	14.30	14.27	15.00	10.92	13.93	13.66	13.38	13.04
19 Dec	Temp	9.16	9.48	8.95	9.27	9.45	9.69	9.95	9.80	9.89	9.66	9.81	9.43	9.80
1967	Sal	8.00	8.00	8.00	9.00	9.00	11.00	10.40	9.70	9.15	8.78	9.01	9.00	9.00
8 Jan	Temp	4.20	2.80	2.80	3.80	3.50	4.20	3.80	4.10	4.10	8.80	8.50	3.50	3.28
1968	Sal	6.50	8.50	8.60	9.30	9.30	10.00	10.30	10.10	9.80	3.50	3.50	9.39	8.62
29 Jan	Temp	5.42	6.43	4.93	5.63	6.77	6.98	5.24	4.56	4.74	4.56	4.52	6.10	5.91
1968	Sal	1.90	3.42	4.05	1.94	2.36	4.99	3.20	2.18	2.00	1.90	2.76	3.22	4.11
13 Feb	Temp	3.50	3.44	3.68	3.70	3.68	3.94	3.23	3.56	3.70	3.28	3.42	3.20	3.18
1968	Sal	8.56	9.21	9.18	9.68	10.00	10.24	11.08	11.20	11.09	9.70	9.60	8.88	9.00
26 Feb	Temp	2.58	2.62	2.80	3.06	3.09	2.88	3.20	2.88	2.90	2.88	3.95	3.94	3.53
1968	Sal	10.00	9.20	9.78	10.86	11.44	11.62	11.90	11.80	11.76	11.40	10.78	10.65	10.24

Table 2. Continued (30 Oct. 1967 - 26 Feb. 1968)

Stations:		27	28	29	30	31	32	33	34	35	36	37	38	39
30 Oct.	Temp	15.27	16.10	15.95	16.48	16.96	16.86	16.77	16.42	16.42	16.38	16.84	16.74	16.09
1967	Sal	11.27	11.45	10.50	13.10	12.81	12.58	12.67	13.32	13.12	15.22	16.95	15.55	15.52
14 Nov.	Temp	12.32	12.30	11.87	13.55	12.73	13.10	12.78	12.78	12.82	12.55	12.76	12.61	--
1967	Sal	10.61	11.71	10.82	13.62	13.03	12.69	12.18	11.28	13.05	14.68	14.51	15.25	--
28 Nov	Temp	10.54	10.83	9.87	10.46	10.82	10.88	11.04	11.07	10.59	10.78	10.84	10.68	--
1967	Sal	13.00	12.96	12.18	15.00	14.72	14.20	13.60	13.23	14.01	15.50	16.50	15.59	--
19 Dec	Temp	10.10	9.69	9.92	10.40	9.96	9.83	9.57	9.61	9.60	9.63	9.91	10.03	--
1967	Sal	8.78	9.00	8.86	11.13	9.86	9.56	9.15	9.32	10.69	10.97	13.26	13.61	--
8 Jan	Temp	2.80	2.93	2.80	4.00	3.80	3.80	3.60	3.50	3.80	4.30	4.10	3.50	--
1968	Sal	7.80	8.25	7.50	11.80	11.30	10.70	9.40	9.50	12.90	14.40	14.10	14.10	--
29 Jan	Temp	5.38	6.62	5.41	4.85	5.34	4.97	4.70	4.68	5.45	5.34	5.56	5.00	--
1968	Sal	4.00	4.14	3.72	7.56	3.09	2.23	2.88	3.00	2.56	3.00	4.42	6.60	--
13 Feb	Temp	3.41	3.12	3.34	--	--	--	--	--	--	--	--	--	--
1968	Sal	8.24	8.70	9.22	--	--	--	--	--	--	--	--	--	--
26 Feb	Temp	4.03	2.81	2.57	3.10	3.00	3.08	2.78	2.61	3.10	3.11	3.10	3.24	--
1968	Sal	9.82	9.17	9.12	12.34	12.08	12.06	11.68	11.42	12.46	13.08	14.10	14.20	--

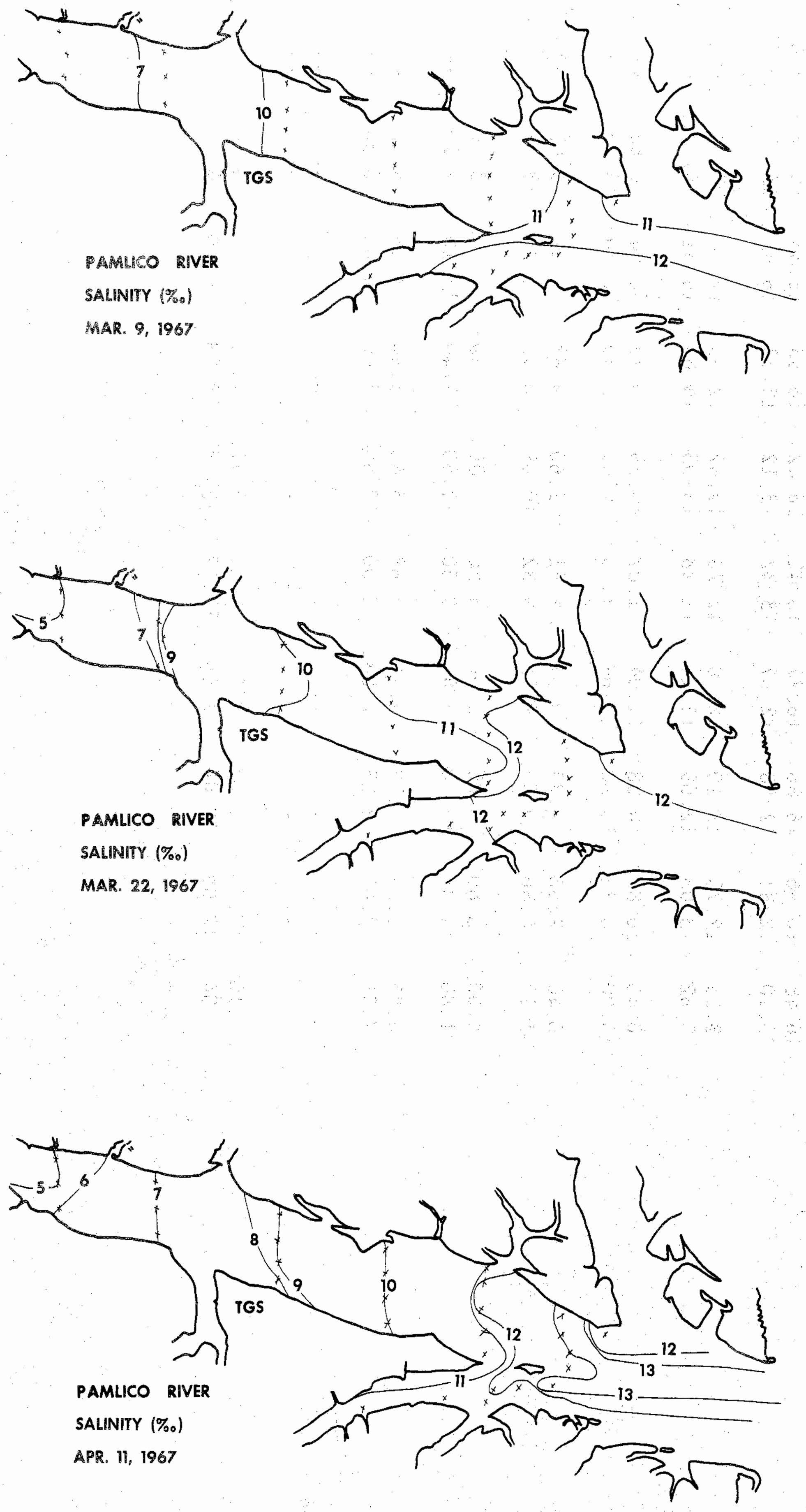


Figure 7. Surface salinities (ppt) in the Pamlico River Estuary for 9 March, 22 March, and 11 April 1967.

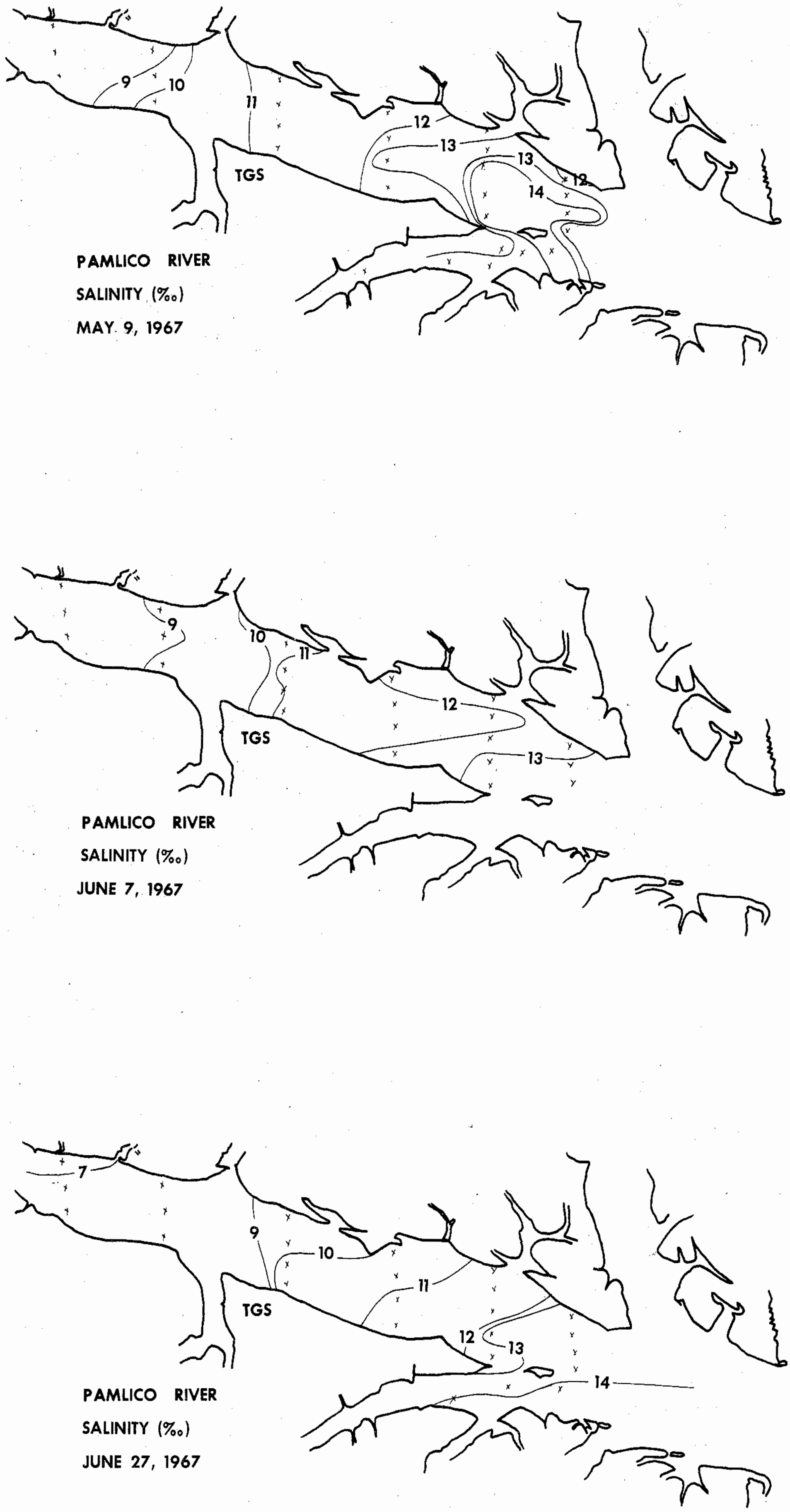


Figure 8. Surface profiles (in ppt) in the Pamlico River Estuary for 9 May, 7 June, and 27 June 1967.

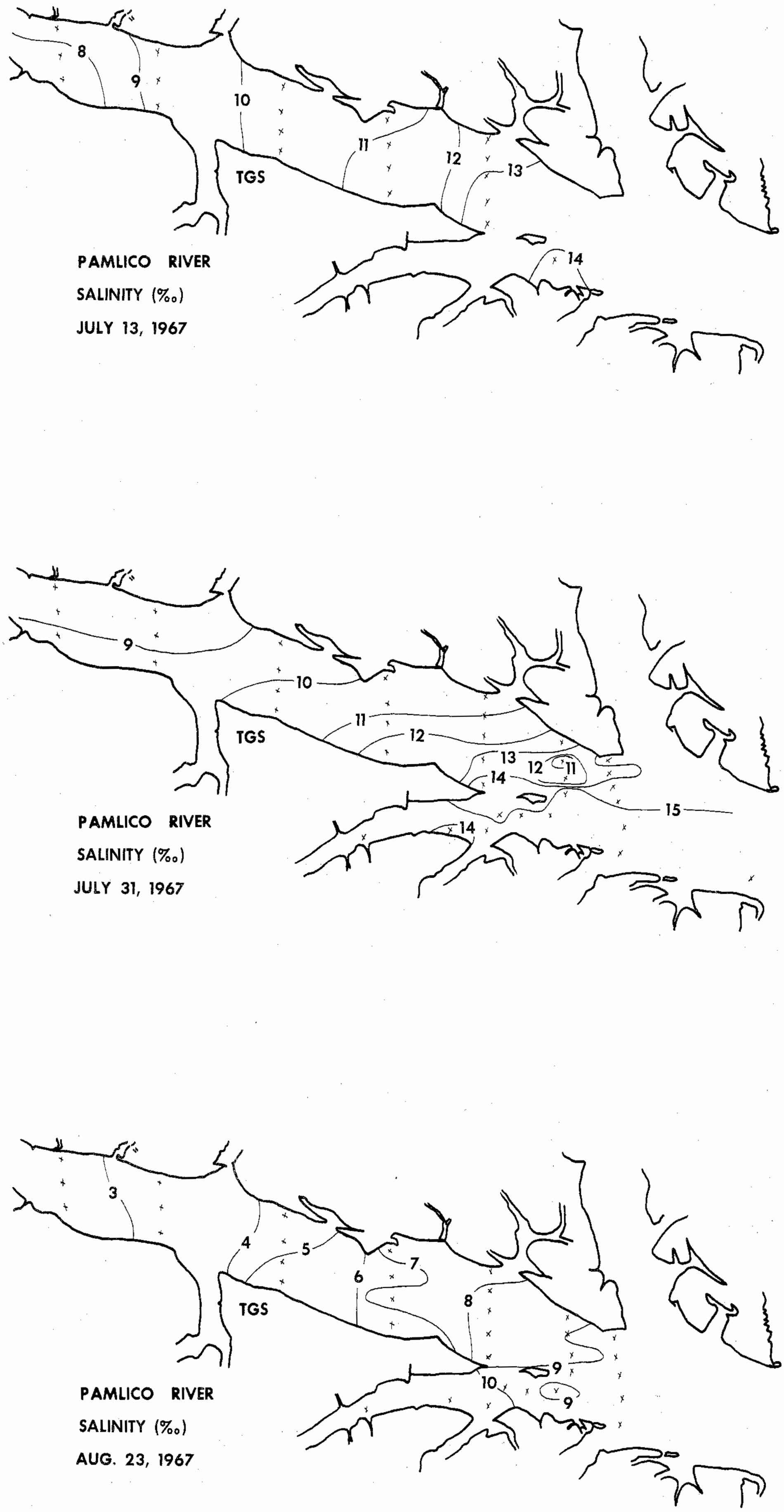


Figure 9. Surface profiles (in ppt) in the Pamlico River Estuary for 13 July, 31 July, and 23 August 1967.

If the salinity maps for July 13 and July 31 are carefully compared (Fig.9), it is obvious that wind from the NW would have produced the distribution on the latter date. When Figure 2 is examined, it is noted that on July 14 there was a strong wind (260 miles) from the WNW. Unfortunately, this explanation does not hold for all of the changes seen because a very similar change that occurred between October 30, 1967, and November 14 (Fig. 11) cannot be accounted for by any high winds during that period (Fig. 2). This type of salinity distribution with low salinities along the south shore, would tend to develop in any case due to the Coriolis Force which affects all estuaries on the eastern coast of the U. S. so that higher salinities are always found on the right side (facing the sea(16)).

The total changes of salinity are primarily due to the incoming freshwater with minor changes superimposed upon this. Thus, there was low flow (Fig. 1) into the estuary from March through June 1967 and relatively high salinities were found (Figs. 7,8). The first lower salinities appeared after the high river flow of mid-August (see Durham Creek, mid-August 1967 (Fig. 1) and August 23, 1967 (Fig. 9)). This low salinity was especially apparent on August 30 (Fig. 9 and see Tar River, August 1967 (Fig. 1)). The next few months had low river flow and the salinity increased (Figs. 11,12). Finally, the high runoff of January 1968 (Fig. 1) flushed out the river, giving the extreme lower salinity condition of January 29 (Fig. 13).

There also appears throughout this 1967-68 data a distinct trend for higher salinities along the north shore of the river. This could be partly due to Coriolis Effect, and to the frequent winds from the NW.

From the above discussion, it can be seen that there are three forces (and their interactions) that affect the distribution of salinity in this estuary; the freshwater inflow, the wind, and the Coriolis Force. The estuary appears

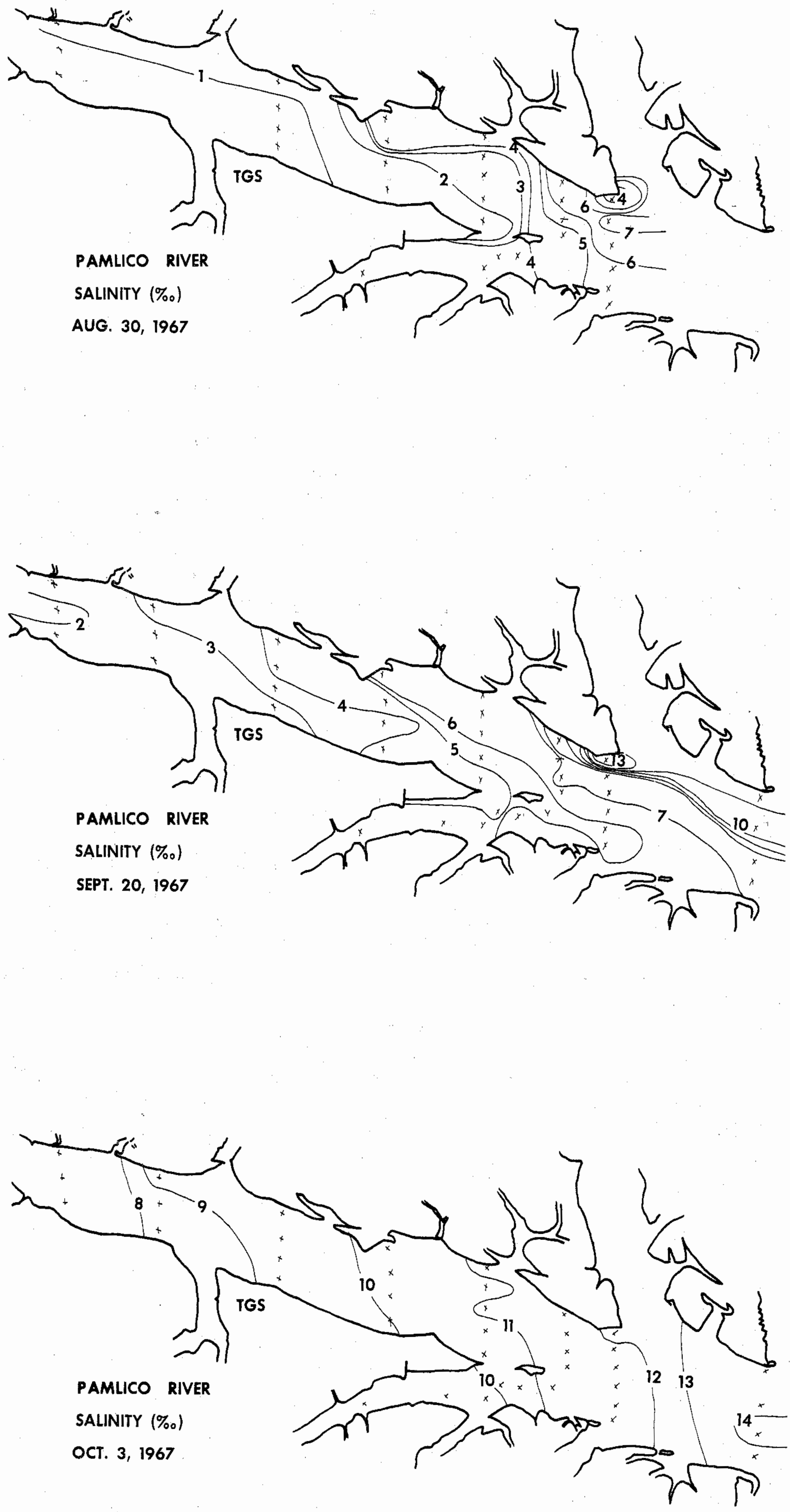


Figure 10. Surface profiles (in ppt) in the Pamlico River Estuary for 30 August, 20 September, and 3 October 1967.

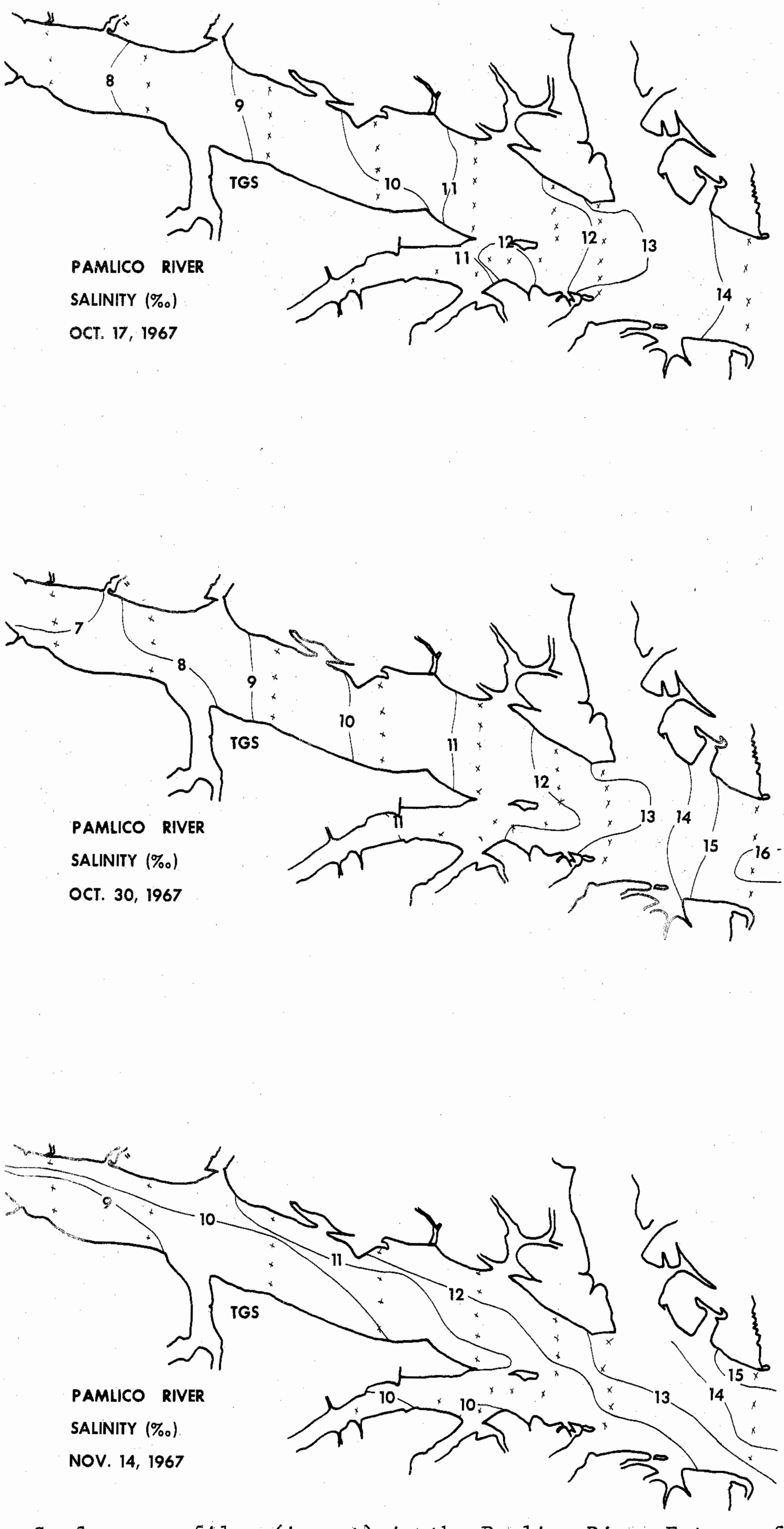


Figure 11. Surface profiles (in ppt) in the Pamlico River Estuary for 17 October, 30 October, and 14 November 1967.

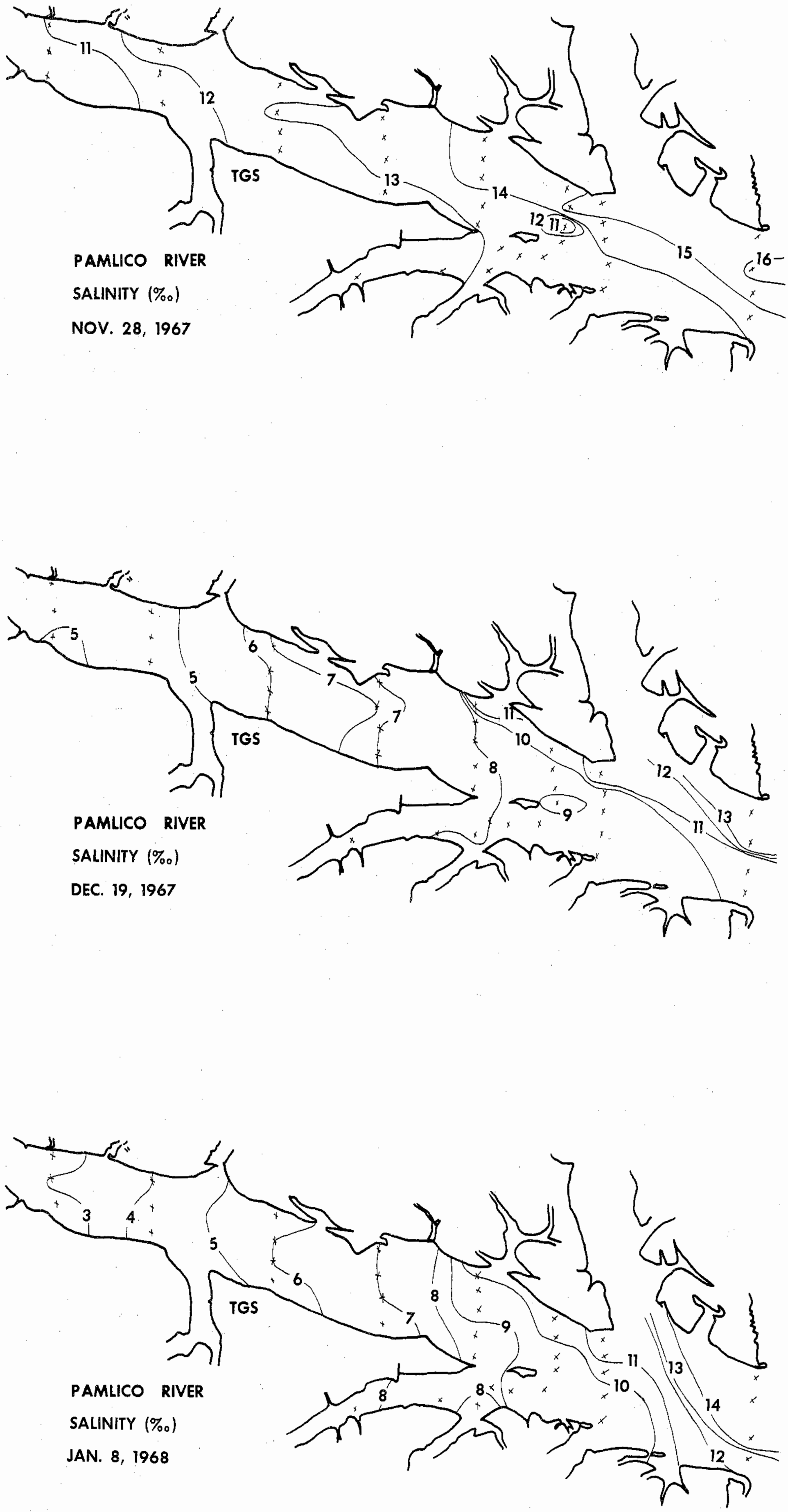


Figure 12. Surface profiles (in ppt) in the Pamlico River Estuary for 28 November, 19 December 1967 and 9 January 1968.

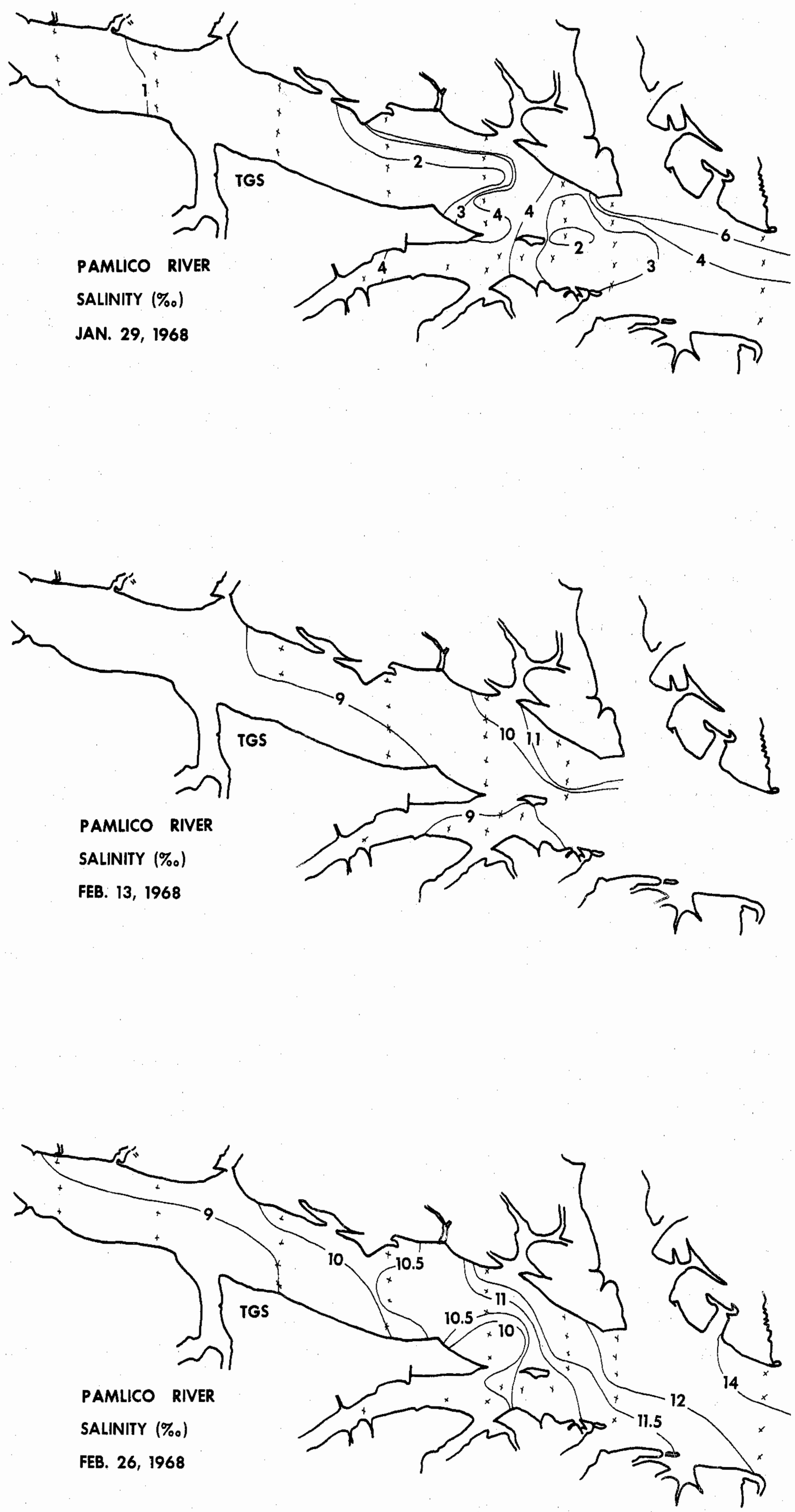


Figure 13. Surface profiles (in ppt) in the Pamlico River Estuary for 29 January, 13 February, and 26 February 1968.

broad enough that the Coriolis Force is noticeable, and the wind can affect the horizontal salinity patterns markedly. However, the inflow of freshwater is by far the dominant force. Normally, the freshwater would tend to flow more along the south shore than along the north as was also found by a fluorescent dye study (17) and by observations of the phosphate concentrations in the river (4). In the last mentioned case, slugs of high phosphate water entering the river at the Texas Gulf Sulfur Plant are always moved downstream along the south shore.

Both surface salinities and amount of stratification are given in Figs. 14 through 19 and Table 3. In these maps (e.g., July 16 in Fig. 14) the surface and bottom salinities are given in the bar graph above or below the map. The numbers above the bar graphs refer to station numbers (4), but these are always the stations in the middle of the estuary.

At the start of this set of data (Fig. 14,15,16 and 17), there was an extended period of low runoff with accompanying higher salinities. Very high salinities were measured on 11 October 1968 (Fig. 16) and the complete and unusual lack of any measurable differences between the top and bottom salinities indicate strong mixing. The salinity of 21.5 ppt noted on this date (Table 3) is exceptionally high.

Moderate to high salinities continued in the river until sometime in March 1969 (Fig. 18, Tables 4,5), after which time there appears to be quite a lot of freshwater entering the estuary (Figs. 18,19).

Temperature

Compared with the great salinity changes, the temperature changes were slight throughout the estuary (Tables 2 and 3). An apparent exception is the 22 March 1967 data (Fig. 20), but there is some evidence of a malfunctioning instrument here (the instrument required repair soon after this date). The 9 March data indicate that the river was warmer than the estuary and this appears to be a re-

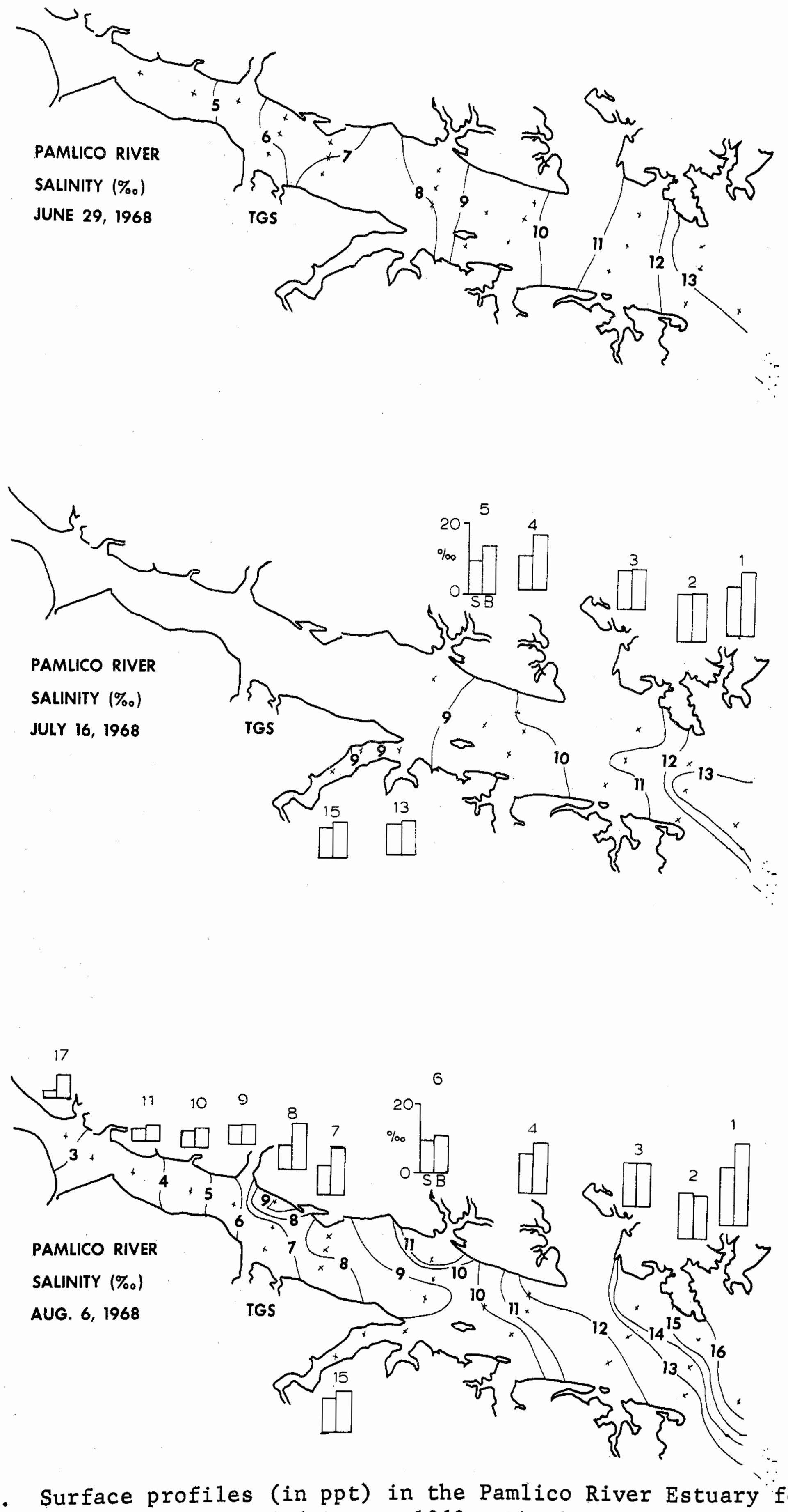


Figure 14. Surface profiles (in ppt) in the Pamlico River Estuary for 29 June, 16 July, and 6 August 1968. The bar graphs immediately above or below the map indicate the salinity (ppt) at the surface (S) and bottom (B) for the stations in the middle of the estuary. Numbers above the graphs are H series stations.

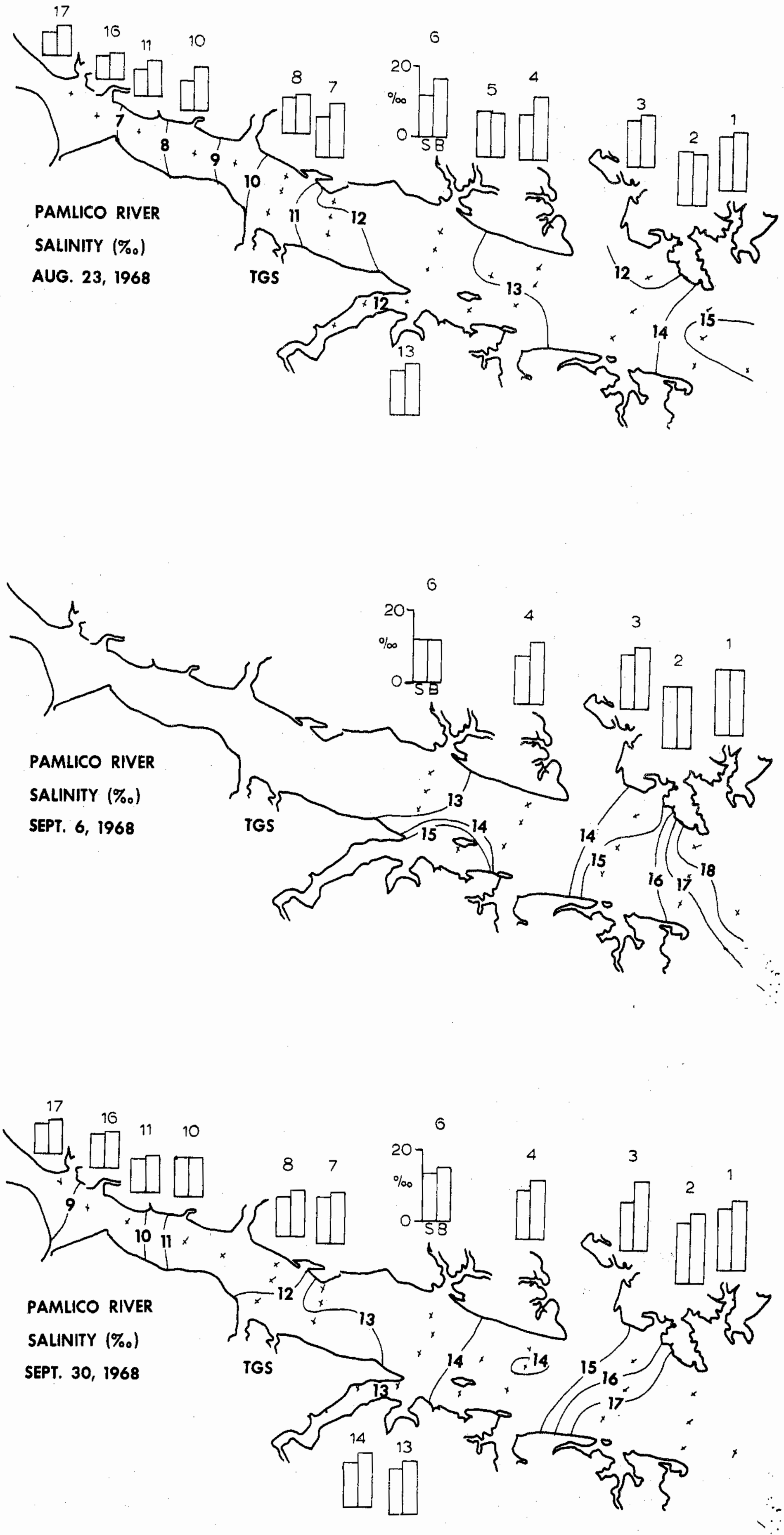


Figure 15. Surface profiles (in ppt) in the Pamlico River Estuary for 23 August, 6 September, and 30 September 1968.

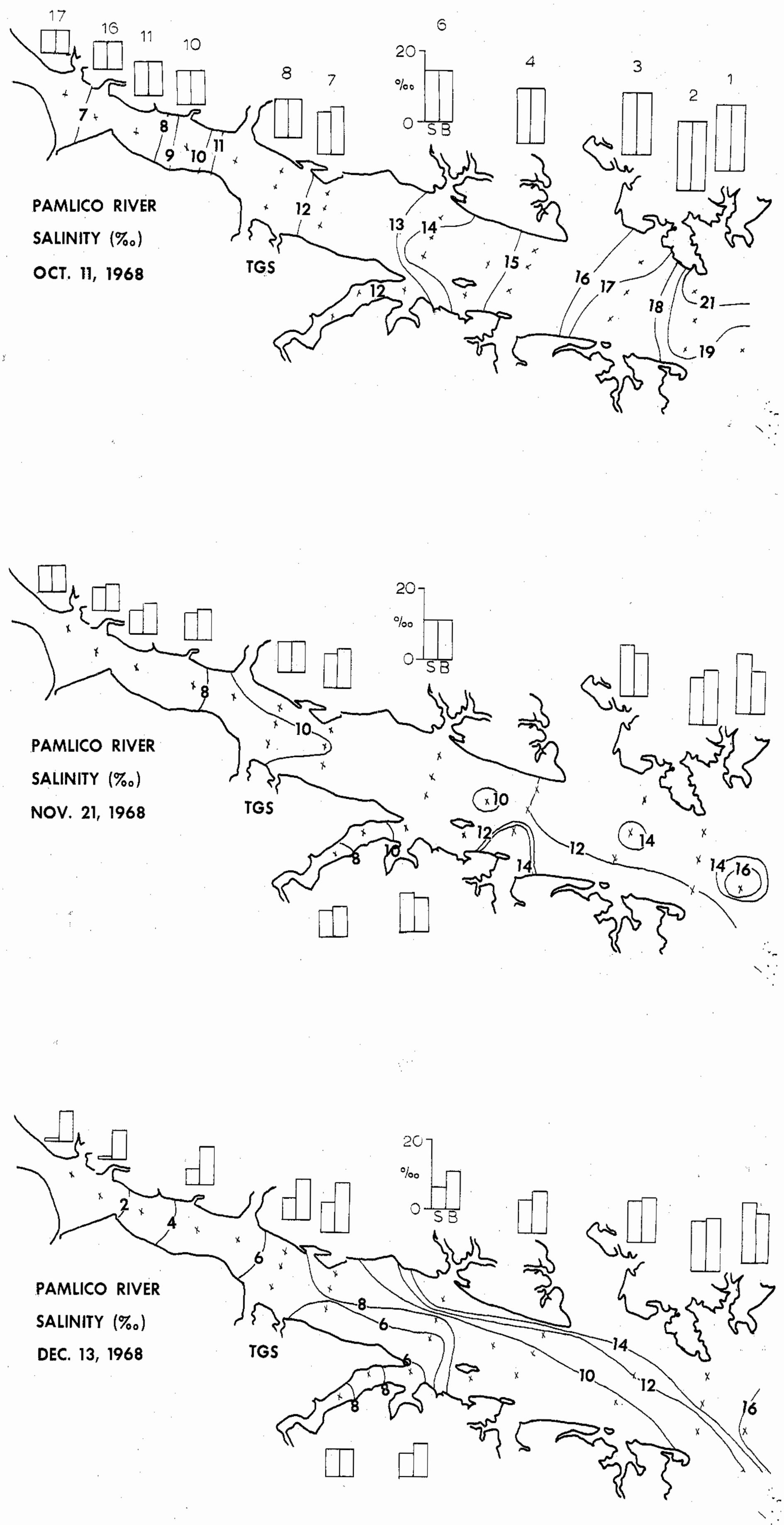


Figure 16. Surface profiles (in ppt) in the Pamlico River Estuary for 11 October, 21 November, and 13 December 1968.

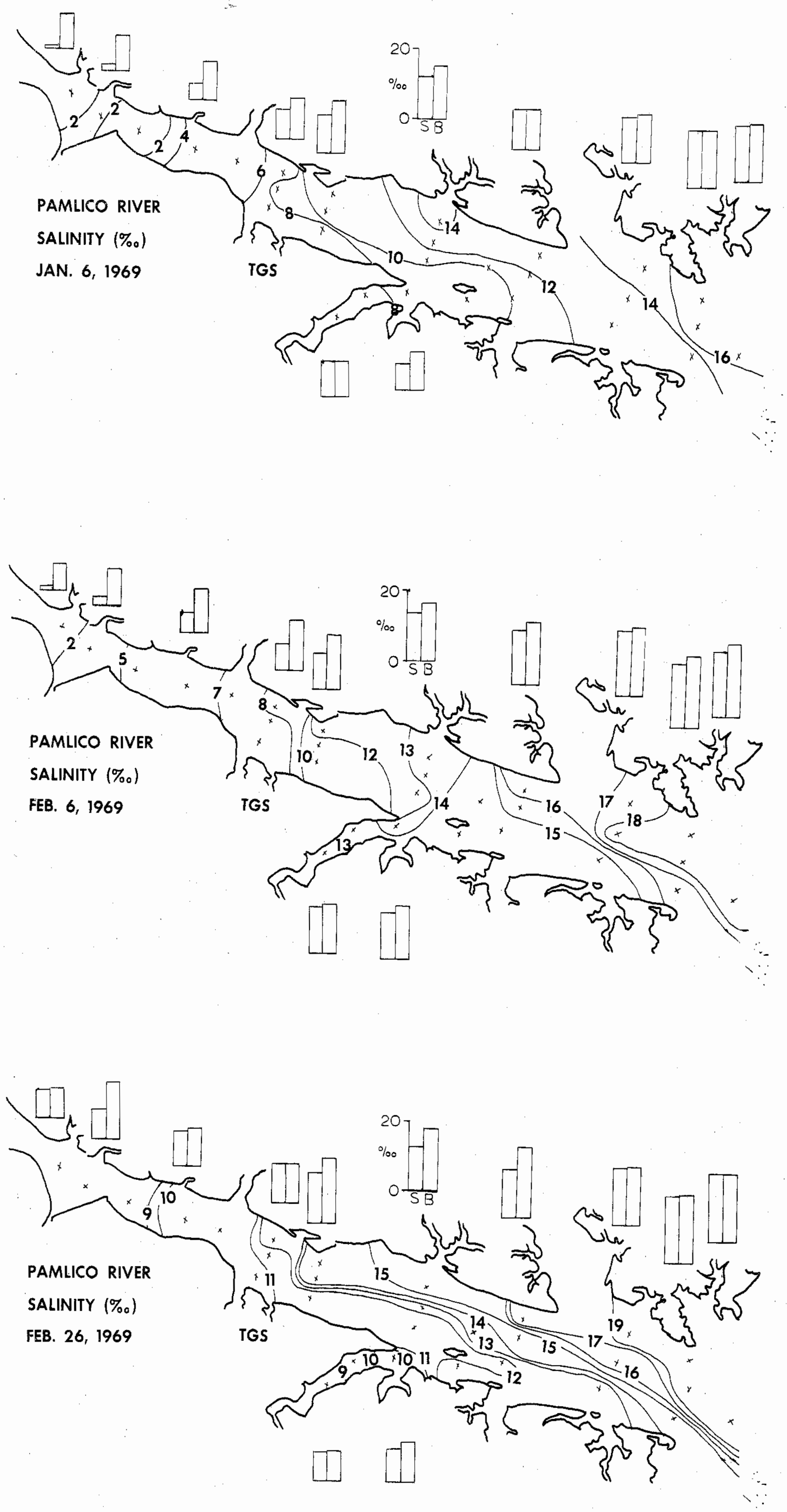


Figure 17. Surface profiles (in ppt) in the Pamlico River Estuary for 6 January, 6 February, and 26 February 1969.

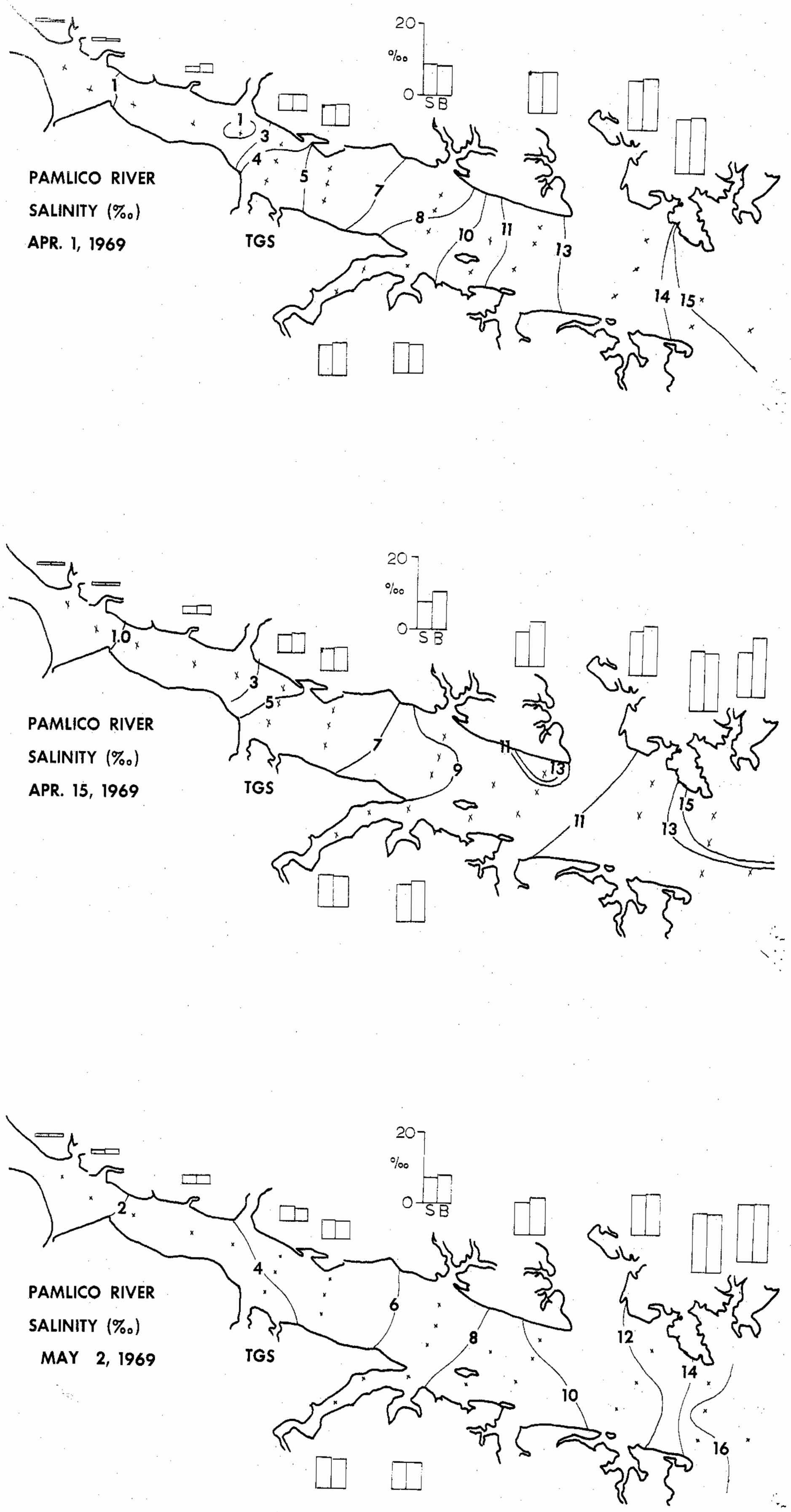


Figure 18. Surface profiles (in ppt) in the Pamlico River Estuary for 1 April, 15 April, and 2 May 1968.

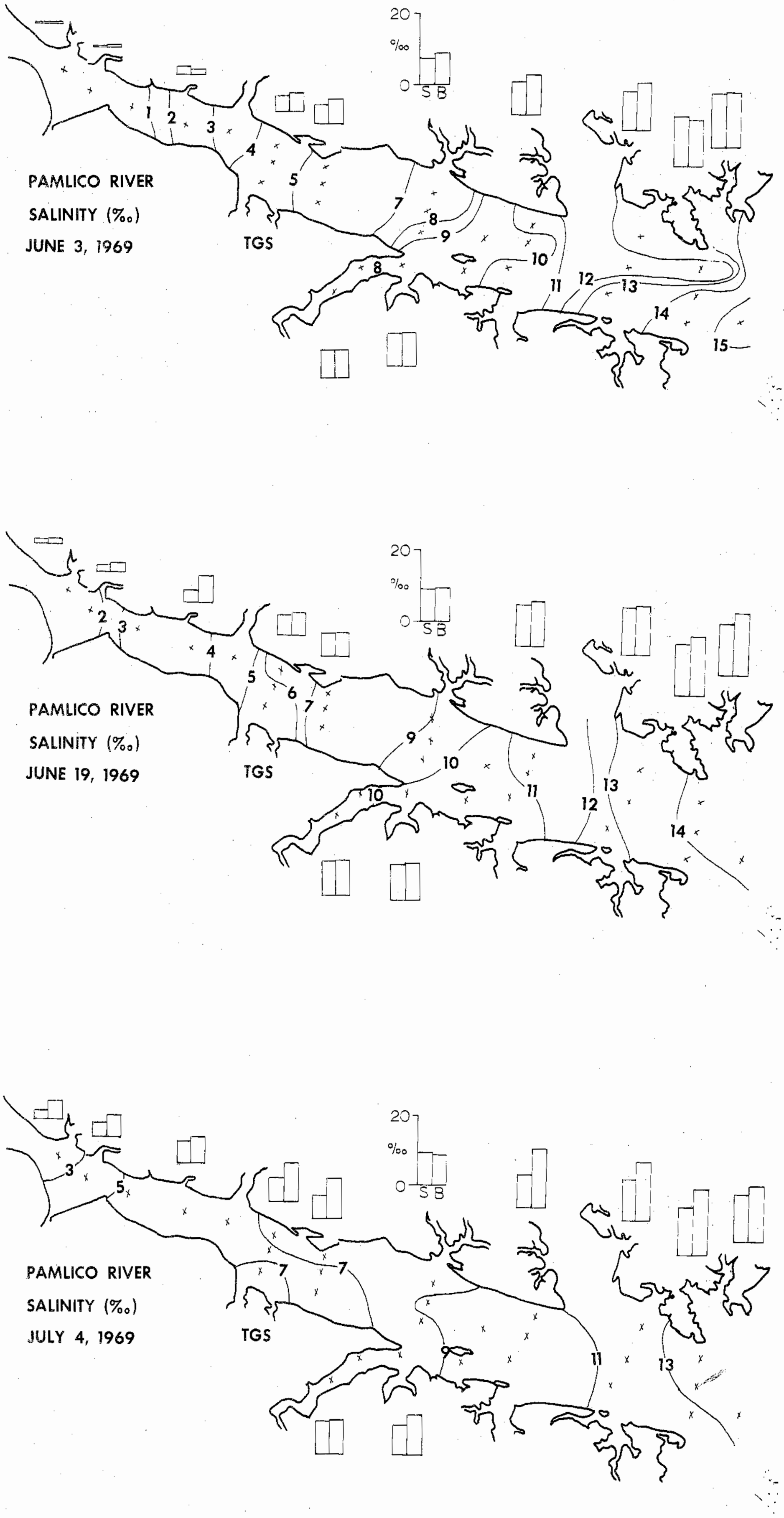


Figure 19. Surface profiles (in ppt) in the Pamlico River Estuary for 3 June, 19 June, and 4 July 1969.

Table 3. Temperatures (C) and Salinity (ppt); at the surface (S) and bottom (B) of the Pamlico River Estuary 29 June 1968 - 21 November 1968.

Stations:		H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S
29 June 1968	T S	28.50	27.95	28.15	28.25	28.50	28.90	28.45	22.80	28.50	28.50
No Data on	T B										
	SAL S	13.20	13.30	13.50	12.70	11.55	11.30	11.30	9.90	9.90	9.50
No Data on	SAL B										
16 Jul.1968	T S	28.30	28.50	28.50	28.90	28.50	29.00	29.30	28.60	28.80	30.20
	T B	27.50	--	--	--	--	--	--	--	27.20	--
	SAL S	13.70	12.90	13.30	11.70	10.60	11.00	10.30	10.00	9.50	9.50
	SAL B	17.05	--	--	--	--	--	--	--	--	--
6 Aug.1968	T S	31.00	28.50	31.00	30.50	29.00	30.50	30.00	29.00	31.50	31.00
	T B	29.50	--	29.50	--	--	29.00	--	--	29.50	--
	SAL S	16.80	15.50	13.20	12.20	14.60	12.60	11.60	12.00	11.20	9.70
	SAL B	23.50	--	12.20	--	--	--	--	--	--	--
23 Aug.1968	T S	30.00	30.00	29.00	30.50	31.00	30.80	31.00	30.00	30.00	30.50
	T B	29.30	--	29.50	--	--	30.30	--	--	36.00	--
	SAL S	15.20	14.20	15.20	14.20	12.00	13.00	13.50	13.00	13.00	12.50
	SAL B	16.50	--	14.50	--	--	14.50	--	--	18.00	--
6 Sept.1968	T S	26.00	26.00	26.50	25.00	26.00	26.00	25.50	25.50	26.00	26.00
	T B	25.50	--	25.00	--	--	25.50	--	--	25.00	--
	SAL S	18.80	18.80	17.50	16.80	14.00	15.20	15.80	13.80	13.80	13.80
	SAL B	18.80	--	17.50	--	--	17.50	--	--	17.50	--
30 Sept.1968	T S	25.50	25.50	26.00	26.00	27.00	26.00	26.00	26.00	26.50	26.00
	T B	24.00	--	24.00	--	--	25.00	--	--	25.50	--
	SAL S	17.50	17.50	17.00	17.50	15.90	16.50	17.50	14.80	13.80	14.20
	SAL B	19.80	--	19.80	--	--	19.80	--	--	16.50	--
11 Oct.1968	T S	22.00	20.50	21.00	22.00	21.00	21.50	21.00	21.00	21.00	20.50
	T B	22.50	--	22.00	--	--	21.50	--	--	--	--
	SAL S	18.80	21.50	19.80	19.80	16.80	17.50	17.50	15.50	15.50	15.50
	SAL B	18.80	--	19.80	--	--	17.50	--	--	15.50	--
21 Nov.1968	T S	9.50	10.00	10.00	9.50	10.00	10.00	9.50	10.00	9.50	9.00
	T B	10.00	--	9.50	--	--	10.00	--	--	9.00	--
	SAL S	16.80	13.00	13.00	12.00	13.00	14.20	12.00	12.00	12.00	15.50
	SAL B	12.00	--	15.50	--	--	12.00	--	--	--	--

Table 3. Continued (29 June 1968 - 21 Nov. 1968).

Stations:		H5	H6N	H6	H6S	H7N	H7	H7S	H8N	H8	H8S
29 June 1968	T S	28.10	28.90	28.70	28.60	29.00	29.00	28.90	28.60	28.50	28.80
No Data on	T B										
	SAL S	9.70	8.70	8.55	8.00	6.70	7.00	7.10	6.20	6.20	5.80
No Data on	SAL B										
16 Jul.1968	T S	29.60	30.50	--	--	--	--	--	--	--	--
No Data on	T B										
	SAL S	9.50	8.60	--	--	--	--	--	--	--	--
No Data on	SAL B										
6 Aug. 1968	T S	31.00	31.00	31.00	31.00	31.50	32.50	32.50	32.50	32.20	33.00
	T B	--	--	31.00	--	--	30.00	--	--	--	--
	SAL S	10.00	11.30	9.20	8.40	8.90	8.60	7.52	9.65	6.90	6.20
No Data on	SAL B										
23 Aug.1968	T S	30.30	32.00	31.50	32.00	32.00	31.00	33.00	32.50	32.50	32.00
	T B	31.00	--	30.00	--	--	29.00	--	--	29.00	--
	SAL S	13.00	12.00	12.00	12.00	12.00	11.20	11.20	10.80	10.50	10.80
	SAL B	12.50	--	16.50	--	--	15.20	--	--	11.20	--
6 Sept.1968	T S	26.00	26.00	26.50	27.00	--	--	--	--	--	--
	T B	--	--	26.00	--	--	--	--	--	--	--
	SAL S	13.80	12.00	12.00	12.00	--	--	--	--	--	--
No Data on	SAL B										
30 Sept.1968	T S	26.00	26.50	26.00	26.00	27.00	27.00	26.50	27.00	26.00	26.00
	T B	--	--	24.00	--	--	26.00	--	--	25.50	--
	SAL S	14.20	13.80	13.80	13.80	13.00	13.00	12.50	11.20	11.00	12.20
	SAL B	--	--	15.20	--	--	14.20	--	--	13.00	--
11 Oct.1968	T S	21.00	21.00	20.00	20.50	20.50	21.00	21.50	21.50	21.50	21.50
	T B	--	--	21.50	--	--	21.00	--	--	20.50	--
	SAL S	14.50	13.50	14.50	14.50	12.00	12.00	12.00	11.00	11.00	11.00
	SAL B	--	--	14.50	--	--	13.50	--	--	11.00	--
21 Nov.1968	T S	9.50	10.50	10.50	10.00	10.50	10.50	10.00	10.00	10.00	10.00
	T B	--	--	9.50	--	--	10.50	--	--	10.50	--
	SAL S	9.80	--	11.00	11.00	11.00	9.80	11.00	12.00	8.80	9.80
	SAL B	--	--	11.00	--	--	11.00	--	--	8.80	--

Table 3. Continued (29 June 1968 - 21 Nov. 1968)

Stations:		H9	H10	H11	H12	H13	H14	H15	H16	H17
29 June 1968	T S	29.20	29.30	29.50	28.70	30.40	--	--	--	--
No Data on	T B									
	SAL S	5.10	4.85	4.20	9.20	--	--	--	--	--
No Data on	SAL B									
16 Jul.1968	T S	--	--	--	--	30.50	30.80	31.40	--	--
No Data on	T B									
	SAL S	--	--	--	--	8.65	9.10	8.30	--	--
No Data on	SAL B									
6 Aug.1968	T S	33.50	33.50	33.00	31.00	33.00	33.00	34.00	30.20	32.50
	T B	29.00	29.50	29.50	--	--	--	--	31.50	--
	SAL S	5.60	4.50	3.70	--	9.10	9.70	9.50	3.10	2.20
No Data on	SAL B									
23 Aug.1968	T S	31.50	32.00	32.00	30.00	33.00	32.00	33.50	33.00	32.00
	T B	--	29.30	30.00	--	30.50	--	--	30.00	30.80
	SAL S	9.50	8.80	7.50	12.50	12.50	11.20	11.20	6.50	6.50
	SAL B	--	12.50	10.00	--	14.50	--	--	7.60	8.80
6 Sept.1968	T S	--	--	--	26.00	--	--	--	--	--
No Data On	T B									
	SAL S	--	--	--	15.20	--	--	--	--	--
No Data on	SAL B									
30 Sept.1968	T S	27.00	26.00	27.00	26.00	27.00	26.50	27.00	27.00	26.00
	T B	--	25.00	25.00	--	25.00	--	--	25.00	25.00
	SAL S	11.00	11.00	9.80	14.20	13.00	12.50	12.80	9.80	8.20
	SAL B	--	11.00	10.20	--	15.20	15.20	--	10.20	9.80
11 Oct.1968	T S	21.50	21.00	22.00	20.50	21.00	21.50	21.50	21.50	21.50
	T B	--	21.50	21.50	--	--	--	--	21.00	21.00
	SAL S	11.00	9.80	7.50	14.50	12.00	11.00	11.00	7.50	6.20
	SAL B	--	9.80	7.50	--	--	--	--	7.50	6.20
21 Nov.1968	T S	10.00	10.00	10.00	9.00	9.00	9.80	10.20	9.50	9.50
	T B	--	10.50	10.50	--	9.00	--	10.00	10.50	10.00
	SAL S	9.80	7.50	6.50	11.00	11.00	8.80	7.50	6.50	7.50
	SAL B	--	8.80	8.80	--	9.80	--	8.80	7.50	7.50

Table 4. Dissolved Oxygen (ml/l), Temperature (C) and Salinity (ppt); at the surface (S) and bottom (B) of the Pamlico River Estuary. 13 Dec. 1968 - 15 Apr. 1969.

Stations:			H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S
13 Dec. 1968	T	S	5.50	5.00	5.20	5.80	--	5.50	5.20	5.50	4.80	5.00
	T	B	5.00	--	5.50	--	--	6.00	--	--	5.50	--
	SAL	S	14.50	15.20	14.20	11.00	--	12.00	9.80	11.00	9.80	9.80
	SAL	B	14.20	--	15.20	--	--	13.00	--	--	12.00	--
	DO	S	7.88	--	7.62	--	--	8.08	--	--	8.26	--
	DO	B	7.56	--	7.67	--	--	5.28	--	--	8.01	--
6 Jan.1969	T	S	3.20	3.20	4.00	3.80	4.00	3.20	3.20	4.00	3.50	3.50
	T	B	3.20	--	4.50	--	--	4.00	--	--	3.20	--
	SAL	S	16.00	16.50	16.50	13.00	15.20	13.00	13.00	13.00	11.80	10.00
	SAL	B	16.50	--	16.50	--	--	14.30	--	--	11.80	--
No Data on	DO	S										
No Data on	DO	B										
6 Feb. 1969	T	S	6.10	6.06	6.30	6.40	6.50	6.20	6.44	6.60	6.20	6.64
	T	B	6.60	--	6.22	--	--	5.80	--	--	6.76	--
	SAL	S	18.50	18.50	18.20	16.40	17.50	18.40	14.90	16.40	15.60	14.90
	SAL	B	20.90	--	20.50	--	--	19.50	--	--	17.80	--
	DO	S	7.44	--	5.91	--	--	7.89	--	--	8.08	--
	DO	B	9.11	--	5.99	--	--	7.31	--	--	7.63	--
26 Feb.1969	T	S	5.50	5.40	5.48	5.78	5.34	5.74	5.78	5.32	5.56	5.92
	T	B	5.32	--	5.48	--	--	5.56	--	--	5.26	--
	SAL	S	19.78	19.96	19.02	14.22	19.58	16.76	11.34	17.28	14.16	11.54
	SAL	B	19.74	--	19.40	--	--	16.90	--	--	20.60	--
	DO	S	6.59	--	7.16	--	--	7.53	--	--	7.40	--
	DO	B	5.44	--	7.64	--	--	8.11	--	--	7.75	--
1 Apr.1969	T	S	--	--	12.56	11.84	12.12	12.24	11.70	11.80	12.14	12.35
	T	B	--	--	12.44	--	--	12.49	--	--	12.02	--
	SAL	S	--	--	15.02	14.76	13.54	13.82	13.42	11.94	11.49	11.32
	SAL	B	--	--	15.64	--	--	14.16	--	--	11.66	--
	DO	S	--	--	6.06	--	--	5.98	--	--	6.51	--
	DO	B	--	--	7.00	--	--	6.74	--	--	5.89	--
15 Apr.1969	T	S	16.88	16.60	12.30	17.02	17.23	17.02	--	17.20	17.82	17.25
	T	B	16.16	--	15.57	--	--	16.67	--	--	16.71	--
	SAL	S	12.54	16.64	16.83	12.14	11.75	12.23	--	13.20	9.50	9.60
	SAL	B	16.55	--	16.21	--	--	13.16	--	--	--	12.44
	DO	S	5.58	--	5.59	--	--	6.10	--	--	--	6.03
	DO	B	4.70	--	4.68	--	--	5.30	--	--	--	5.28

Table 4. Continued (13 Dec. 1968 - 15 Apr. 1969).

Stations:			H5	H6N	H6	H6S	H7N	H7	H7S	H8N	H8	H8S
13 Dec.1968	T	S	5.00	6.00	5.50	5.20	6.00	6.00	6.40	5.50	5.80	5.50
	T	B	--	--	6.50	--	--	6.50	--	--	7.00	--
	SAL	S	9.20	14.20	6.50	5.50	9.80	8.80	4.80	6.50	6.50	6.50
	SAL	B	--	--	11.00	--	--	14.20	--	--	12.00	--
	DO	S	--	--	8.73	--	--	8.79	--	--	9.64	--
	DO	B	--	--	7.97	--	--	8.26	--	--	8.25	--
6 Jan.1969	T	S	3.50	4.20	3.80	3.50	4.50	4.00	4.50	4.80	4.50	3.80
	T	B	--	--	4.50	--	--	4.50	--	--	5.50	--
	SAL	S	10.00	14.20	12.00	10.00	11.00	10.00	7.50	6.20	8.50	6.20
	SAL	B	--	--	15.00	--	--	15.20	--	--	12.00	--
No Data on	DO	S										
No Data on	DO	B										
6 Feb.1969	T	S	6.34	6.78	7.00	7.54	7.20	8.14	7.15	7.79	7.39	7.56
	T	B	--	--	7.16	--	--	6.60	--	--	6.54	--
	SAL	S	14.70	13.00	13.10	12.80	12.40	10.60	10.30	8.80	7.70	7.90
	SAL	B	--	--	16.20	--	--	15.60	--	--	14.50	--
	DO	S	--	--	8.13	--	--	6.56	--	--	8.80	--
	DO	B	--	--	7.18	--	--	8.30	--	--	6.32	--
26 Feb.1969	T	S	5.74	5.62	5.94	6.10	5.82	5.74	6.12	6.08	5.86	6.12
	T	B	--	--	5.40	--	--	5.46	--	--	5.86	--
	SAL	S	13.82	15.84	12.62	11.18	14.90	14.84	11.90	12.56	11.63	10.98
	SAL	B	--	--	18.00	--	--	18.70	--	--	11.62	--
	DO	S	--	--	10.03	--	--	7.73	--	--	8.85	--
	DO	B	--	--	7.75	--	--	8.06	--	--	9.34	--
1 Apr.1969	T	S	12.19	12.40	12.36	11.86	12.29	12.54	12.00	12.54	12.22	12.48
	T	B	--	--	12.26	--	--	12.54	--	--	12.10	--
	SAL	S	10.81	7.82	7.96	8.39	5.72	5.65	5.17	3.96	4.49	4.29
	SAL	B	--	--	8.14	--	--	5.72	--	--	4.49	--
	DO	S	--	--	6.10	--	--	6.62	--	--	6.56	--
	DO	B	--	--	3.28	--	--	6.46	--	--	6.75	--
15 Apr. 1969	T	S	17.39	17.53	17.92	16.71	18.18	17.80	17.88	17.88	17.71	17.65
	T	B	--	--	17.78	--	--	16.86	--	--	17.56	--
	SAL	S	10.28	9.85	7.60	7.90	6.35	6.20	6.95	4.16	5.32	5.33
	SAL	B	--	--	10.57	--	--	6.95	--	--	5.58	--
	DO	S	--	--	--	5.65	--	6.26	--	--	6.02	--
	DO	B	--	--	--	5.20	--	5.65	--	--	5.78	--

Table 4. (Continued 13 Dec. 1968 - 15 Apr. 1969)

Stations:			H9	H10	H11	H12	H13	H14	H15	H16	H17
13 Dec.1968	T	S	5.80	5.00	5.50	4.80	5.00	3.00	3.50	5.00	5.50
	T	B	--	6.40	--	--	4.50	--	3.50	5.80	6.80
	SAL	S	5.50	4.80	3.00	9.80	6.50	8.80	7.80	1.00	1.00
	SAL	B	--	11.00	--	--	9.80	--	7.80	8.80	8.80
	DO	S	--	9.11	--	--	8.52	--	8.69	9.04	8.54
	DO	B	--	8.11	--	--	8.35	--	7.94	8.10	8.12
6 Jan.1969	T	S	4.50	4.00	4.00	3.50	3.00	3.00	3.20	4.20	4.80
	T	B	--	4.90	--	--	2.80	--	3.20	5.00	5.50
	SAL	S	5.50	4.50	1.00	8.50	7.50	8.50	10.00	2.00	1.00
	SAL	B	--	11.00	--	--	11.00	--	10.00	10.00	10.00
No Data on	DO	B									
No Data on	DO	S									
6 Feb.1969	T	S	7.40	7.42	7.68	6.42	6.42	6.52	6.80	7.90	8.30
	T	B	--	6.74	--	--	6.39	--	6.56	6.74	6.96
	SAL	S	7.08	5.60	5.40	14.50	13.60	14.30	13.10	2.80	1.10
	SAL	B	--	12.00	--	--	15.30	--	14.40	10.60	7.80
	DO	S	--	8.13	--	--	6.78	--	8.12	7.95	6.58
	DO	B	--	7.09	--	--	5.87	--	7.86	7.22	7.35
26 Feb.1969	T	S	5.90	6.00	6.12	5.72	6.12	6.26	6.28	6.52	5.90
	T	B	--	5.72	--	--	6.12	--	6.20	5.10	5.90
	SAL	S	10.94	10.45	8.40	12.18	9.76	10.30	8.34	8.70	8.00
	SAL	B	--	11.20	--	--	11.92	--	8.68	16.92	8.70
	DO	S	--	6.88	--	--	8.39	--	7.80	--	9.18
	DO	B	--	8.43	--	--	6.62	--	6.64	9.00	9.03
1 Apr.1969	T	S	11.06	12.70	12.17	12.14	13.68	14.08	14.44	12.72	13.04
	T	B	--	12.70	--	--	13.40	--	14.44	12.72	13.04
	SAL	S	0.18	1.91	1.34	10.16	8.66	8.63	8.96	0.86	0.30
	SAL	B	--	2.06	--	--	8.50	--	9.20	0.84	0.20
	DO	S	--	6.73	--	--	6.20	--	6.00	5.91	6.21
	DO	B	--	7.08	--	--	6.20	--	5.98	6.60	5.89
15 Apr.1969	T	S	17.59	17.44	17.77	17.15	16.96	17.60	17.39	17.88	17.95
	T	B	--	17.26	--	--	17.76	--	17.10	17.92	17.88
	SAL	S	2.77	2.04	1.21	10.75	10.12	8.69	8.62	0.58	0.28
	SAL	B	--	2.17	--	--	11.77	--	8.60	0.58	0.28
	DO	S	--	5.20	--	--	5.36	--	5.33	4.38	5.91
	DO	B	--	5.16	--	--	5.28	--	5.55	5.15	5.14

Table 5. Temperature (C), Salinity (ppt) and Dissolved Oxygen (ml/l); at the surface (S) and bottom (B) of the Pamlico River Estuary. 2 May 1969 - 4 July 1969.

Stations:			H1	H2N	H2	H2S	H3N	H3	H3S	H4N	H4	H4S
2 May 1969	T	S	17.81	17.60	18.06	17.44	17.60	17.76	17.20	17.12	18.00	17.86
	T	B	17.96	--	18.16	--	--	17.68	--	--	17.89	--
	SAL	S	16.31	15.99	16.61	14.13	12.53	11.44	10.68	10.22	9.40	9.35
	SAL	B	16.32	--	16.44	--	--	11.53	--	--	10.30	--
	DO	S	5.95	--	5.66	--	--	5.87	--	--	5.87	--
No Data on	DO	B										
3 June 1969	T	S	21.90	21.80	22.98	21.74	22.32	22.22	21.39	21.16	22.64	22.32
	T	B	21.90	--	21.81	--	--	21.81	--	--	21.58	--
	SAL	S	15.64	11.12	14.02	14.33	12.43	11.24	13.32	10.78	9.54	10.26
	SAL	B	15.73	--	13.36	--	--	13.88	--	--	11.34	--
	DO	S	5.34	--	5.04	--	--	5.55	--	--	5.31	--
	DO	B	5.78	--	5.09	--	--	5.39	--	--	5.54	--
19 June 1969	T	S	26.42	26.30	26.43	26.35	26.34	26.16	26.29	26.01	26.38	26.79
	T	B	26.44	--	26.50	--	--	26.46	--	--	26.31	--
	SAL	S	14.59	14.85	14.55	13.26	13.65	13.04	12.50	11.80	11.60	10.90
	SAL	B	17.46	--	16.62	--	--	13.82	--	--	12.68	--
	DO	S	5.18	--	5.08	--	--	5.35	--	--	4.57	--
	DO	B	4.92	--	4.77	--	--	3.89	--	--	3.07	--
4 July 1969	T	S	28.92	28.78	29.08	28.73	29.24	29.15	28.53	29.18	28.90	28.77
	T	B	28.73	--	28.42	--	--	28.44	--	--	28.20	--
	SAL	S	13.65	14.11	13.09	11.54	12.72	11.66	11.02	10.34	9.38	9.70
	SAL	B	15.81	--	18.44	--	--	16.77	--	--	16.72	--
	DO	S	6.12	--	5.09	--	--	6.56	--	--	4.44	--
	DO	B	2.92	--	1.12	--	--	1.61	--	--	0.54	--

Table 5. Continued (2 May 1969 - 4 July 1969)

Stations:			H5	H6N	H6	H6S	H7N	H7	H7S	H8N	H8	H8S
2 May 1969	T	S	17.86	18.83	18.31	18.35	18.62	18.87	18.42	18.66	19.06	18.82
	T	B	--	--	17.77	--	--	18.01	--	--	18.12	--
	SAL	S	9.54	6.86	7.02	7.57	5.58	5.33	5.40	4.73	4.04	3.60
	SAL	B	--	--	7.85	--	--	5.30	--	--	3.96	--
	DO	S	--	--	6.26	--	--	6.55	--	--	6.69	--
	DO	B	--	--	5.82	--	--	6.07	--	--	6.86	--
3 June 1969	T	S	22.52	23.36	23.58	23.60	24.43	25.14	23.92	23.48	22.96	24.09
	T	B	--	--	21.86	--	--	21.98	--	--	22.10	--
	SAL	S	9.06	7.12	7.62	8.30	5.72	5.63	5.52	4.45	4.67	4.88
	SAL	B	--	--	8.99	--	--	7.17	--	--	5.41	--
	DO	S	--	--	5.67	--	--	5.54	--	--	5.93	--
	DO	B	--	--	5.10	--	--	4.18	--	--	4.76	--
19 June 1969	T	S	26.30	26.16	26.32	26.41	26.55	26.42	26.42	26.12	26.26	26.38
	T	B	--	--	26.32	--	--	26.21	--	--	26.24	--
	SAL	S	10.51	9.00	9.33	9.32	7.96	7.49	7.20	6.25	5.79	5.77
	SAL	B	--	--	9.43	--	--	7.62	--	--	6.08	--
	DO	S	--	--	4.84	--	--	5.32	--	--	5.52	--
	DO	B	--	--	2.90	--	--	2.18	--	--	1.11	--
4 July 1969	T	S	28.76	29.70	29.48	28.81	28.96	29.06	29.66	29.32	29.01	28.77
	T	B	--	--	28.96	--	--	28.10	--	--	27.72	--
	SAL	S	10.12	8.26	9.40	8.36	7.40	6.76	6.78	7.20	6.96	7.68
	SAL	B	--	--	8.93	--	--	11.68	--	--	11.00	--
	DO	S	--	--	5.26	--	--	5.52	--	--	5.19	--
	DO	B	--	--	0.53	--	--	0.00	--	--	0.00	--

Table 5. Continued (2 May 1969 - 4 July 1969)

Stations:			H9	H10	H11	H12	H13	H14	H15	H16	H17
2 May 1969	T	S	18.76	18.97	18.91	18.00	19.10	18.88	18.76	19.00	19.26
	T	B	--	18.60	--	--	18.96	--	18.58	18.35	18.89
	SAL	S	3.70	2.42	2.91	9.12	7.62	8.44	8.32	1.24	0.56
	SAL	B	--	2.42	--	--	7.62	--	8.28	1.48	0.56
	DO	S	--	7.43	--	--	5.97	--	6.52	6.57	5.63
	DO	B	--	1.10	--	--	6.13	--	6.88	5.79	5.92
3 June 1969	T	S	24.16	24.66	23.00	22.41	22.22	22.34	22.36	24.16	24.35
	T	B	--	22.58	--	--	21.32	--	21.70	21.88	22.21
	SAL	S	3.10	2.24	0.91	9.54	9.01	7.62	7.97	0.23	0.07
	SAL	B	--	1.66	--	--	9.22	--	7.97	0.66	0.08
	DO	S	--	5.21	--	--	5.40	--	5.47	6.28	7.45
	DO	B	--	3.78	--	--	4.22	--	4.39	5.06	4.84
19 June 1969	T	S	26.48	26.44	26.35	26.09	27.15	26.78	26.90	26.13	26.00
	T	B	--	26.24	--	--	26.34	--	26.31	26.04	25.72
	SAL	S	4.89	3.67	3.05	10.75	10.05	9.96	9.84	1.80	1.34
	SAL	B	7.42	--	--	--	10.57	--	9.94	2.73	1.36
	DO	S	3.77	--	--	--	5.36	--	6.44	4.01	2.68
	DO	B	1.58	--	--	--	2.93	--	4.69	2.81	1.36
4 July 1969	T	S	29.18	29.82	28.86	29.05	28.57	29.40	29.02	30.92	28.49
	T	B	--	28.47	--	--	28.78	--	29.12	28.60	28.49
	SAL	S	5.18	6.06	5.52	9.16	8.91	10.43	9.06	4.12	2.53
	SAL	B	--	7.40	--	--	11.45	--	9.64	6.28	5.04
	DO	S	--	6.39	--	--	4.57	--	--	4.49	4.93
	DO	B	--	0.18	--	--	2.20	--	--	4.15	0.90

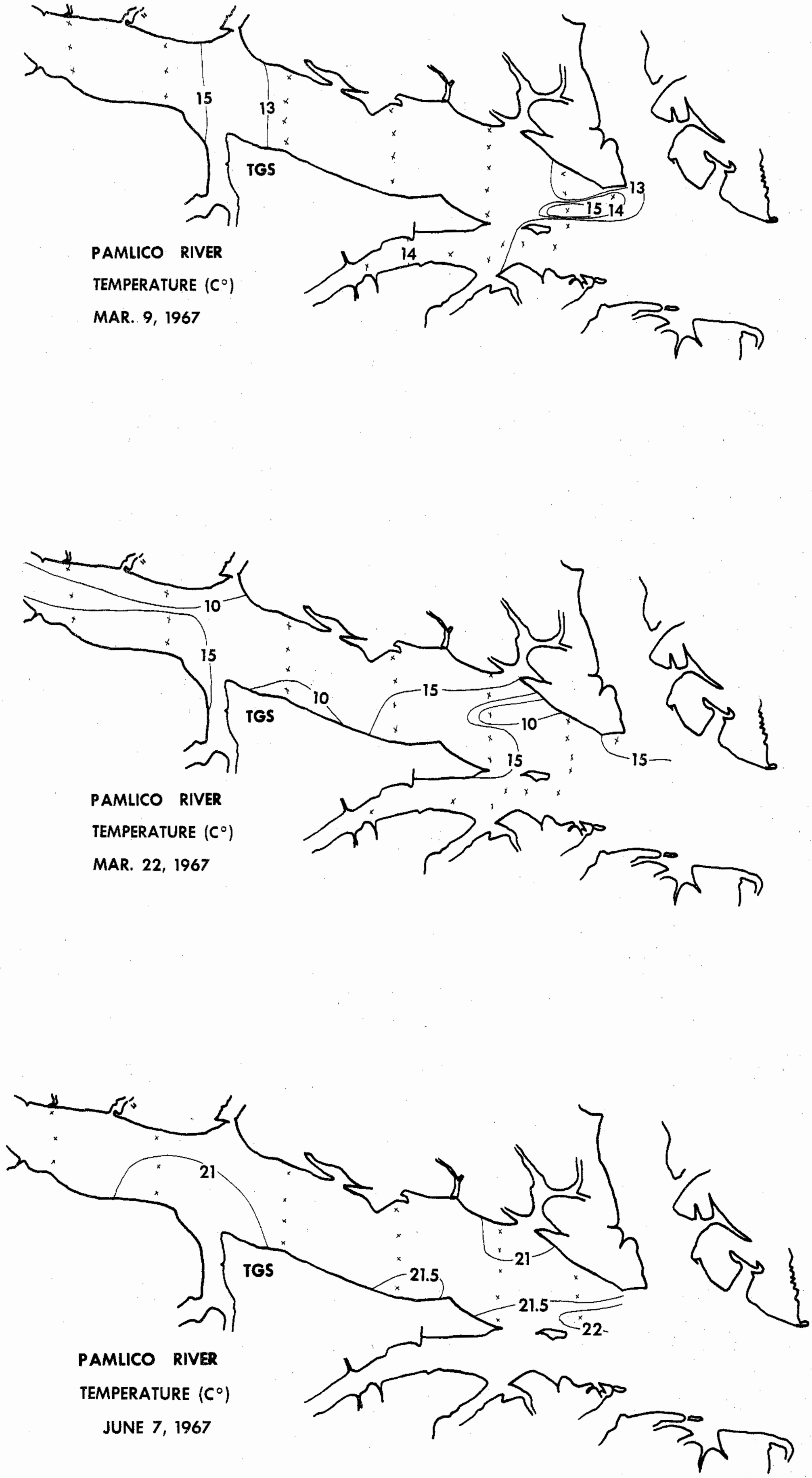


Figure 20. Surface temperatures (C) in the Pamlico River Estuary for 9 March, 22 March, and 7 June 1967.

occurring spring pattern. In the fall there is a reversal of this situation as the sound waters cool slower than the river waters and are therefore warmer.

The maximum temperature of 1967 (31.2^{o}C, 88.2^{o}F) was recorded on 23 August (Fig. 21), but the lowest temperature recorded on that same date was 24.5C (76.1^{o}F). Both of these extremes were along the shore. This illustrates just how difficult it is to determine the average temperature of this estuary. Following this date, the estuary began to cool and the warmer water of the sound occasionally intruded (20 September, Fig. 22). This same pattern was noted all fall (Figs. 23 and 24). Another example of the variability to be found on a single day is the 4 degree range (C or 7^{o}F) seen on 8 January 1968 (Fig. 24). It is extremely difficult to explain these data without taking samples every day. Finally the entire estuary was virtually isothermal at 3.5 to 3.7C (38.3 to 38.7^{o}F) on 13 February (Fig. 25).

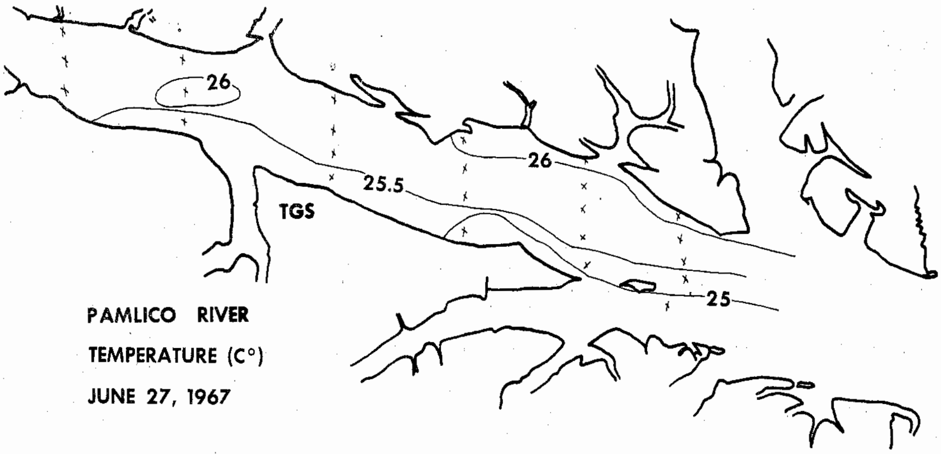
The summer of 1968 was quite warm and surface temperatures reached 34.0C on 6 August (Fig. 26). A temperature of 36.0C (96.8^{o}F) was found at the bottom at Station H4 on 23 August (Table 3). There was statification of the salinity at this station also, and so this is likely a pocket of warm, saline water that is heated by the sunlight. This resembles the greenhouse effect of atmospheric heating and has been found in many aquatic situations.

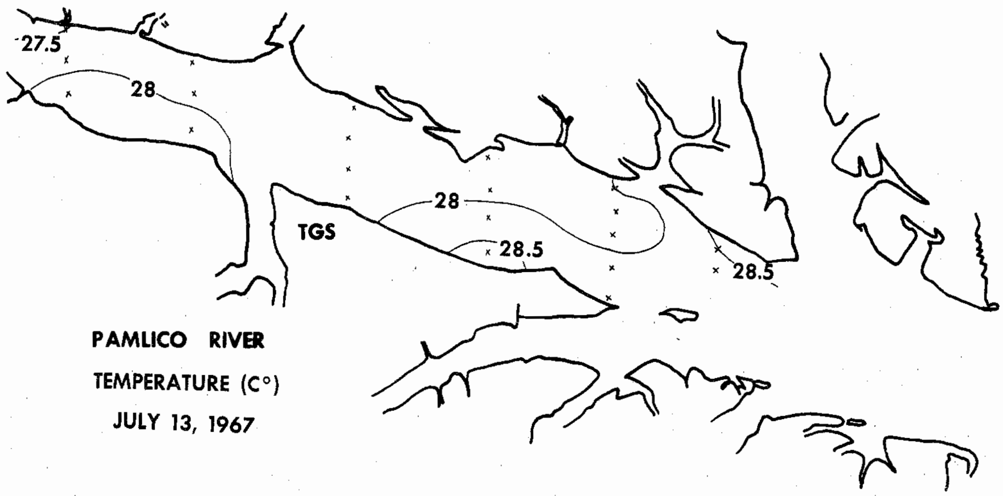
The fall cooling was uneventful (Figs. 27 and 28) and the whole estuary cooled at about the same rate. Minimum temperatures were reached in January (Fig. 29), followed by a rapid rise in temperature during February.

The spring warming was a good example of the lag in the sound, as indicated by the intrusion of cooler water on 15 April (Fig. 30); the sound was at 13C (55^{o}F) and the river at 16 or 17 C (61 or 63^{o}F). Temperatures above 31C (88^{o}F) were measured in the river on 4 July (Fig.31).

Dissolved Oxygen

The dissolved oxygen concentration is dependent on the water temperature





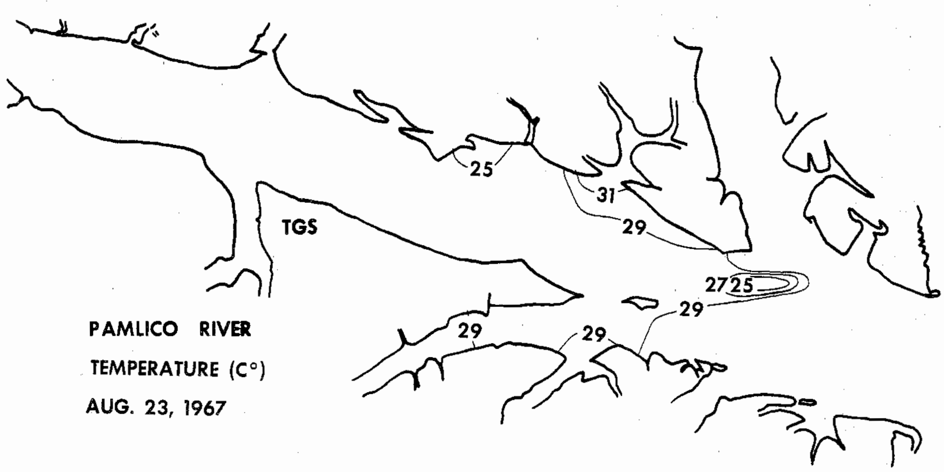


Figure 21. Surface temperatures (C) in the Pamlico River Estuary for 27 June, 13 July, and 23 August 1967.

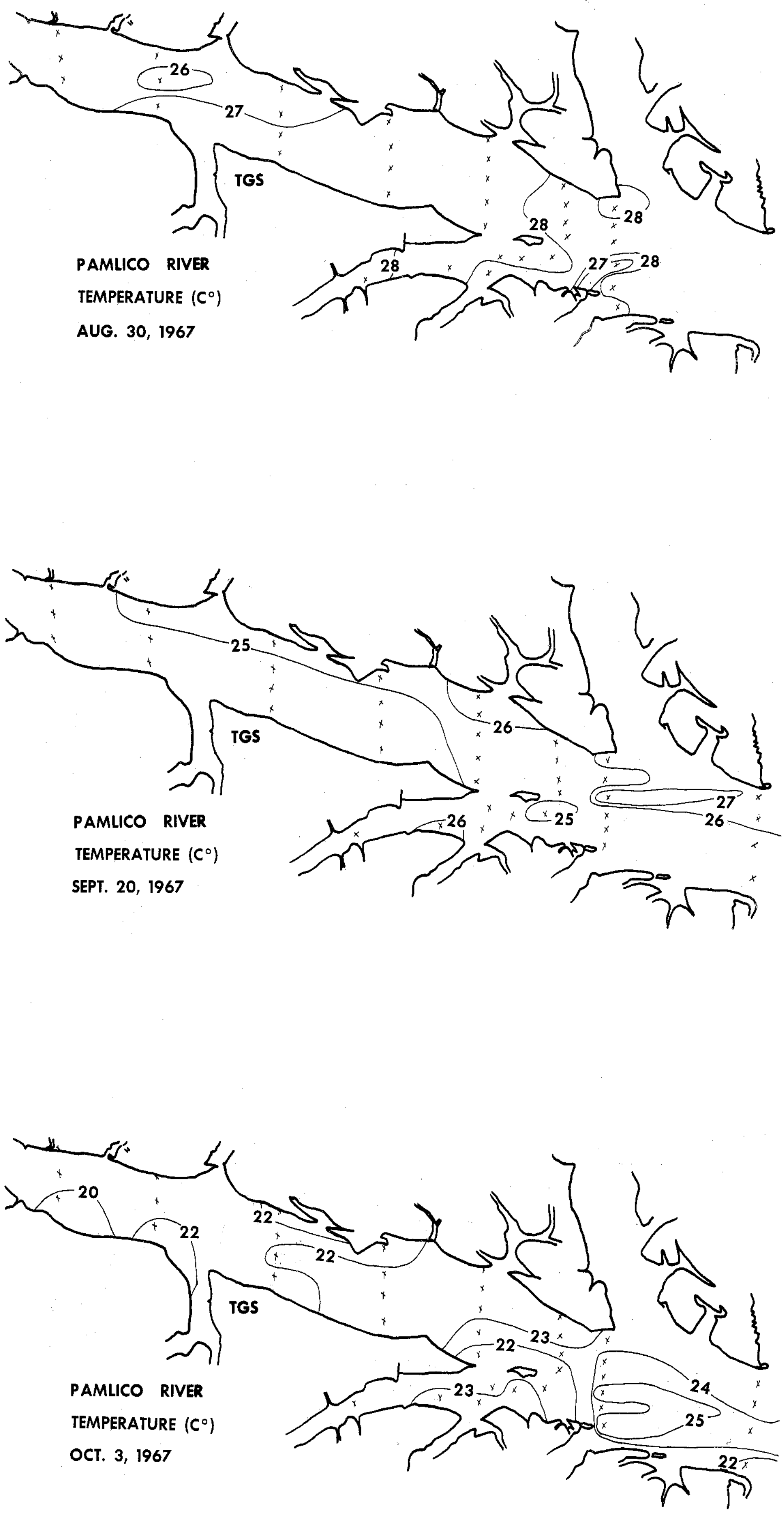


Figure 22. Surface temperatures (C) in the Pamlico River Estuary for 30 August, 20 September, and 3 October 1967.

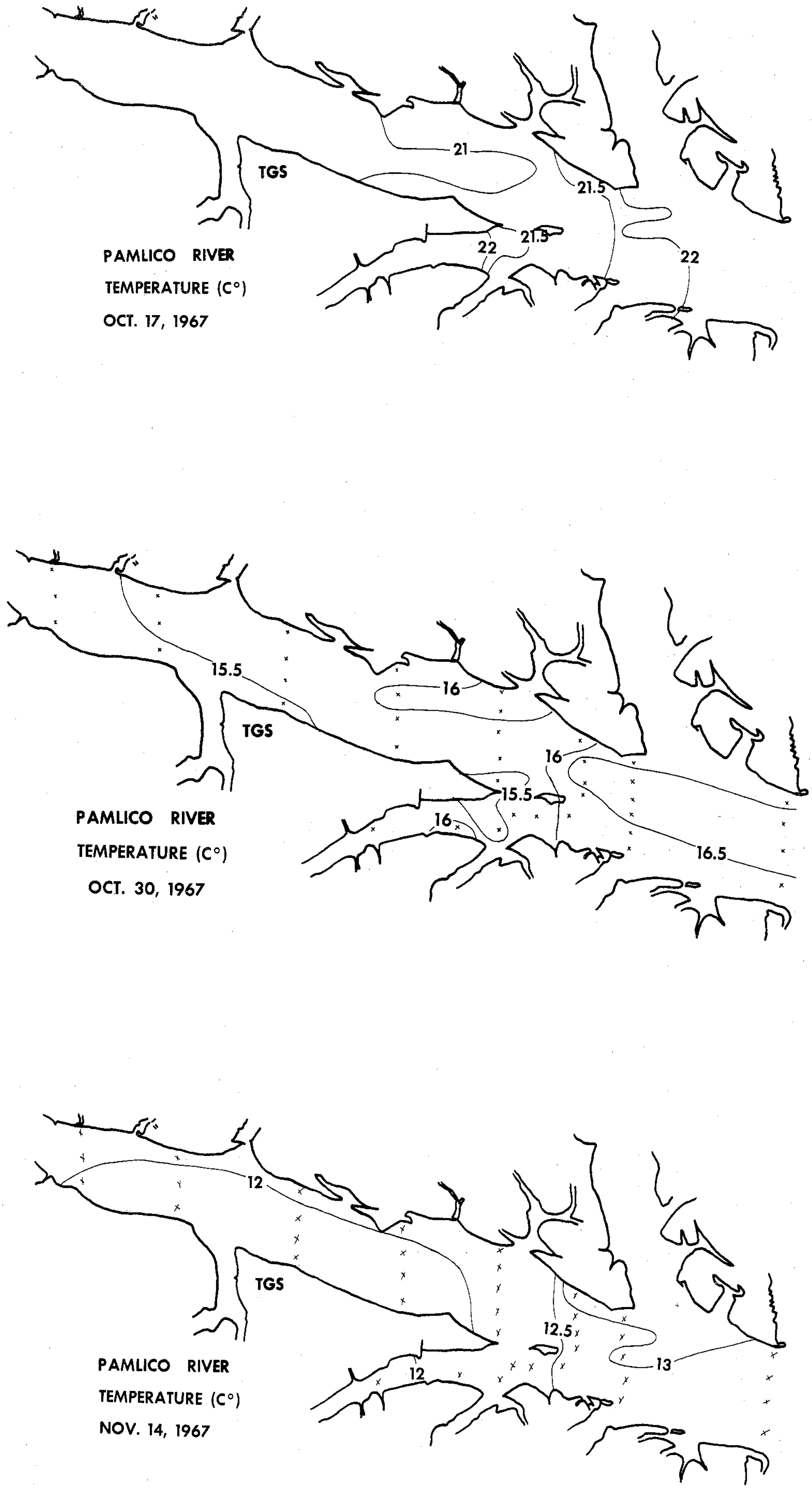
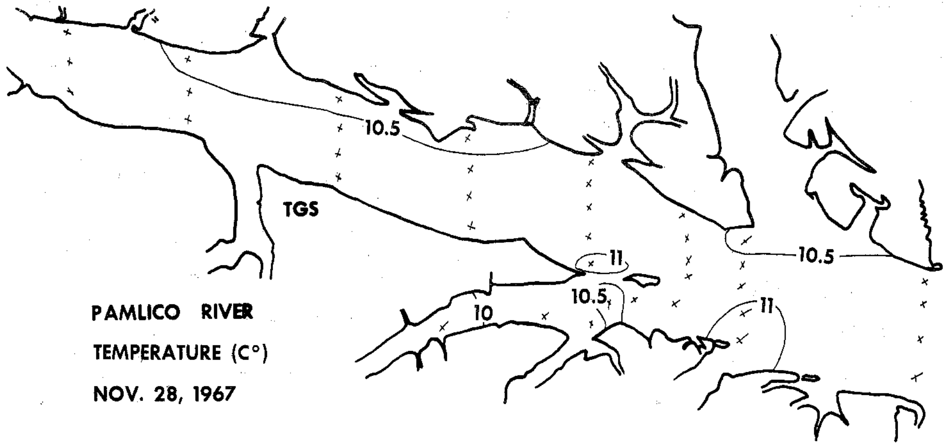
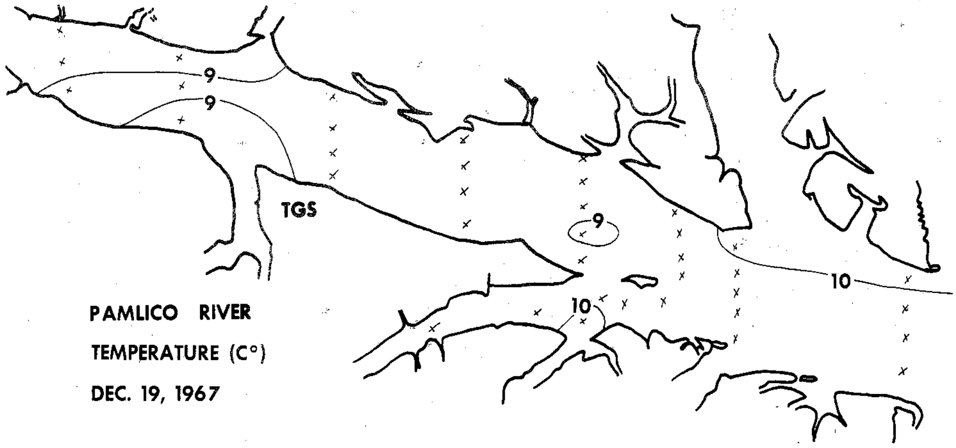


Figure 23. Surface temperatures (C) in the Pamlico River Estuary for 17 October, 30 October, and 14 November 1967.





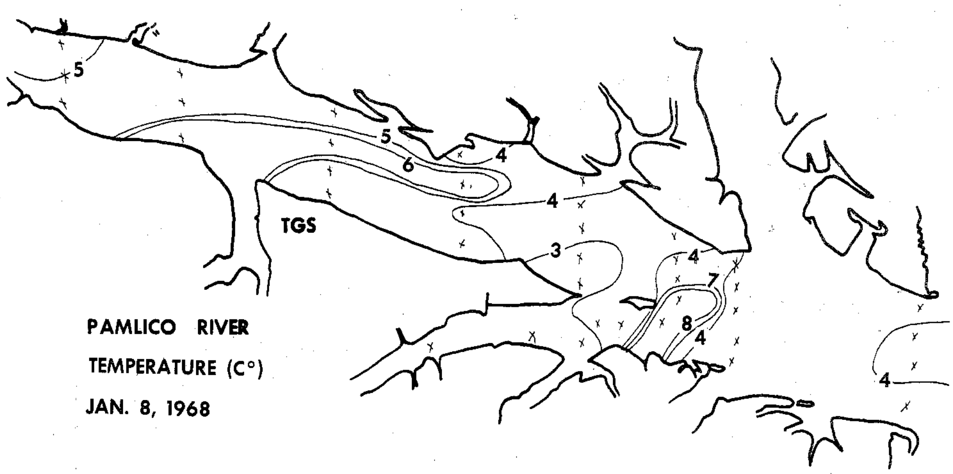


Figure 24. Surface temperatures (C) in the Pamlico River Estuary for 28 November, 19 December 1967 and 9 January 1968.

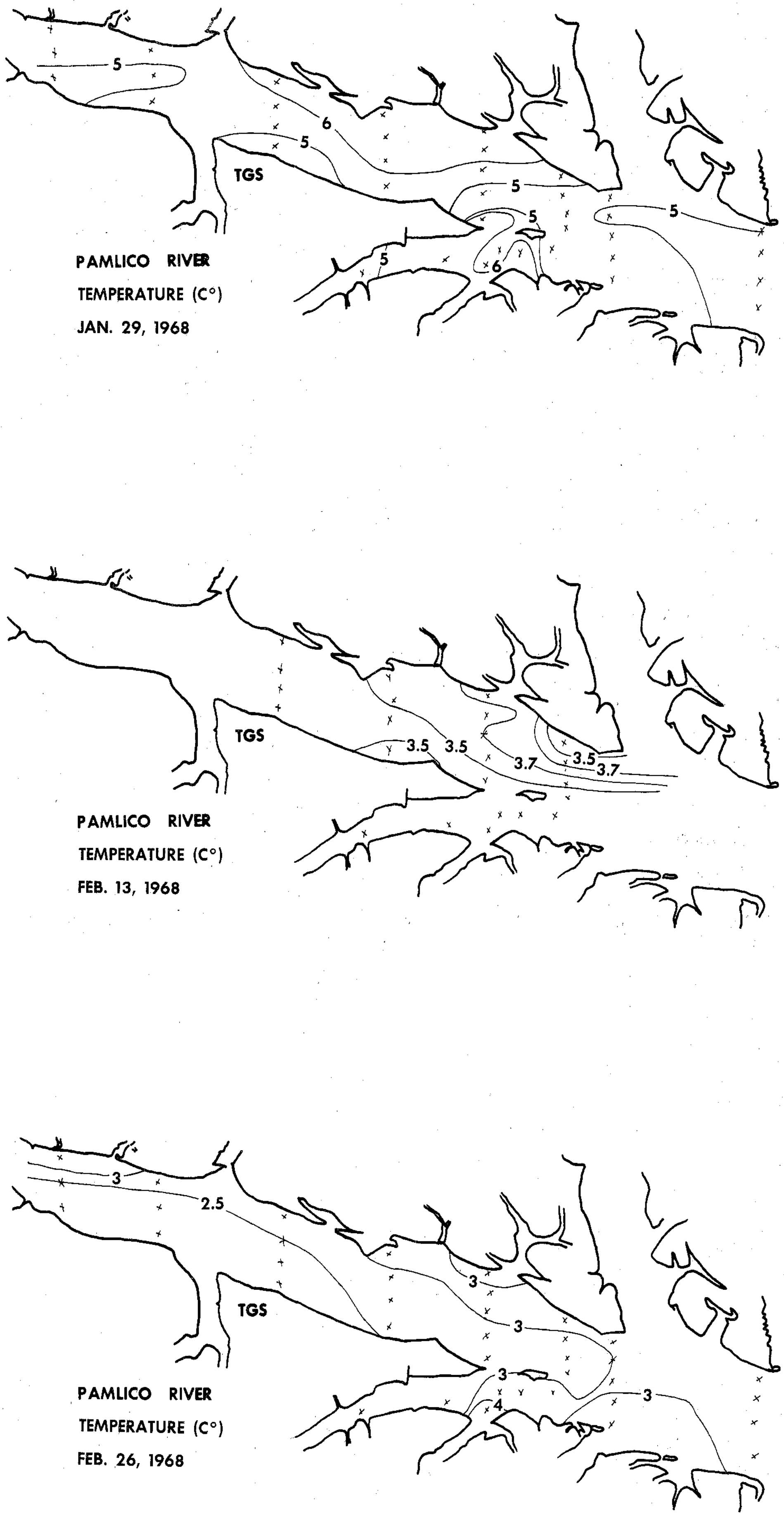
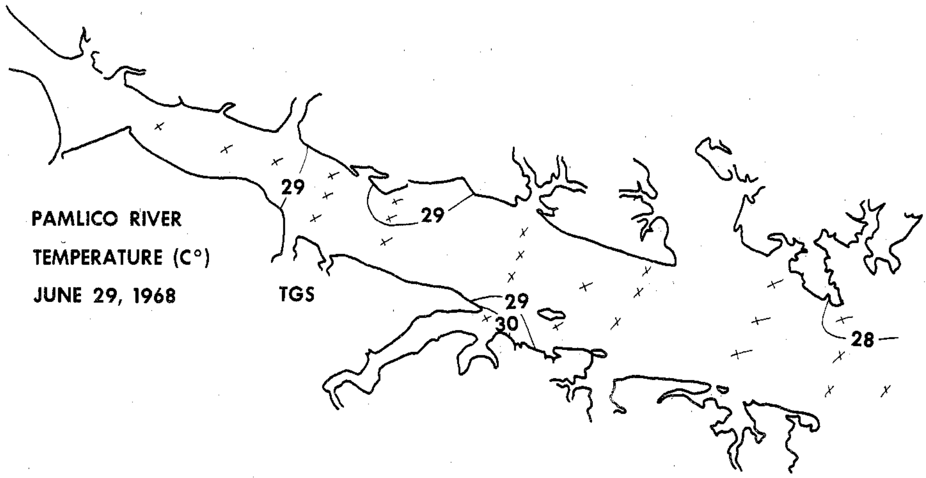
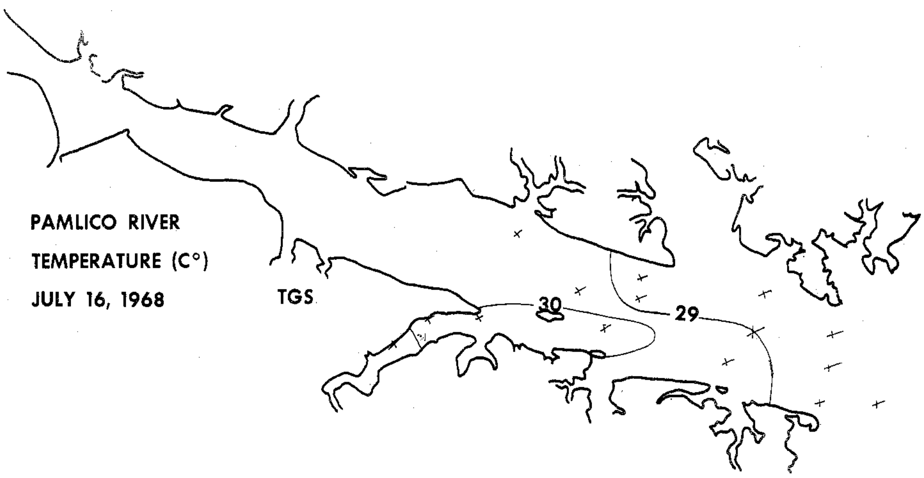


Figure 25. Surface temperatures (C) in the Pamlico River Estuary for 29 January, 13 February, and 26 February 1968.





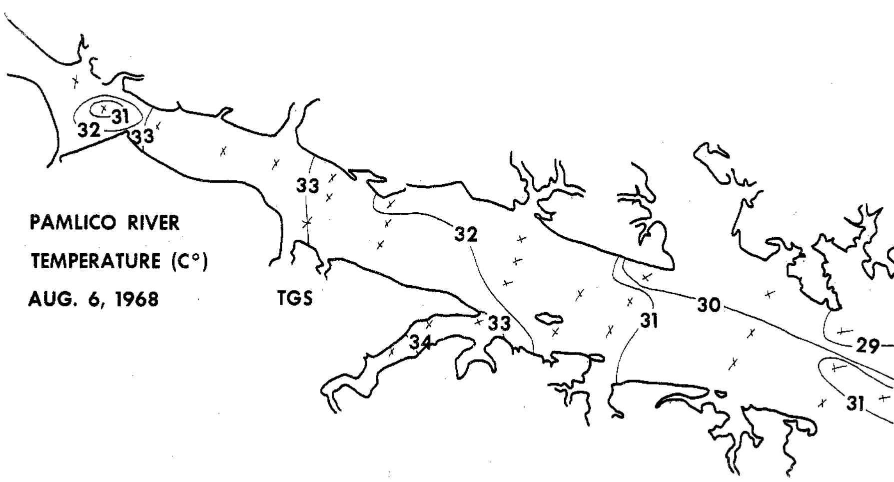


Figure 26. Surface temperature (C) in the Pamlico River Estuary for 29 June, 16 July, and 6 August 1968.

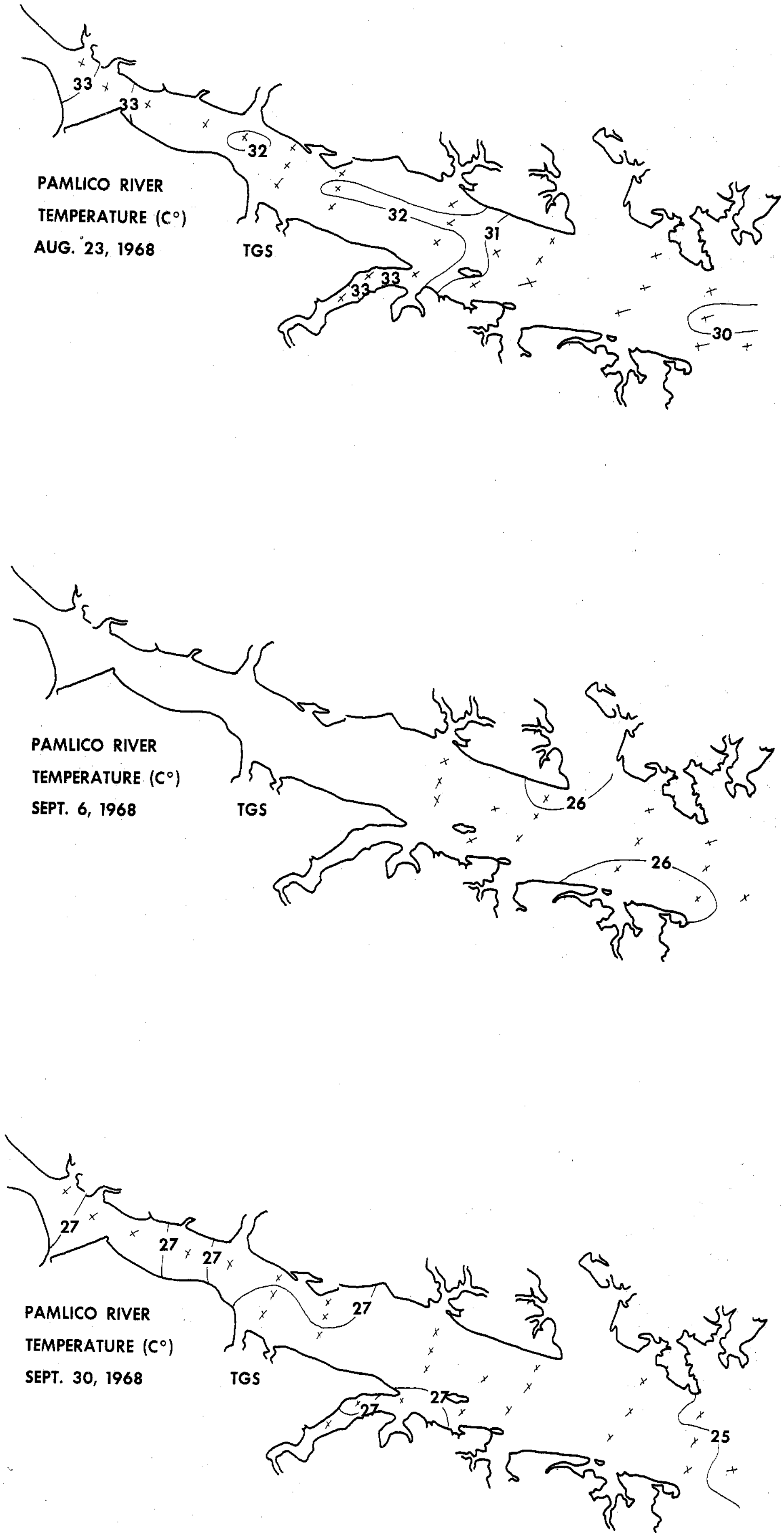


Figure 27. Surface temperatures (C) in the Pamlico River Estuary for 23 August, 6 September, and 30 September 1968.

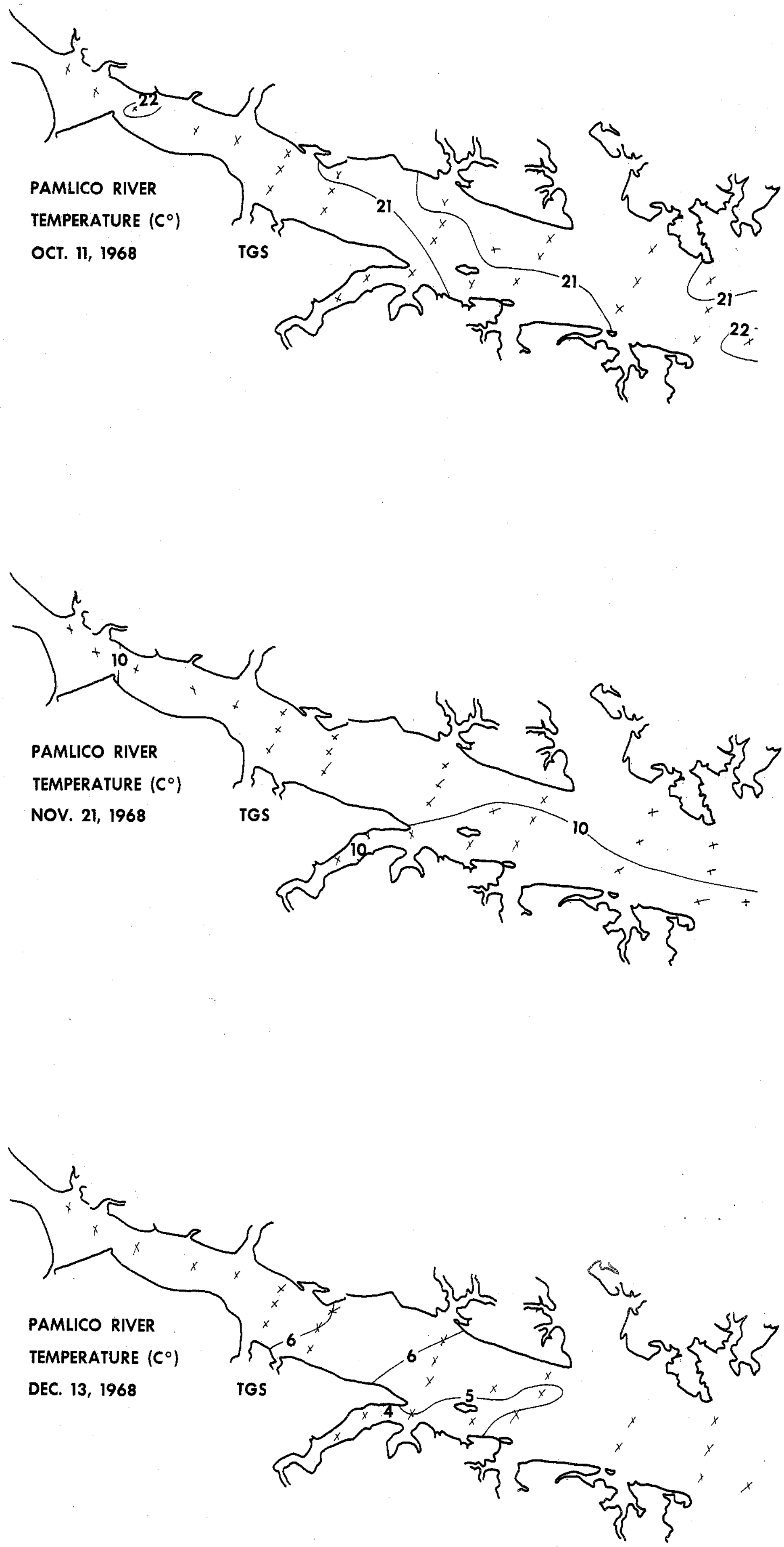


Figure 28. Surface temperatures (C) in the Pamlico River Estuary for 11 October, 21 November, and 13 December 1968.

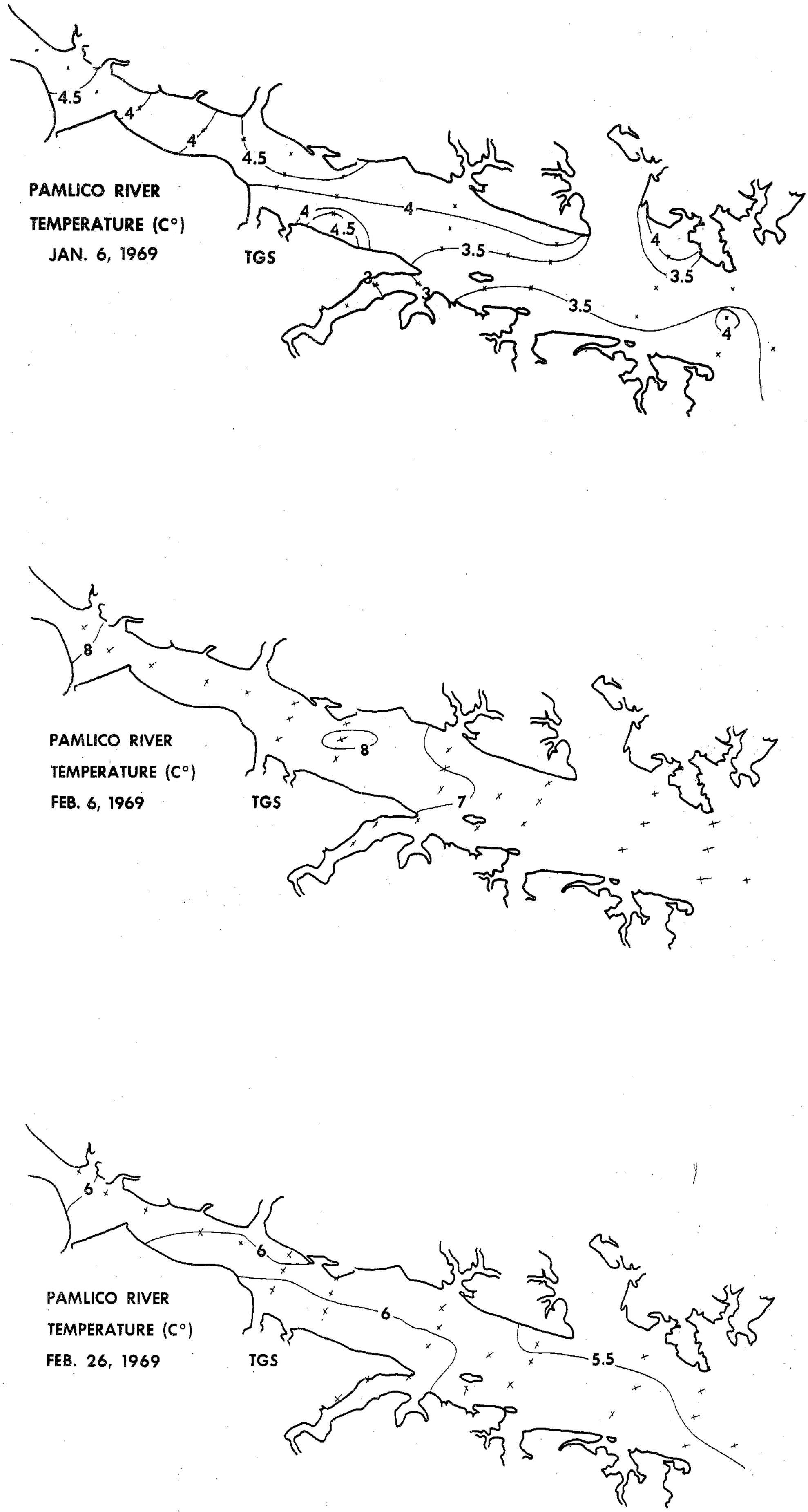


Figure 29. Surface temperatures (C) in the Pamlico River Estuary for 6 January, 6 February, and 26 February 1969.

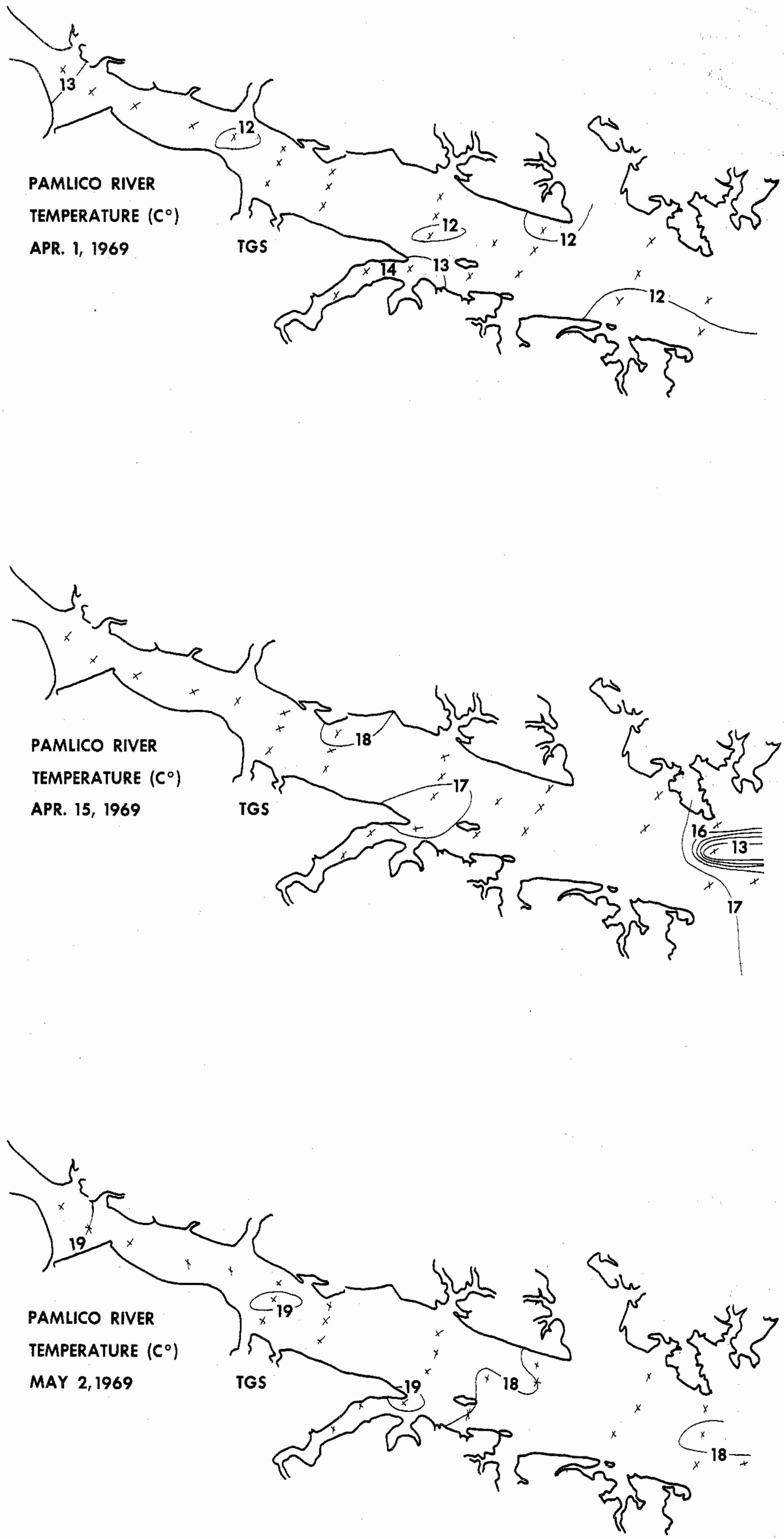


Figure 30. Surface temperatures (C) in the Pamlico River Estuary for 1 April, 15 April, and 2 May 1969.

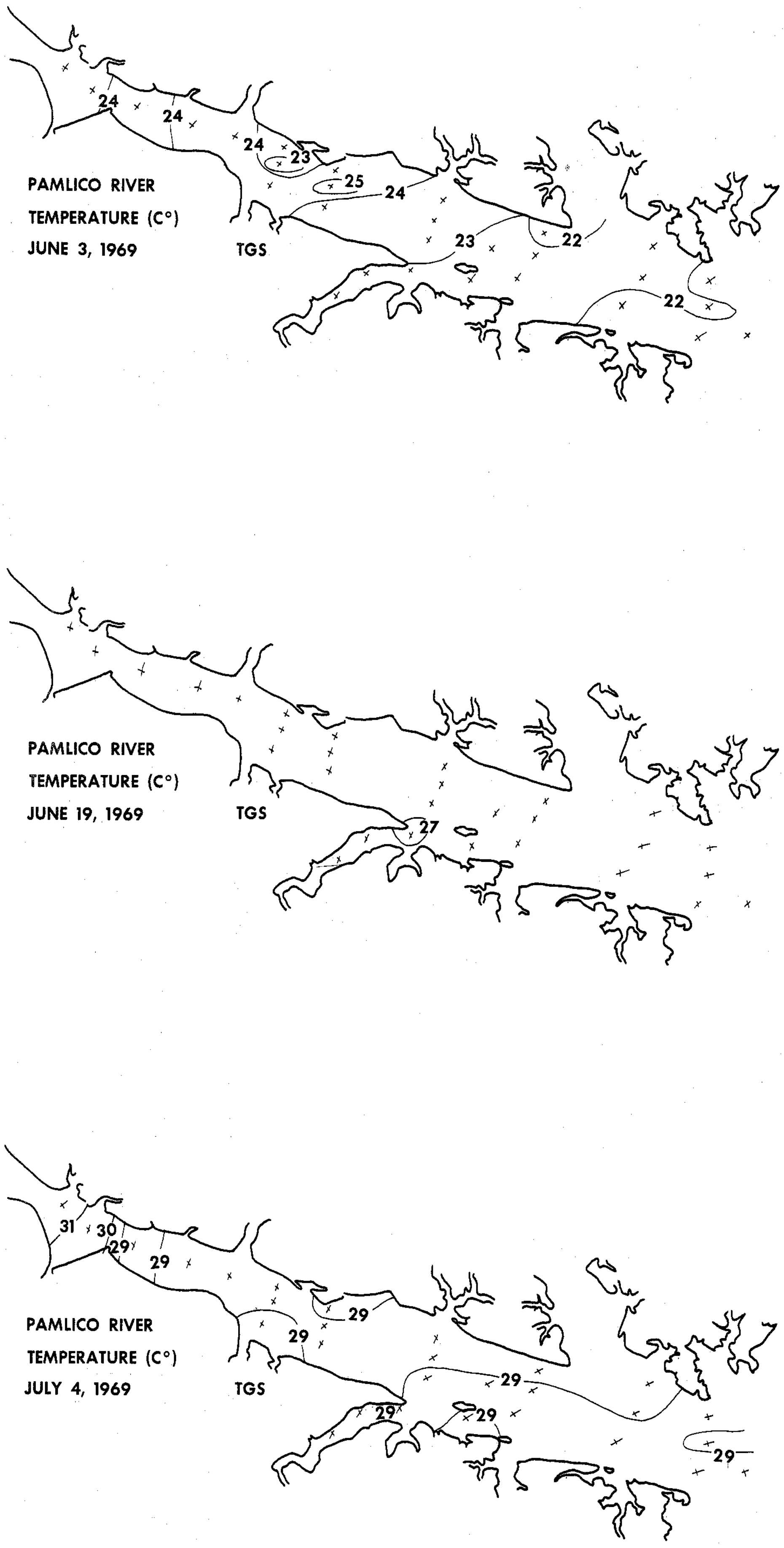


Figure 31. Surface temperatures (C) in the Pamlico River Estuary for 2 June, 19 June, and 4 July 1969.

(cold water holds more oxygen than warm) and the biological activity. Photosynthesis will produce oxygen, while respiration (or breakdown processes) will remove oxygen from the water. The concentrations found in the estuary are, therefore, a balance between the process of equilibrium of oxygen with the air, the photosynthesis and the respiration. Data for 13 December 1968 through 4 July 1969 are given in Tables 4 and 5 and Figs. 32 through 37.

For the winter months, the surface waters are close to oxygen saturation and sometimes even supersaturated (Table 6). For example, on 13 December (Fig.32) when the biological activity was low, the physical conditions determined the oxygen concentrations(close to 100% saturation). The one exception was at Station H8 where there was probably a high rate of photosynthesis. This high oxygen concentration just upstream from Texas Gulf Sulfur Company outfall is rather a common feature of the river, although this high value (127%) was slightly downstream from TGS on 26 February. It is also obvious that, although the absolute quantity of oxygen in the water decreased due to the warm water temperature (compare 13 December with 26 February and 1 April), the oxygen content was still close to saturation.

The same general pattern for surface dissolved oxygen continued into May, June and July (Figs. 33 and 34) with high concentrations, usually well above saturation, present in the middle of the river. Another trend is for lower concentrations at the two stations closest to the inflowing Tar River. This shows up on 6 February, 1 April and especially on 19 June when the percentage of saturation dropped to 48% (Table 6). It is likely that this is caused by sewage from cities upriver, especially Washington, N. C.

Another problem that arises with oxygen data is that there is likely to be a strong daily variation of oxygen concentration in the river. During times of high primary productivity (photosynthesis), there could be a fluctuation of more

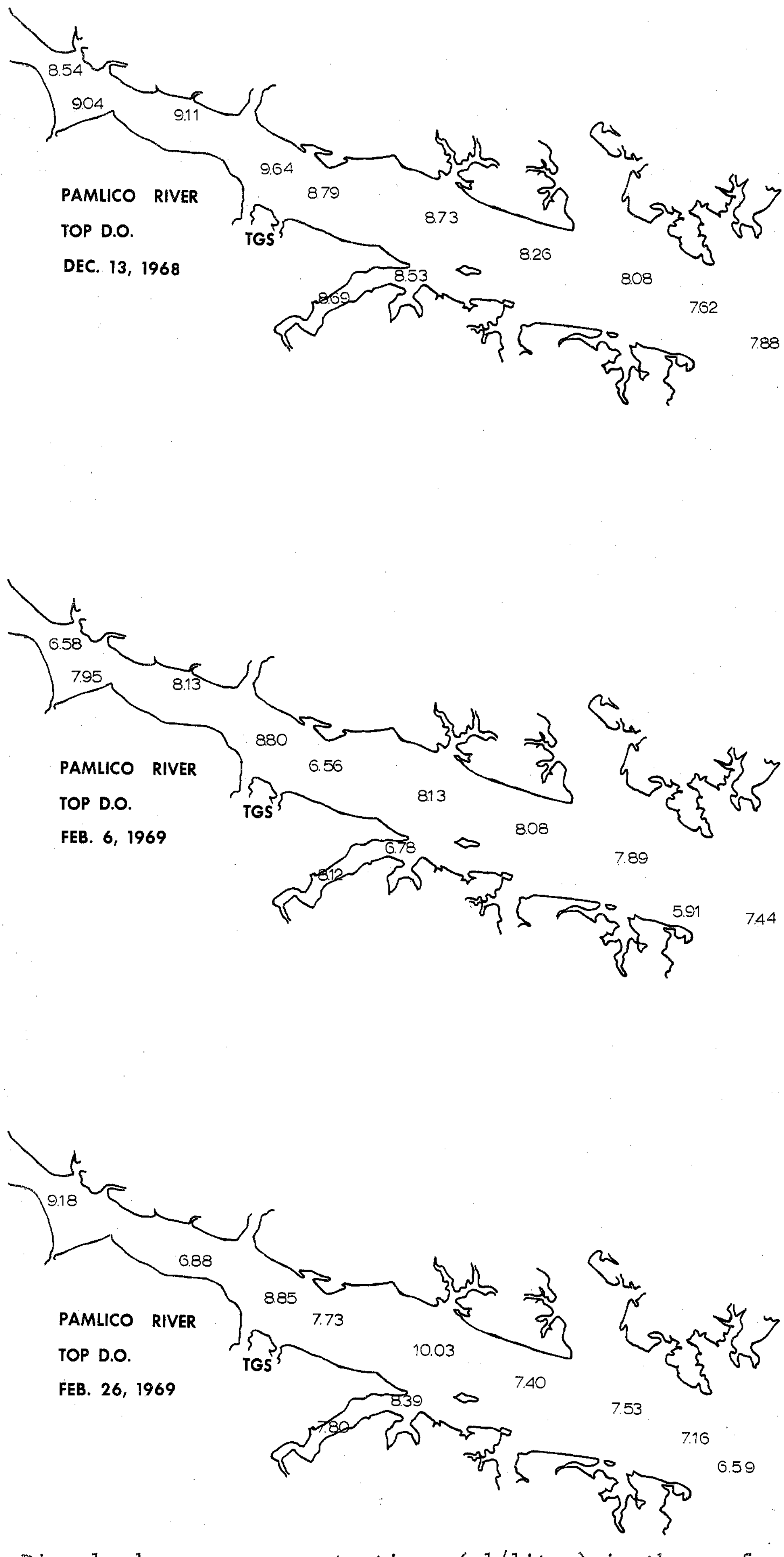


Figure 32. Dissolved oxygen concentrations (ml/liter) in the surface water of the Pamlico River Estuary on 13 December 1968, 6 February and 26 February 1969.

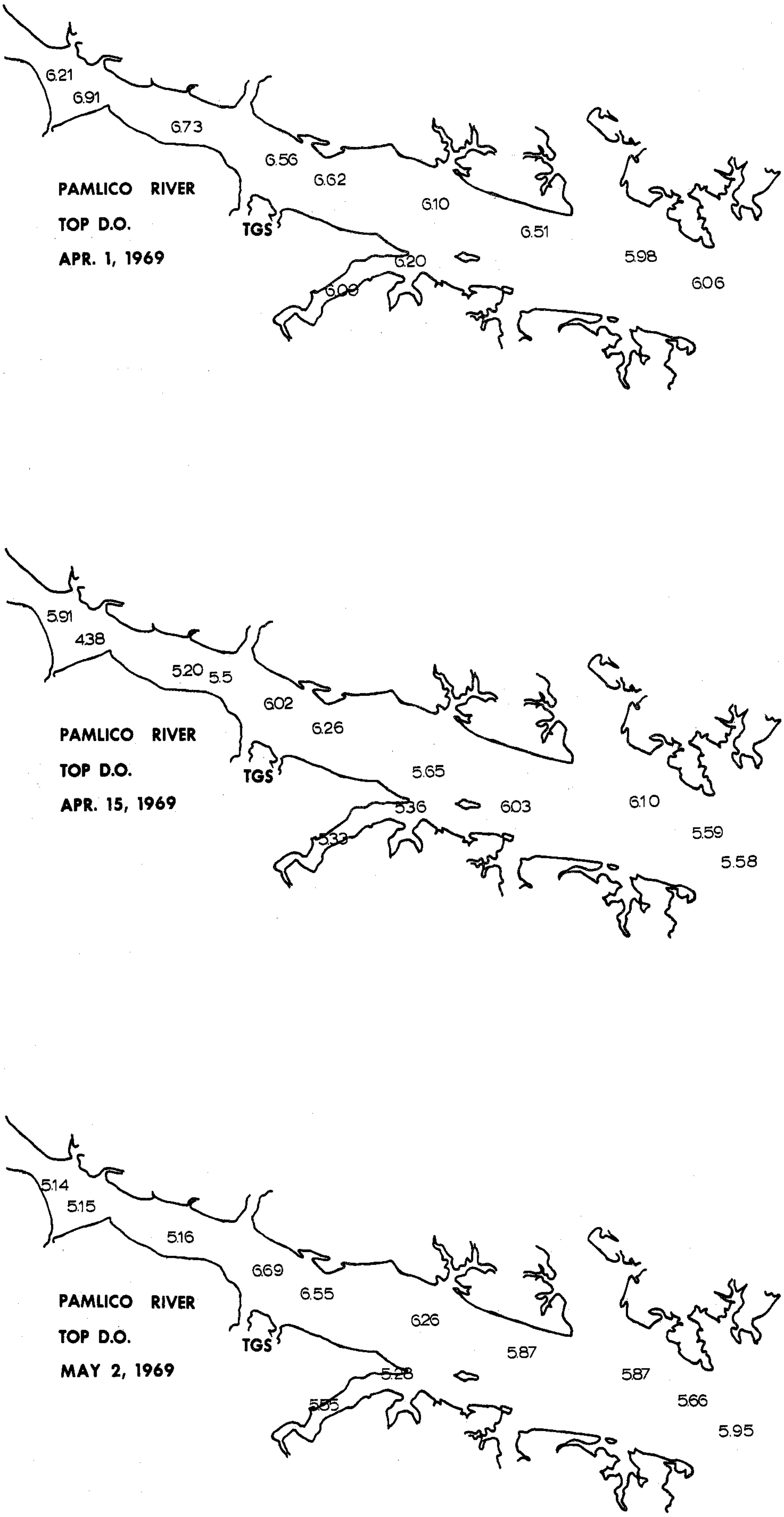


Figure 33. Dissolved oxygen concentrations (ml/liter) in the surface water of the Pamlico River Estuary on 1 April, 15 April and 2 May 1969.

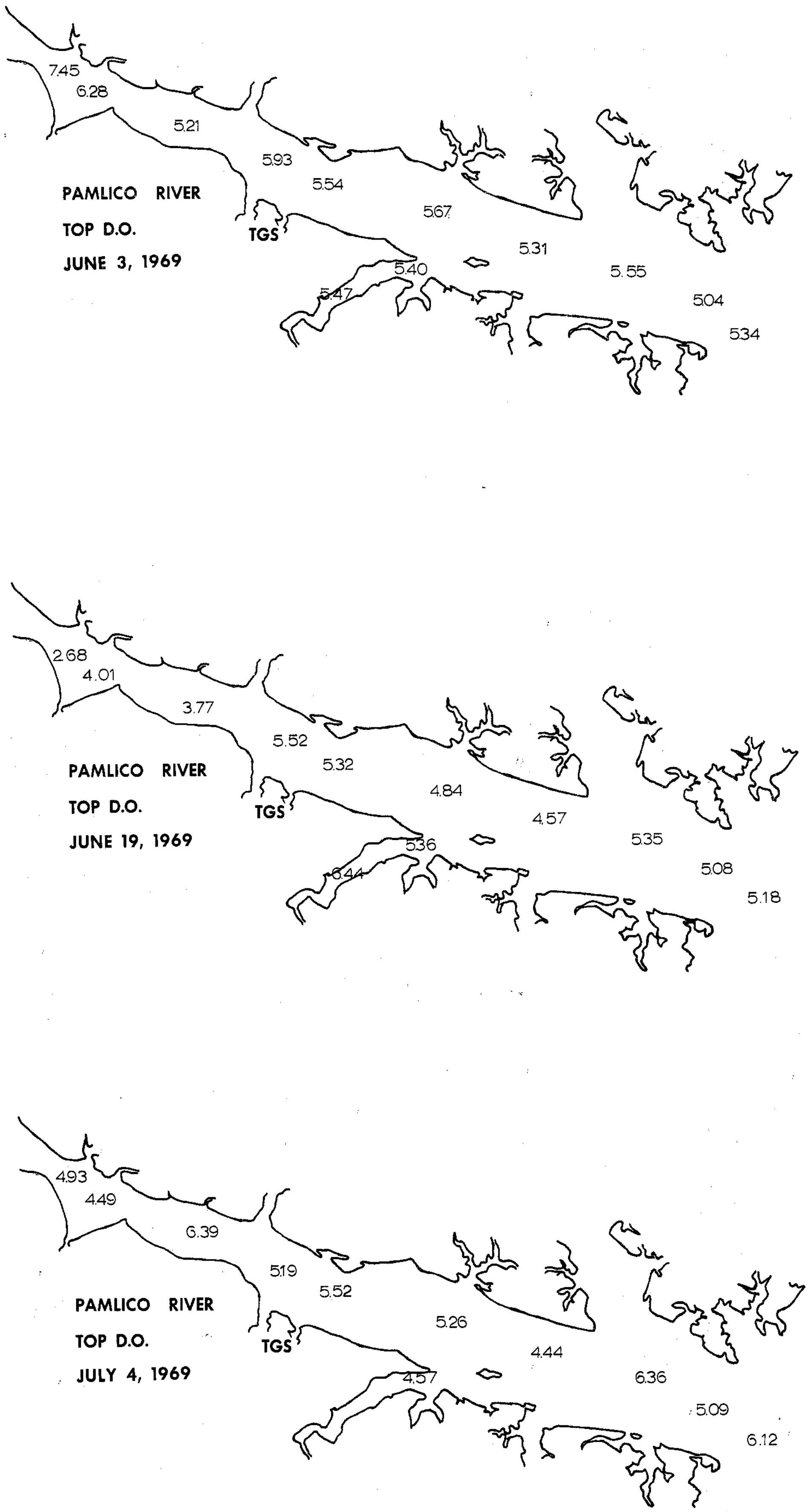


Figure 34. Dissolved oxygen concentrations (ml/liter) in the surface water of the Pamlico River Estuary on 3 June, 19 June and 4 July 1969.

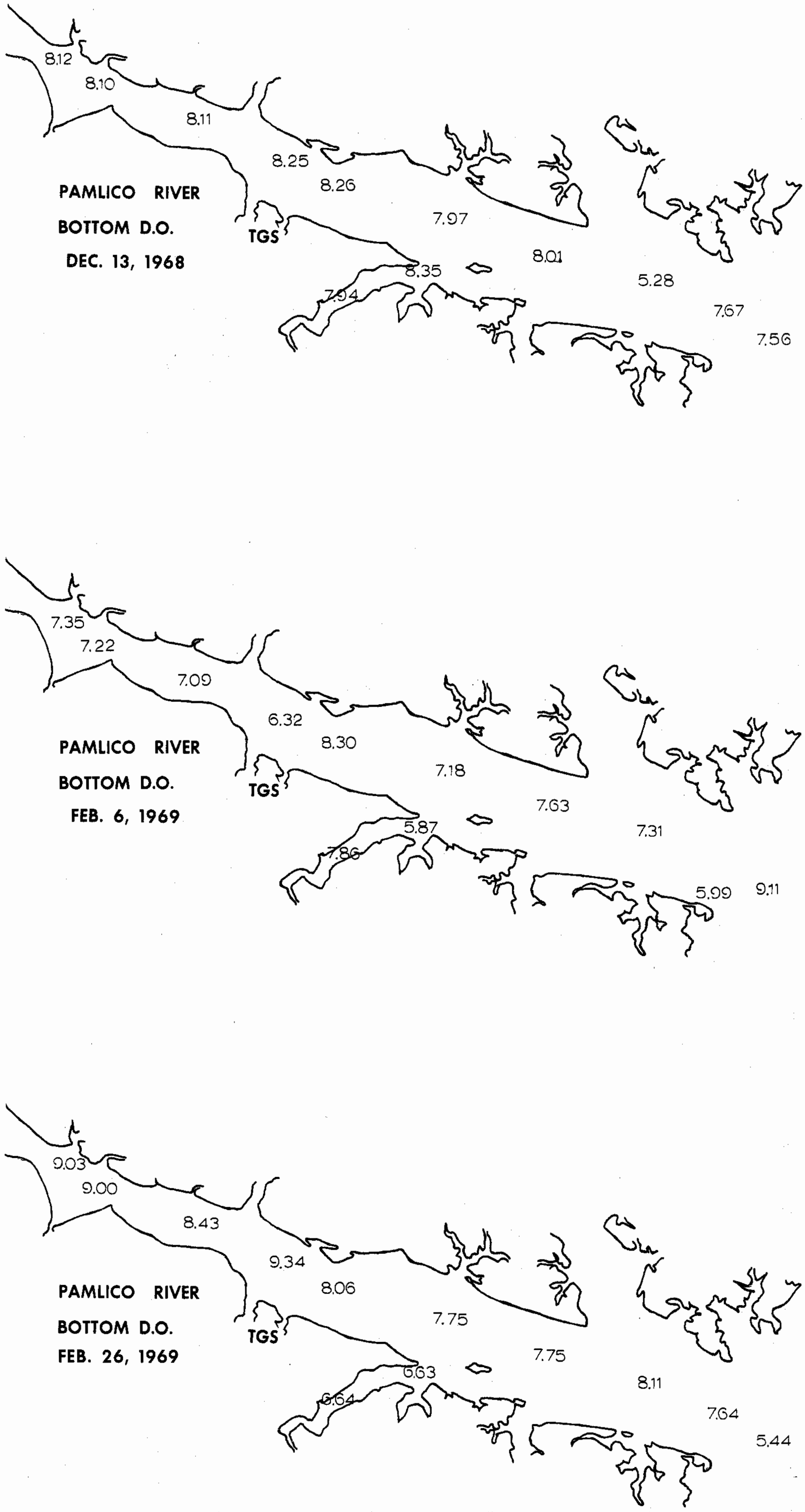


Figure 35. Dissolved oxygen concentrations (ml/liter) in the bottom water of the Pamlico River Estuary on 13 December 1968, 6 February, and 26 February 1969.

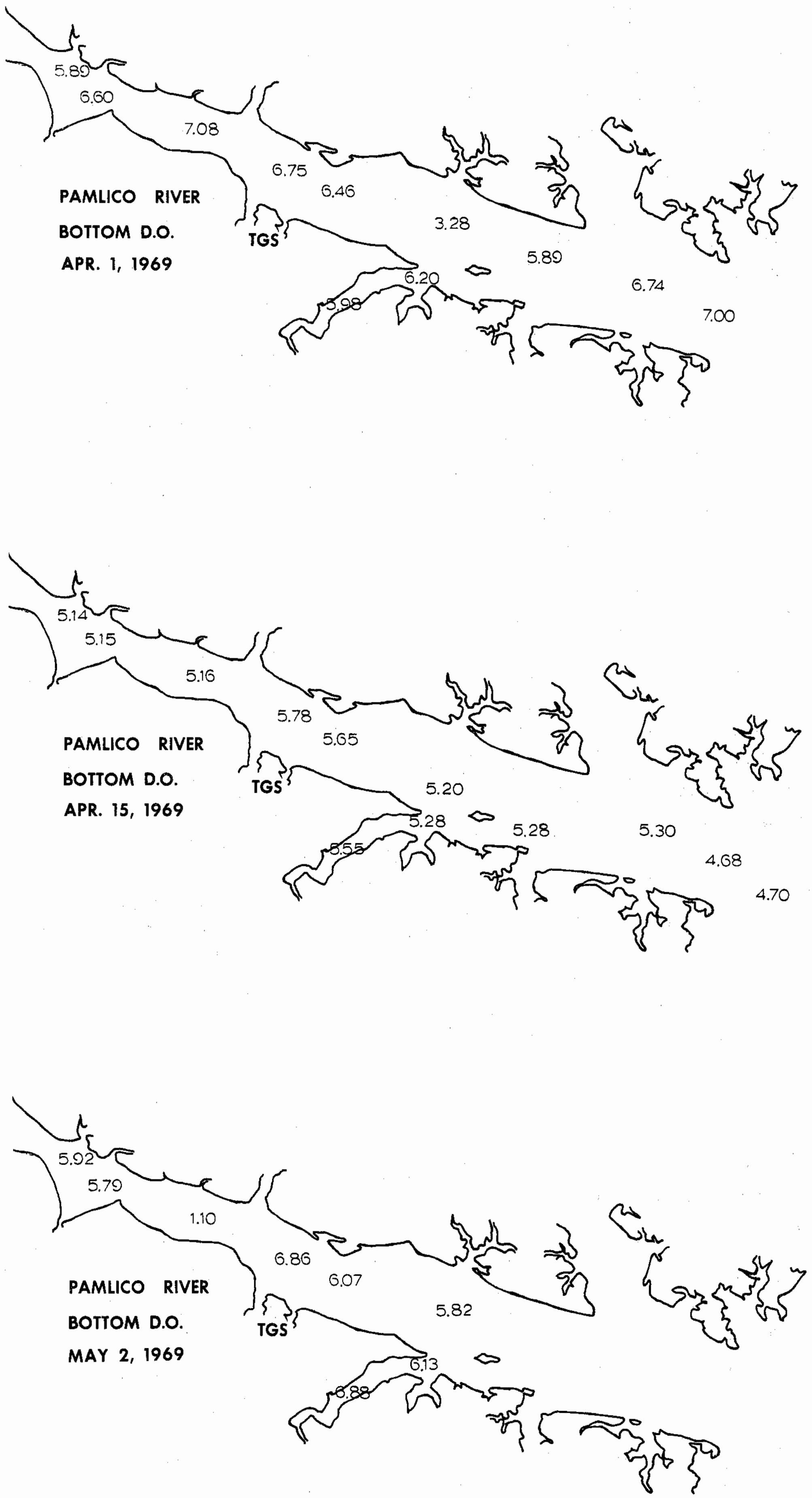


Figure 36. Dissolved oxygen concentrations (ml/liter) in the bottom water of the Pamlico River Estuary on 1 April, 15 April, and 2 May 1969.

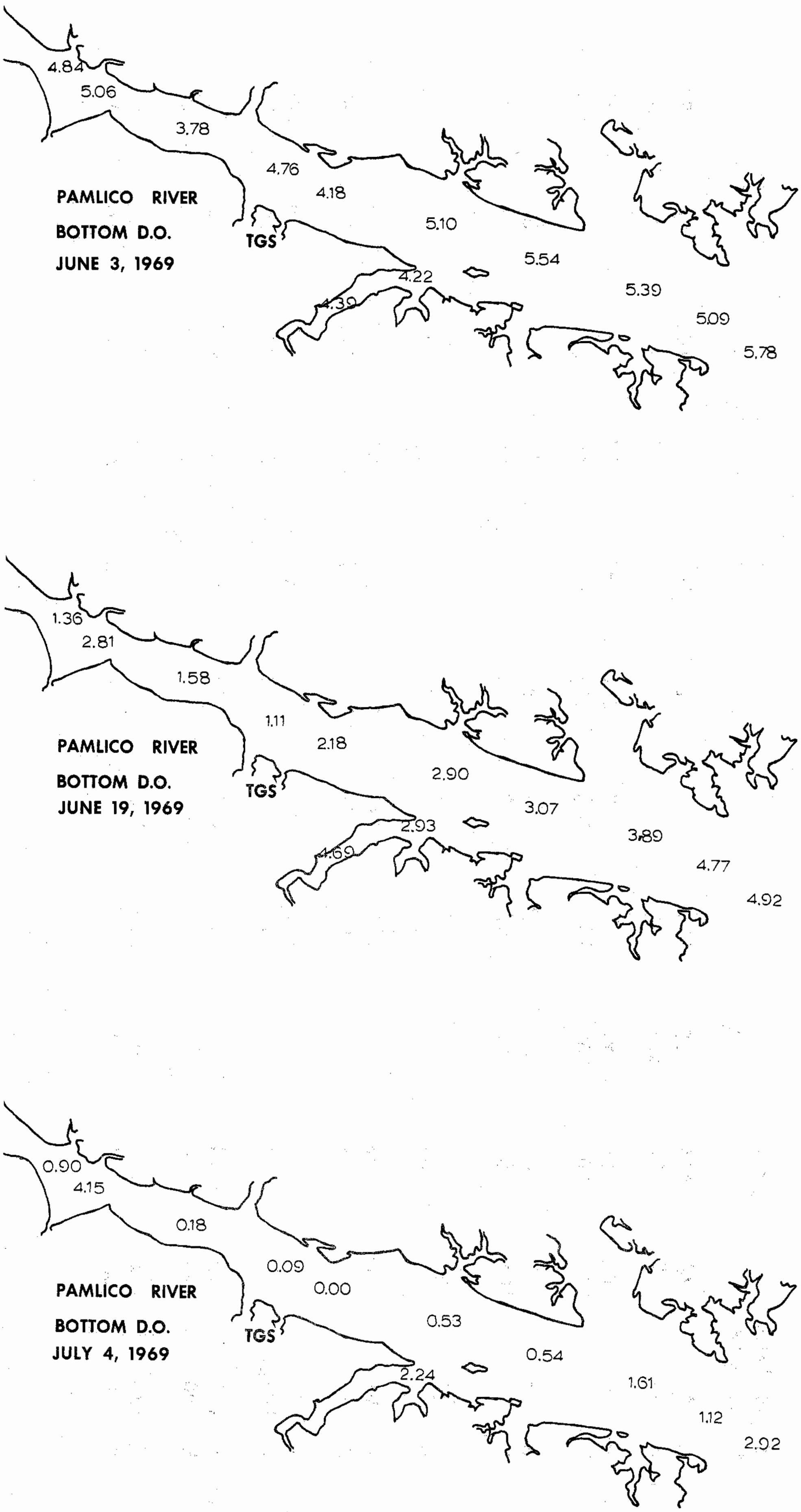


Figure 37. Dissolved oxygen concentrations (ml/liter) in the bottom water of the Pamlico River Estuary on 3 June, 19 June, and 4 July 1969.

Table 6. Percent Saturation of Dissolved Oxygen at the surface (S) and bottom (B) of the Pamlico River Estuary 13 December 1968 - 4 July 1969.

Station:		H1	H2	H3	H4	H6	H7	H8	H10	H13	H15	H16	H17
13 Dec.	S	100	96	101	100	106	109	118	108	102	101	105	100
1968	B	95	98	67	100	102	107	107	103	100	92	100	103
6 Jan.	S	No Data											
1968	B	No Data											
6 Feb.	S	98	78	104	105	106	87	113	103	88	106	100	83
1969	B	95	80	96	102	96	109	82	96	77	102	92	93
26 Feb.	S	86	93	98	94	127	99	111	86	105	97	--	113
1969	B	71	100	105	102	100	105	118	106	84	83	115	112
1 Apr.	S	--	91	89	95	88	94	92	94	92	91	82	87
1969	B	--	106	101	86	47	92	95	99	91	91	92	82
15 Apr.	S	91	85	99	--	--	100	95	80	86	85	68	91
1969	B	77	76	86	--	--	89	91	79	87	88	80	79
2 May	S	101	96	96	96	101	106	108	118	98	107	104	89
1969	B	--	--	--	--	93	97	108	17	101	113	91	93
3 June	S	97	93	99	94	101	101	103	92	95	96	109	129
1969	B	105	91	97	98	93	72	82	64	73	76	84	81
19 June	S	101	99	103	88	92	100	102	--	103	123	72	48
1969	B	98	95	76	59	55	41	21	--	56	89	51	24
4 Jul.	S	124	103	132	88	105	108	101	126	89	--	89	93
1969	B	60	23	33	11	10	--	--	4	44	--	80	17

than 1 ml/liter over a 24 hour cycle. Until a number of studies at 3 or 4 hour intervals are carried out, it will be difficult to interpret the small changes that occur from station to station.

The oxygen concentrations near the bottom of the water column are generally similar to the surface concentrations for much of the year with the exception of summer (Table 6, Figs. 35, 36 and 37). The values are very close to saturation during periods of complete circulation (13 December for example). However, even on this date there was a small pocket of water with lowered concentrations -- here, down to 67% of saturation. The exact cause of this pocket is unknown, but in such a biologically productive system, it would only take a week or ten days of stratification to develop low oxygen conditions.

There was adequate oxygen in the bottom water during the spring and early summer, but very low quantities were found after 19 June (Fig. 37). This middle area of the river is also the region of highest productivity, so it is logical that the abundant organic material would sink down into the stratified bottom waters, be attacked by bacteria and thus cause the low oxygen. It is interesting to note that the stratification that was responsible for this deoxygenation (Fig. 18) was not very pronounced on 19 June (a difference of only 1 or 2 ppt), but did increase to 4 or 5 ppt by 4 July 1969.

The oxygen sampling continued during 1969 and 1970. The results will be reported later, but the low oxygen found on 4 July (Fig. 37) was not present on 6 August 1969. The two upstream stations had less than 1 ml/l, as did one station midway along the estuary. The others were all above 4 ml/l. By 21 August 1969, all stations showed more than 2 ml/l and by 17 September all stations were greater than 3 ml/l. However, two weeks later on 1 October, there were two stations below 1 ml/l. On 29 October, all stations were above 5 ml/l. There were no more low values until after mid-June 1970. Therefore, although there are periods of anaerobic conditions (no oxygen) in the bottom waters, these are irregular and the stratification is unstable and easily destroyed.

CONCLUSIONS

It must be kept in mind that these data are part of a series of reports. Many phenomena reported here cannot be correctly interpreted until the biological data are published. For example, to interpret the oxygen data correctly, the primary productivity and algal biomass information must be compared with the oxygen data.

The salinity distribution in the estuary depends mainly upon the quantity of inflowing freshwater. Variations, chiefly, in the distribution across the estuary, were caused by wind.

The freshwater moves down the estuary and mixes with the saline water from Pamlico Sound. Sometimes, if the wind is not too strong for a few days, the saline water is trapped beneath the fresher water and stratification occurs. There is even some evidence that the saline bottom water is moving upstream (this is known from a number of estuaries). When the stratification occurs during the summer, the oxygen can become depleted in a matter of days. This is not a permanent situation, as the shallow estuary is easily mixed by wind. However, the anaerobic waters kill most of the benthic animals in these areas with the result that these deeper parts of the river are very sparsely populated (2). Larval animals move into these regions every fall and winter, but then are killed during the summer.

The anaerobic layers can also kill fish, but this happens only rarely. In one case, the south wind pushed the surface water to the north. Bottom water then appeared along the south shore; and as it contained no oxygen, killed large numbers of fish (e.g., flounders).

The temperature data prove that there is a great deal of variability within the estuary. This makes it very difficult to decide just what is the normal temperature of an estuary, a question that becomes very important if an industry or power plant locates on an estuary. Present temperature regulations, for example, prohibit the heating of estuaries more than 1.5°F or 1C. Also, the maximum temperatures reached in this estuary in the absence of significant thermal pollution, 33 or 34C (95°F) are above the allowable limits as set by the Federal Water Quality Administration.

REFERENCES

1. Miller, R. 1970. Distribution and energetics of an estuarine population of the Ctenophore, Mnemiopsis leydii. Unpubl. Ph.D. thesis, N.C.S.U., Raleigh.

2. Tenore, K. 1970. The macrobenthos of the Pamlico River Estuary, N.C. Unpubl. Ph.D. thesis, N.C.S.U., Raleigh.

3. Copeland, B. J. , K. Tenore and D. B.Horton. 1969. Oligohaline Regimes p. 789-828. In H. T. Odum, B. J. Copeland and E. A. McMahan (eds.). Coastal Ecological Systems of the U. S. Report to the Federal Water Pollution Control Administration, Washington.

4. Hobbie, J. E. 1970. Phosphorus concentrations in the Pamlico River Estuary of North Carolina. Report No. 33 of the Water Resources Research Institute of the University of N. C. 47 pp.

5. Peters, D. 1968. A study of relationships between zooplankton abundance and selected environmental variables in the Pamlico River Estuary of eastern North Carolina. Unpubl. M.S. thesis, N.C.S.U., Raleigh.

6. Tenore, K. 1967. Some effects of the bottom substrate on the ecology of Rangia cuneata in the Pamlico River Estuary. Unpubl. M.S. thesis, N.C.S.U., Raleigh.

7. Moore, D.J. 1969. The uptake and concentrations of fluouride by the blue crab, Callinectes sapidus. Unpubl. Ph.D. thesis, N.C.S.U., Raleigh.

8. Sherk, J. A. 1969. Effects of low levels of phosphate mining effluent on periphyton in controlled artificial estuaries. Unpubl. Ph.D. thesis, N.C.S.U., Raleigh.

9. Crawford, C. 1967. The heterotrophic uptake of amino acids in natural waters. Unpubl. M.S. thesis, N.C.S.U., Raleigh.

10. Tenore, K. R. 1968. Effects of bottom substrate on the brackish water bivalve, Rangia cuneata. Chesapeake Science. 9:238-248.

11. Moore, D. J. 1969. A field and laboratory study of fluoride uptake by oysters. Report of the Water Resources Research Institute of the University of N. C. 13 pp.

12. Hobbie, J. E., C. C. Crawford, and K. Webb. 1968. Amino acid flux in an estuary. Science. 159:1463-1464.

13. Carpenter, J. H. 1965. The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method. Limnol. Oceanog. 10:141-143.

14. Truesdale, G. A. and A. L. H. Gameson. 1957. The solubility of oxygen in saline water. J. Cons. Perm. int. Explor. Mer. 22:163-166.

15. Carney, C. B., A. V. Hardy and C. H. M. van Bavel. 1964. Weather and climate in North Carolina. Bulletin 396. Ag. Exp. Sta., N.C. State Univ.,Raleigh.

16. Bowden, K. F. 1967. Circulation and diffusion, p. 15-36. <u>In</u> G. H. Lauff (ed.), Estuaries. Publication No. 83, AAAS, Washington, D. C.

17. Horton, D. B., E. J. Kuenzler and W. J. Woods. 1967. Current studies in the Pamlico River, an estuary of North Carolina. Report No. 6 of the Water Resources Research Institute of the University of N. C. 21 pp.