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ABSTRACT

Environmental conditions in the Virginian waters of the Chesapeake Bay area during the summerof 1995 have been characterized as a severe drought. This drought was punctuated on 27 June with a headwater (James and Rappahannock River) rain storm that produced a "freshet". Although it did not rain in the Tidewater area of Virginia, surface salinities were depressed by the run-off, and main-stem bottom oxygen levels dropped to zero in the James and Rappahannock rivers. The effects of the reduced oxygen were apparent on the James River oyster stock, particularly the reduction in spatfall, and to a lesser degree on the Rappahannock River young-of-the-year striped bass index. Long-term effects of the June flood and/or the drought must be monitored.

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) has collected surface and bottom physical environmental data from the Virginia river tributaries to the Chesapeake Bay as part of the juvenile finfish trawl survey for 40 years (Bonzek et all 1995). These were collected coincident with the biological data (species enumeration) since the survey's inception in 1955. These data have included surface and bottom salinity (ppt), temperature (C), and oxygen (ppm) from the river mouth (mile 0) to as far up each river as the survey penetrates. For most years the cruises were up the main stem of each river. The tributaries are the Rappahannock, York, and James Rivers.

This 40 year period has allowed the development of a climatological profile for the rivers, both physical and biological (Bonzek et al 1995). Over the years this has allowed VIMS scientists to note both episodic perturbations and longer term trends (Wojick 1978, Norcross 1983). Departures from the climatological norm were particularly severe during 1995, and while the general pattern was one of a drought (VDMTF 1995), heavy rains in the mountains of Virginia during June produced anomalous conditions that had profound biological impacts downstream in the estuarine-marine environment. The purpose of this report is to bring together the VIMS data sets, as well as other reports, describing the down-stream impacts of this June 1995 storm.

METHODS

VIMS instituted the "trawl survey" in April 1955 as a series of mid-channel stations in the York River, VA. By 1964 the Rappahannock and James Rivers had become part

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1 VIMS Contribution No. 2053

of the monthly survey. Today, a station consists of a five minute tow with a 30' semi-balloon otter trawl parallel to the isobaths. Tow speed is approximately 2.5 knots (3.8 K/h). Surface and bottom hydrographic data (temperature, salinity and oxygen) are measured following each tow. More detailed sampling protocols are reported in Bonzek et al (1995) and Land et al (1995).

RESULTS

Researchers in the field began, in early July 1995, to notice anomalous conditions in the Rappahannock and James rivers that were possibly related to torrential rains that on 27 June dropped up to 31.6 in (803 mm) on the Rapidan River (James River drainage) at Ruckersville, Madison Co. Rainfall was estimated to have exceeded 4 in/h (23 mm) (Michaels 1995). In Madison Co. alone 35,000 acres of crops were destroyed or damaged; state-wide there were eight deaths, 2,000 homes destroyed or damaged, and total damage estimated to exceed $112 million. The York, which drains the Piedmont plain of Virginia, did not show the effects of this rain.

On average, in 1995 the Chesapeake Bay drainage streamflow was well below normal (USGS 1995), and in fact during April 1995 a record low flow value was recorded (<60,000 cu ft). Air temperatures each month were above normal (per comm, State Climatologist's Office) averaging +1-2 F (1 C) in Richmond and +2-5 F (3-4 C) in Norfolk. This situation is reflected in the river surface and bottom water temperatures, depicted in the May-August 1995 plots (Fig 1-24). The heavy mountain rains on 27 June produced a low salinity surface flow, a freshet, that not only brought an extreme sediment load, but also served to intensify June stratification and resulted in an up-river (mile 25, kilometer 46) dissolved oxygen sag in both the James and Rappahannock. By July the oxygen had become depleted in both rivers from around river mile 25 (kilometer 46) to the mouth. The situation was particularly acute in the James River (Fig 14c).

Streamflow data from the United States Geological Survey (USGS) show spring 1995 running about one third of 1994's. The Palmer Drought Index (Palmer 1964) for the late summer 1995 in Tidewater, Virginia was -4.04 (VDMTF 1995), the lowest on record. Bay-wide the drought is apparent in the USGS streamflow data. The June freshet, while increasing the Rappahannock and James flow, did very little, however, to increase the overall Bay-wide discharge for the summer months as the rain fell locally on the head waters of these rivers in the western part of Virginia.

Figures 1 through 24 present graphs of salinity, dissolved oxygen (DO), and water temperature, by river and approximate river mile, for May through August 1995. Each graph presents the historical mean (represented by the lines with solid points), values for the present year (represented by the lines with open points), and the historical minimum and maximum values (represented by the lower and upper shaded areas, respectively).

In mid-July there were reports from the Virginia Department of Emergency Services, and the Virginia Marine Resources Commission of resource--particularly oysters--problems in the James. Our own survey personnel (trawl survey and juvenile striped bass survey) reported persistent discoloration of the water, and dead or dying catfish, carp and gar in the up-stream reaches of the Rappahannock.

DISCUSSION

Eastern oysters, *Crassostrea virginica*, are effected by salinities below 6-7 ppt, which reduce feeding and growth rates. If lower salinities occur when temperatures are below 10.0 C they have little impact as oysters are dormant. But when low salinities occur during spring through fall when oysters are growing, storing glycogen, or preparing to spawn, these activities cease (Austin et al., 1989, Zaborski and Haven, 1980). Oyster spatfall was almost completely absent from the Virginia tributaries of the James and Rappahannock through August, and was attributed to the heavy June runoff. The freshwater runoff "...apparently wiped out spatfall during the peak period between mid-July and mid-August" (Morales-Alamo, 1995). The Virginia Marine Resources Commission, monitoring the oyster beds, noted that the June "freshet" produced an influx of freshwater downstream, and resulted in mortalities of up to 90% on some public oyster rocks (Deepwater Shoal) in the James River, and close to 100% on some private grounds. Further, it interrupted the peak of the spawning season (Andrew-Spear, 1995).

The Virginia young-of-the-year striped bass (*Morone saxatilis*) survey, which consists of five rounds of samples between river miles 12-15 (kilometer 22) up to 76-78 (kilometer 144) during the first week of July through September, also documented the effects of the June flood (Austin et al, 1996). The survey found warmer than normal shore temperatures (32.0 C, normal range is mid-20's), and lower than normal shore salinities (5 ppt, normal range is 15-20 ppt) as far down river as river miles 12 to 22 (kilometer 22) in both the James and Rappahannock. Researchers who conducted the survey also reported that

> "The river (Rappahannock) was quite turbid...extending down river to mile R37 (kilometer 68). While no dead or dying striped bass were caught in our samples, dead and dying fish were encountered along the river and many reports from other sources were noted. We did note that juvenile striped bass in our samples appeared to be emaciated and in generally poor condition."

The primary long term impact of the June flood was the record depression of the mid-river bottom oxygen levels to near zero or zero levels. May and June surface and bottom salinities generally ran 2.5 to 5 ppt above the long term average and oxygen levels were generally average. In July salinities were generally 2.5 ppt below average, a one month drop of 5 to 8 ppt, river-wide. Most dramatic were hypoxic and anoxic conditions. While anoxic conditions are fairly typical in parts of the mid-Rappahannock, they extended from about river mile 25 (kilometer 46) in both the Rappahannock and James to mile 10 (kilometer 18.5) in the Rappahannock, and to the mouth of the James River. By August, salinity conditions were back to near the long term norm in all rivers; but oxygen remained below normal, hypoxic down to the mouth of the Rappahannock River, and anoxic from river miles 10 to 20 (kilometer 18.5-37) in the Rappahannock.

Not since Hurricane Agnes in 1972 has a June flood produced such a summer-long impact on the physical environment (Anderson 1973) and subsequent biological impacts on the biota (e.g. oyster: Haven et al. 1976; Setsler, 1989). It is interesting to speculate too on the possible impacts of Agnes on striped bass recruitment as the 1972 year class was the lowest on record. It may be some time before the eventual record shows whether or not the June 1995 flood approaches any of the long term Agnes impacts. Primary among the impacts may be the reduction in oyster recruitment of the already severely depressed James River oyster stocks. Fortunately, unlike Agnes the impacts should not be Bay-wide.

CONCLUSIONS

The spring-summer 1995 marine-estuarine lower Chesapeake Bay environment was characterized as in extreme drought with unusually high salinities. In the middle of this (27 June) there was an extreme rainfall event in the headwaters of the Rappahannock River, and particularly the James River which produced an episode of heavy streamflow, a freshet. This produced a freshwater lens that overlay the more saline deeper water, causing increased stratification, and which carried tons of sediment into the lower rivers. The combination of these events produced hypoxic and anoxic conditions that lasted for nearly a month. The effects of the combined drought with a freshet on the biota are unknown, but will become apparent in the future.

ACKNOWLEDGEMENTS

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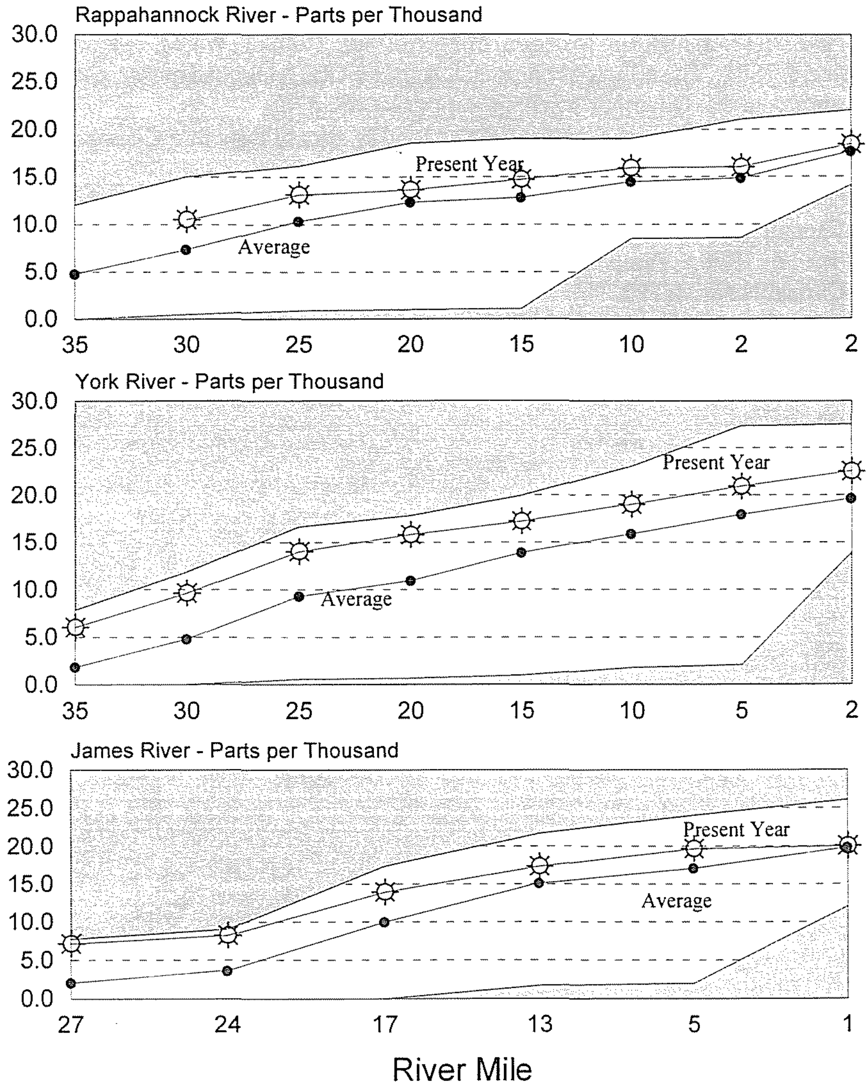

FIGURE 1a-c. Bottom salinity, May 1995, James, York and Rappahannock rivers, VA.

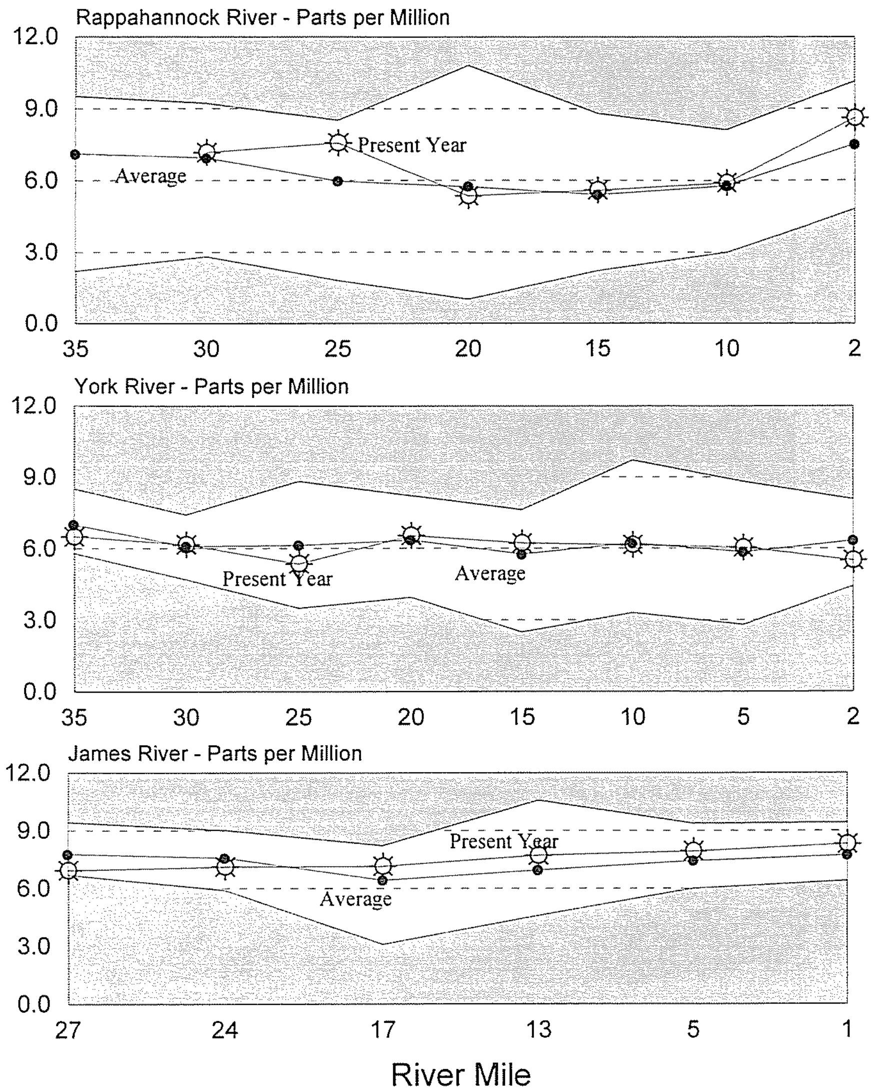

FIGURE 2a-c. Bottom dissolved oxygen, May 1995, James, York and Rappahannock rivers, VA.

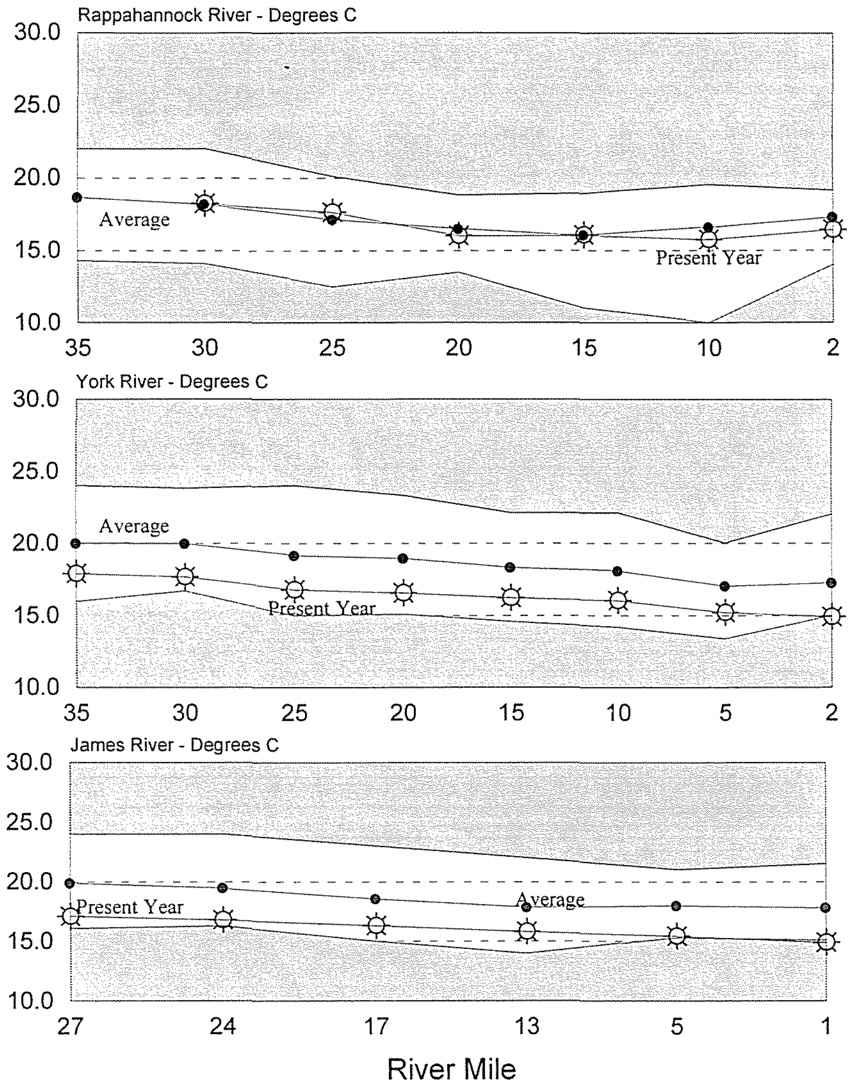

FIGURE 3a-c. Bottom water temperature, May 1995, James, York and Rappahannock rivers, VA.

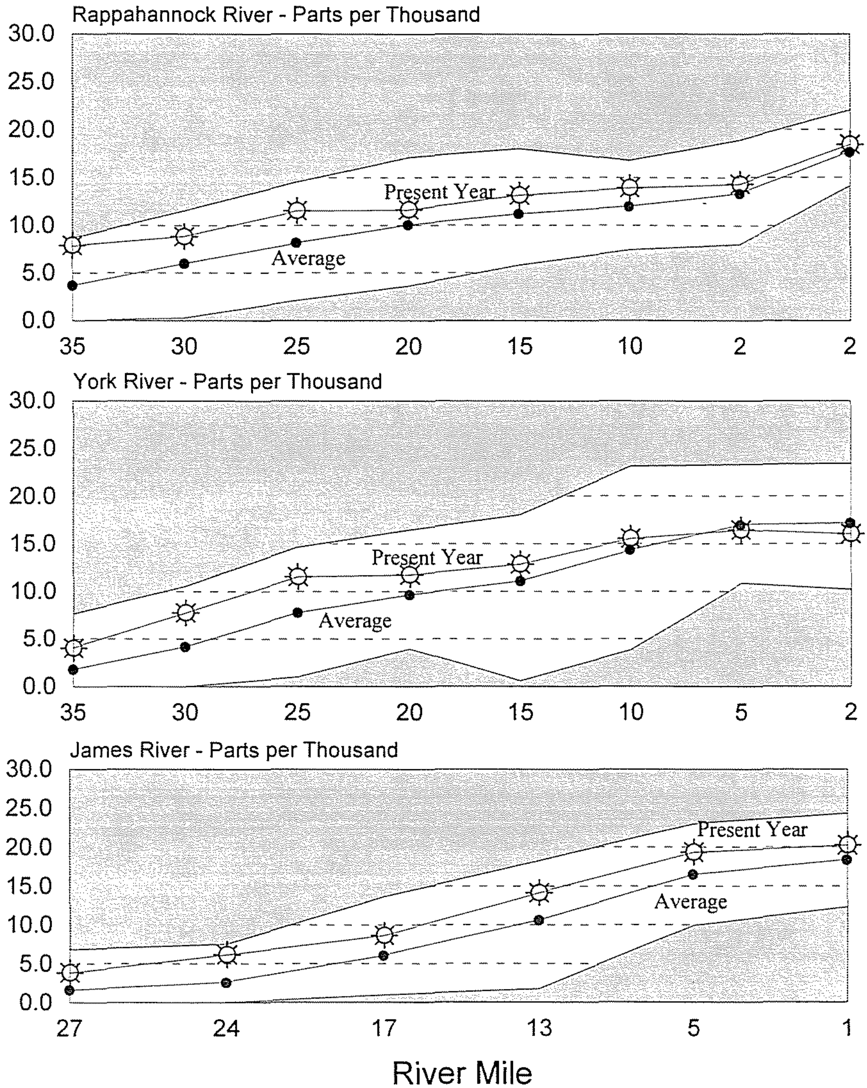

FIGURE 4a-c. Surface salinity, May 1995, James, York, and Rappahannock rivers, VA.

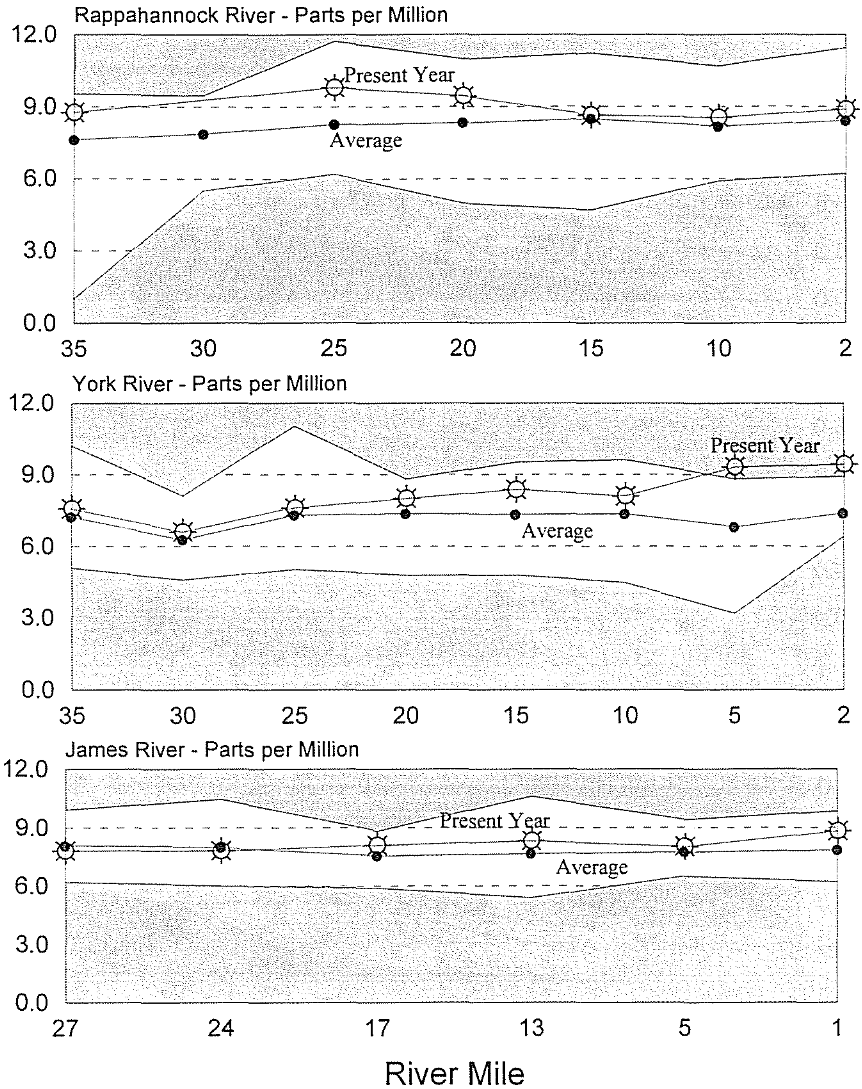

FIGURE 5a-c. Surface dissolved oxygen, May 1995, James, York and Rappahannock rivers, VA.

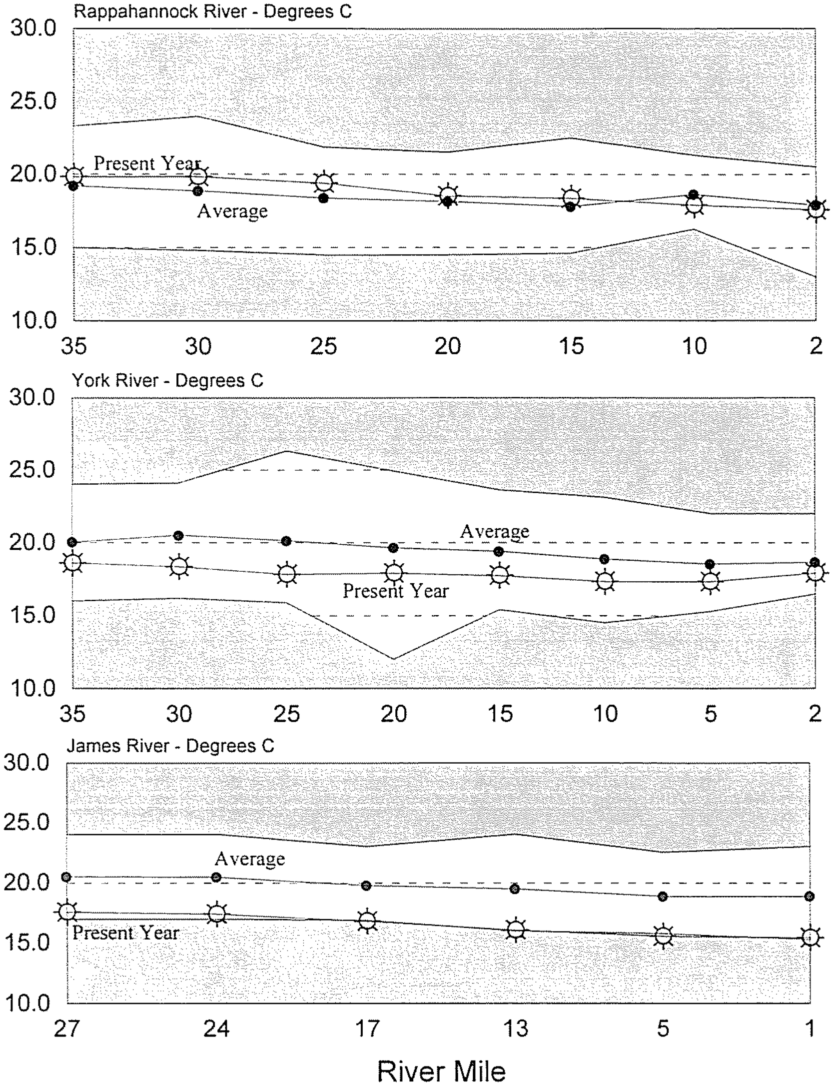

FIGURE 6a-c. Surface water temperature, May 1995, James, York and Rappahannock rivers, VA.

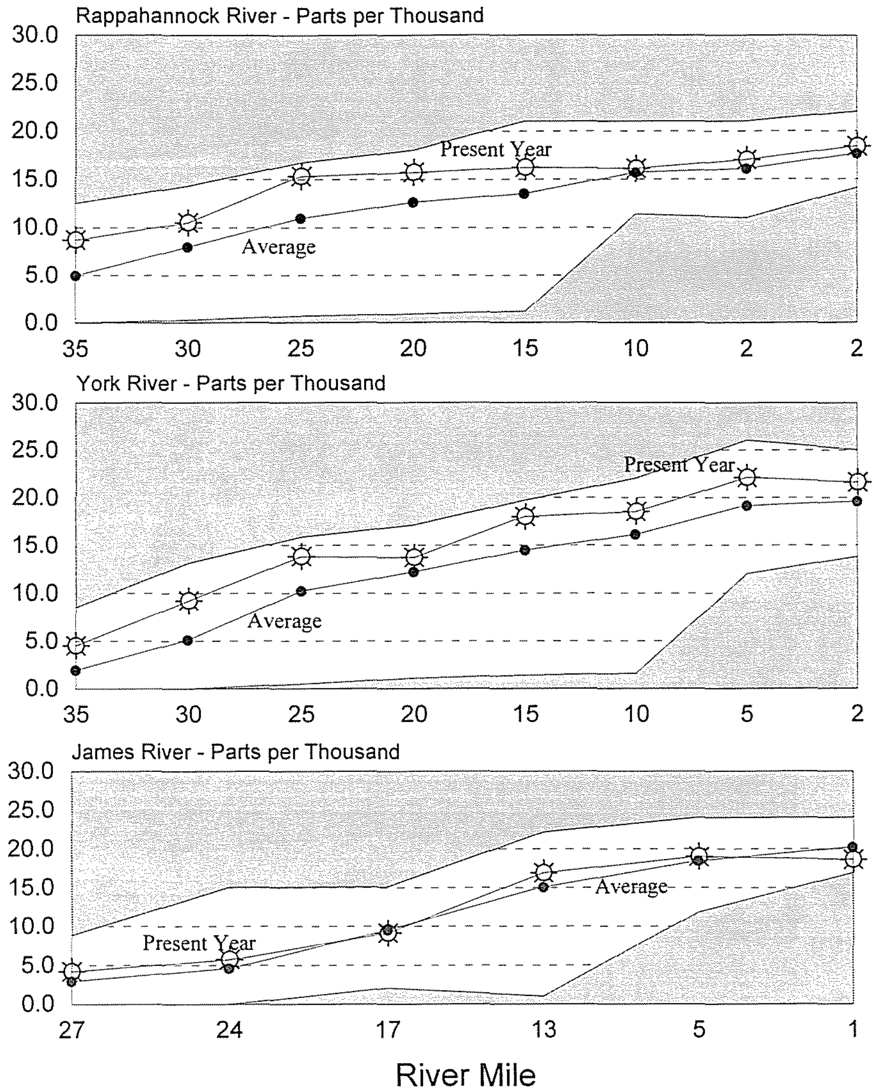

FIGURE 7a-c. Bottom salinity, June 1995.

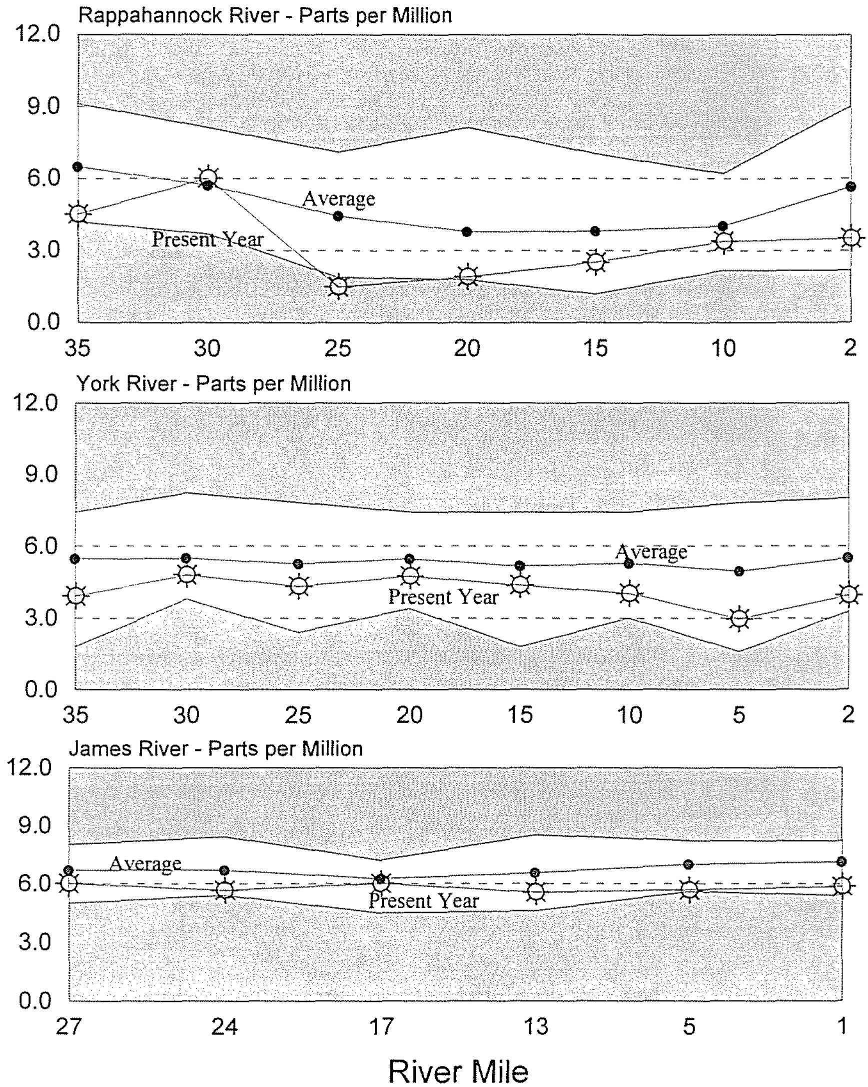

FIGURE 8a-c. Bottom dissolved oxygen, June 1995.

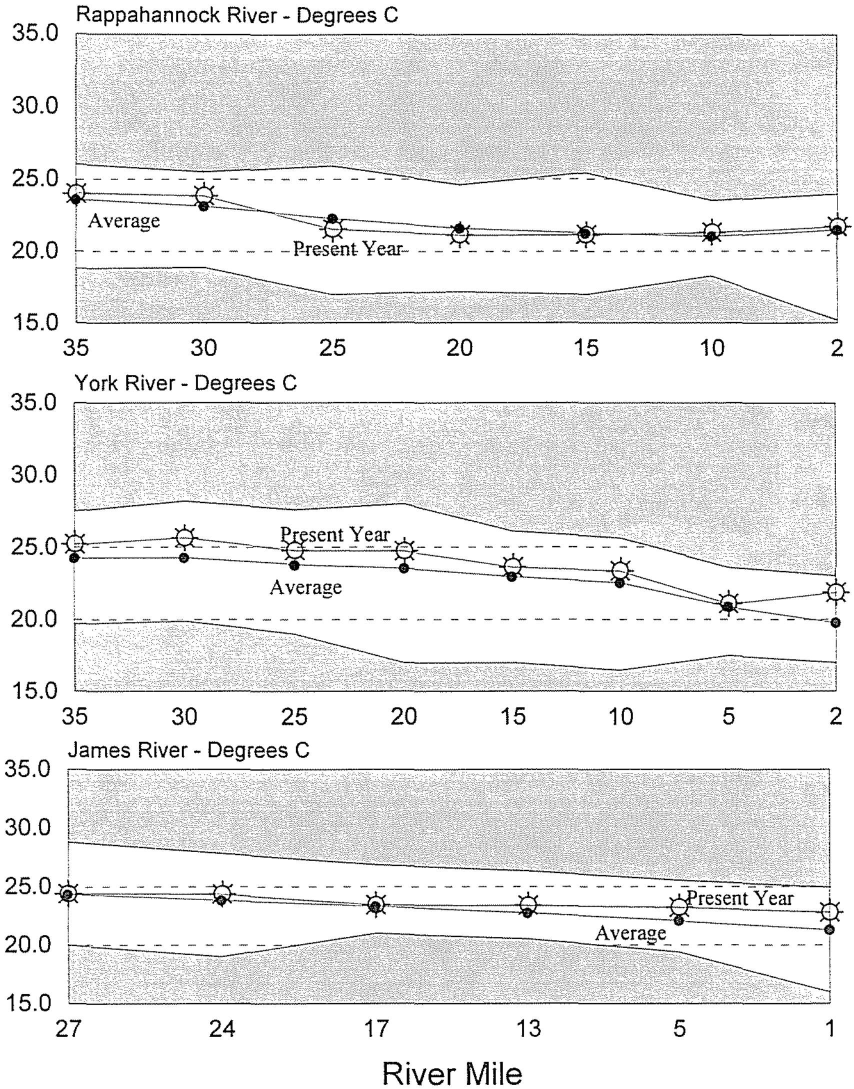

FIGURE 9a-c. Bottom water temperature, June 1995.

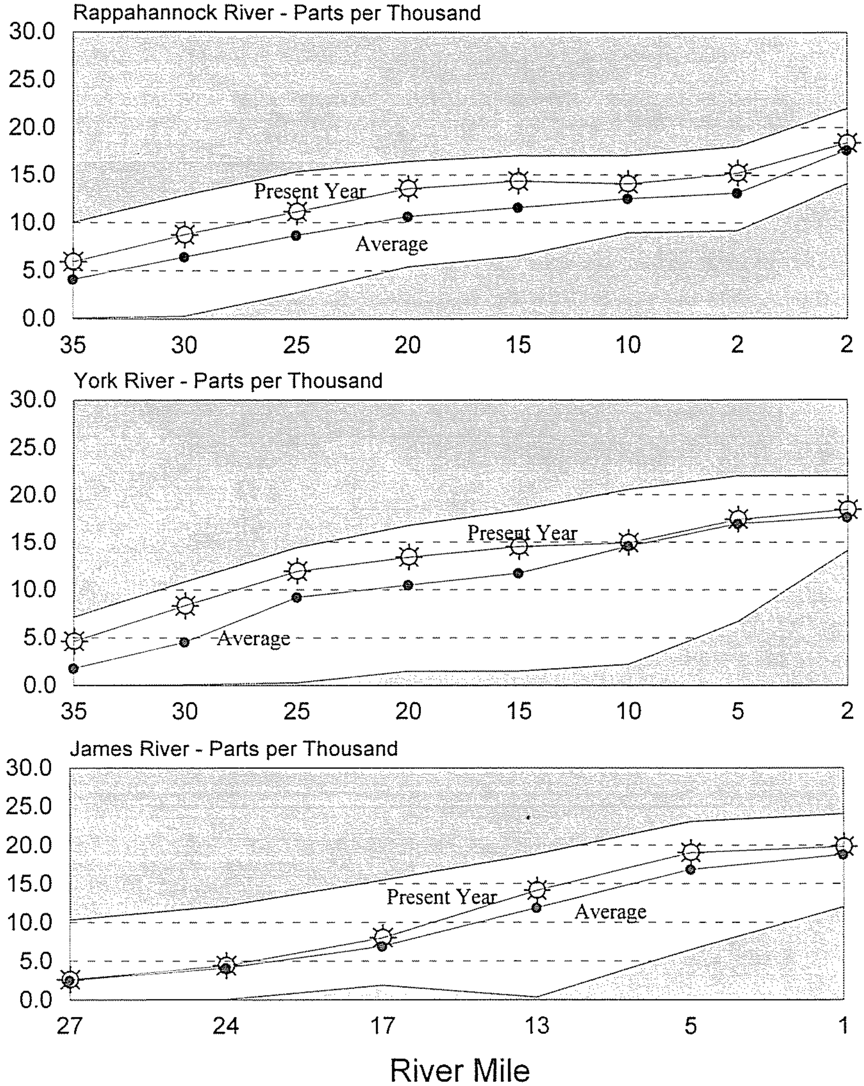

FIGURE 10a-c. Surface salinity, June 1995.

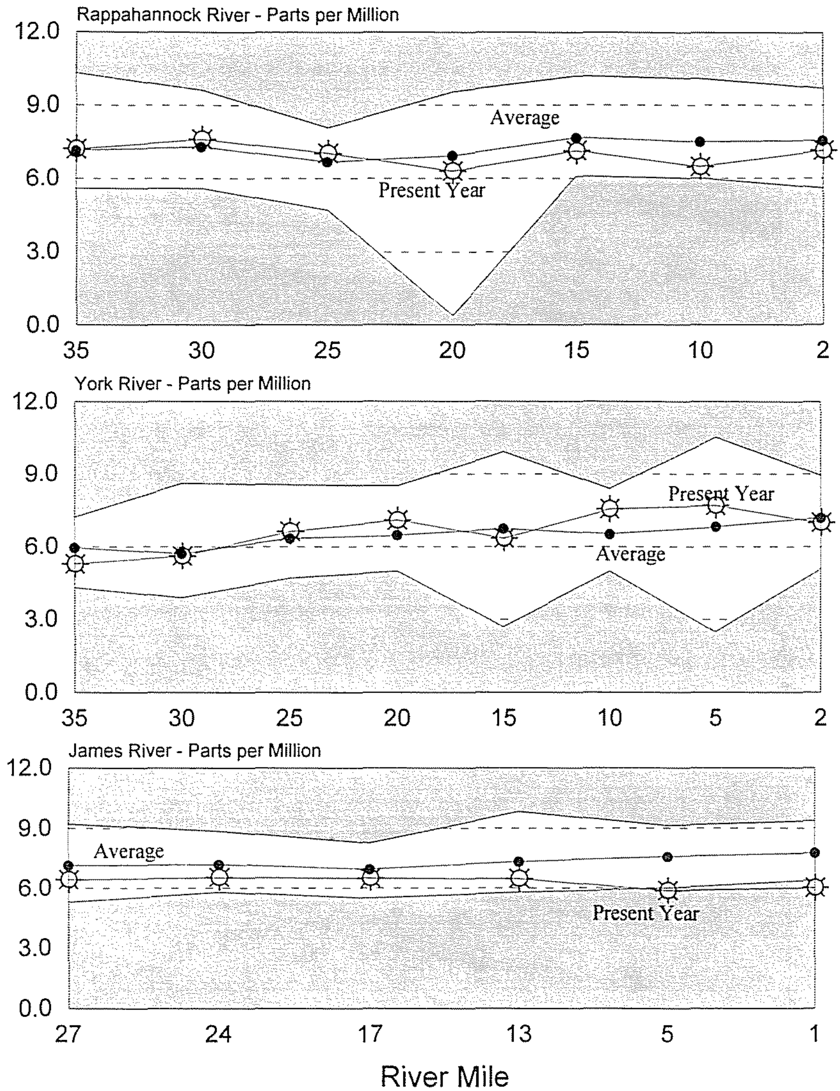

FIGURE 11a-c. Surface dissolved oxygen, June 1995.

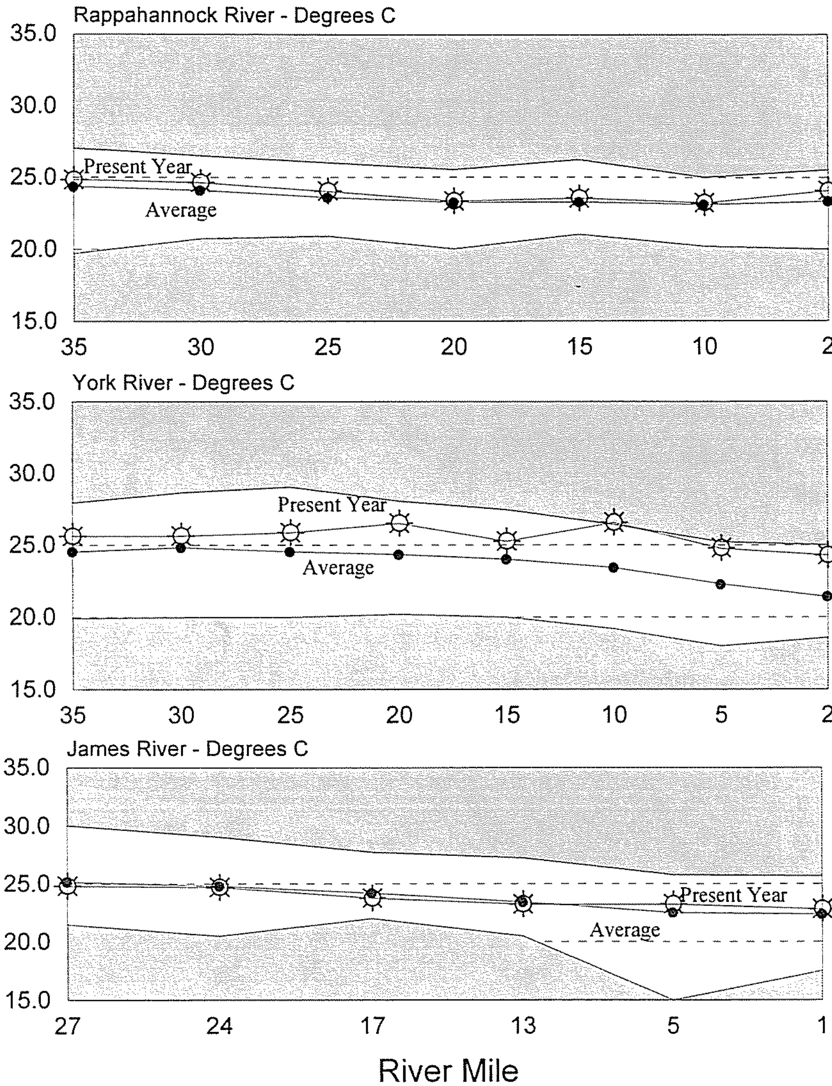

FIGURE 12a-c. Surface water temperature, June 1995.

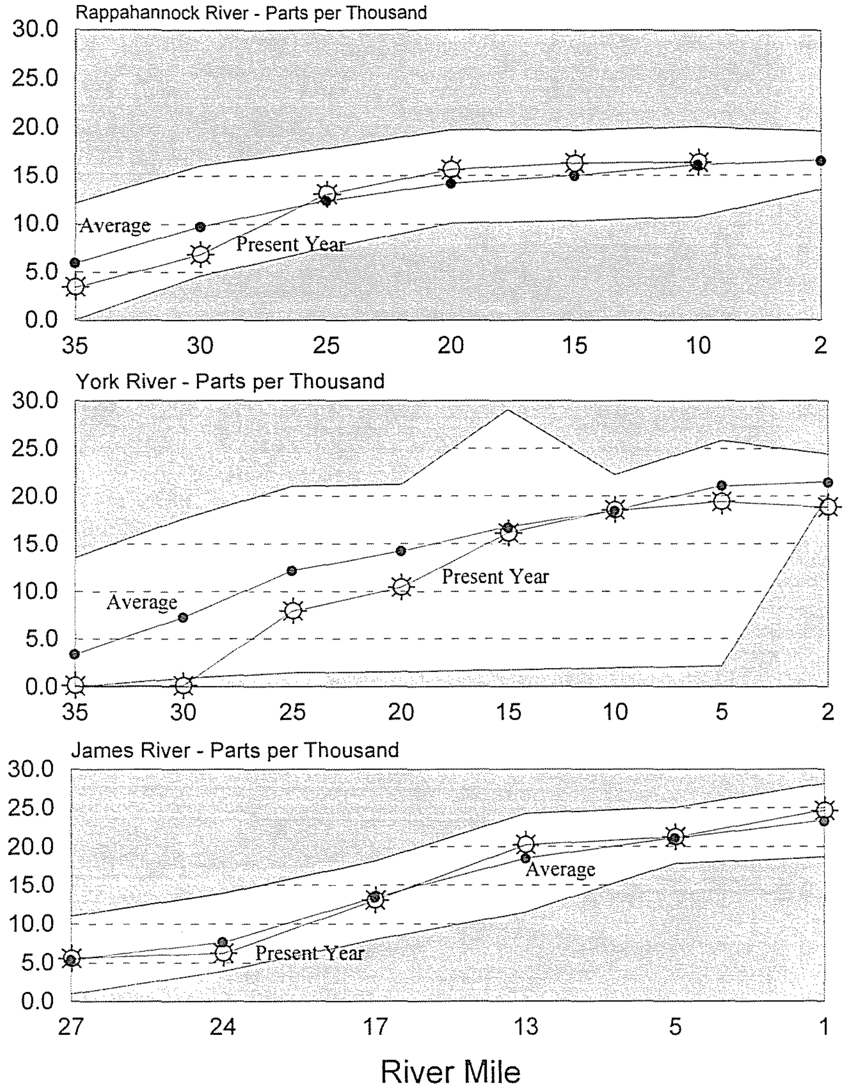

FIGURE 13a-c. Bottom salinity, July 1995.

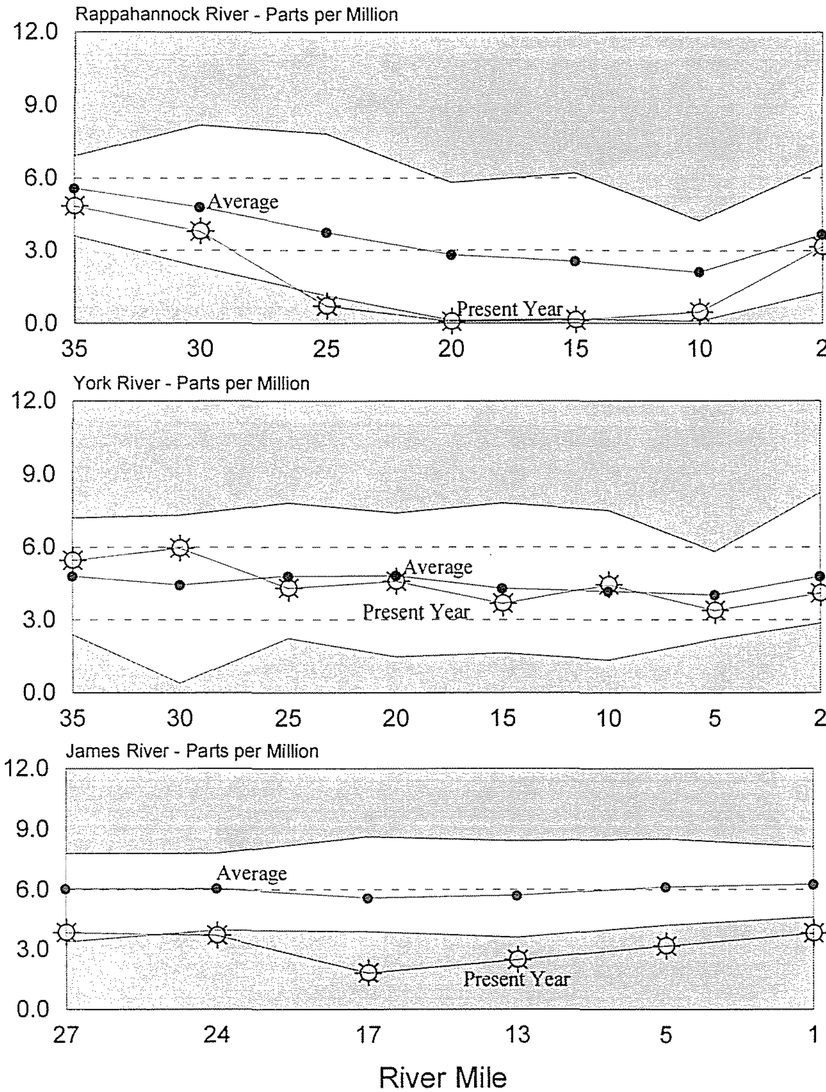

FIGURE 14a-c. Bottom dissolved oxygen, July 1995.

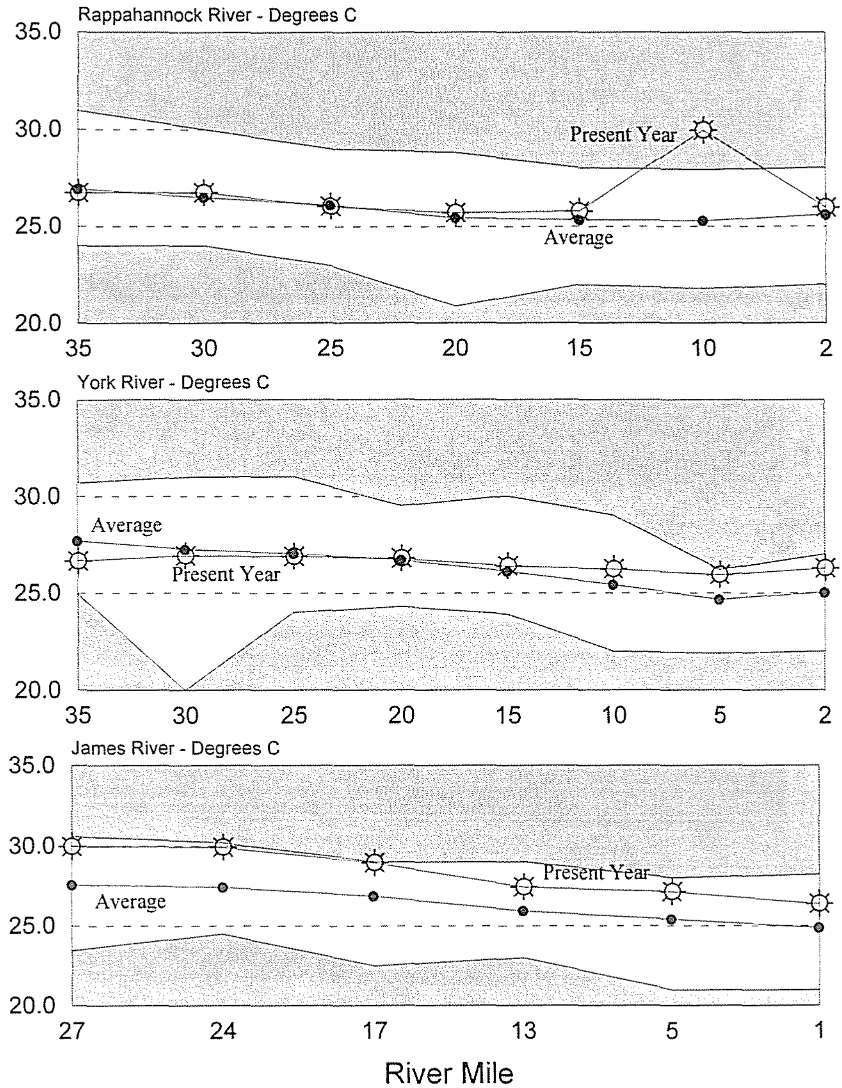

FIGURE 15a-c. Bottom water temperature, July 1995.

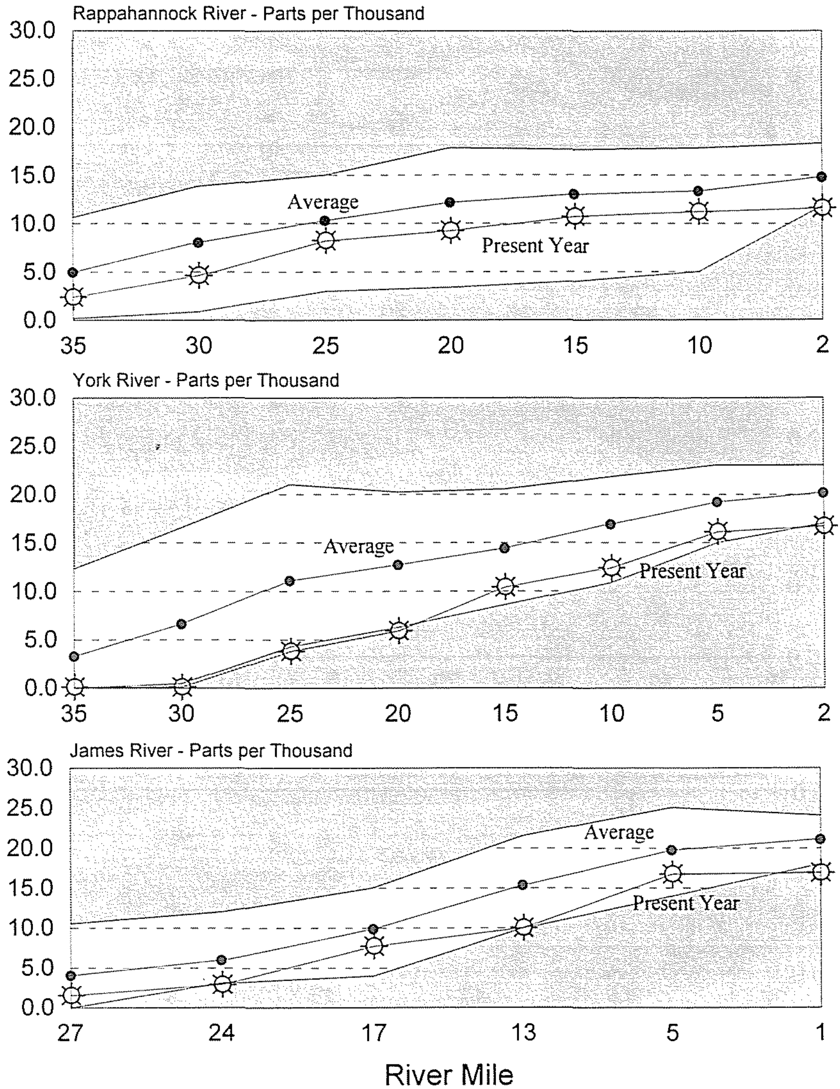

FIGURE 16a-c. Surface salinity, July 1995.

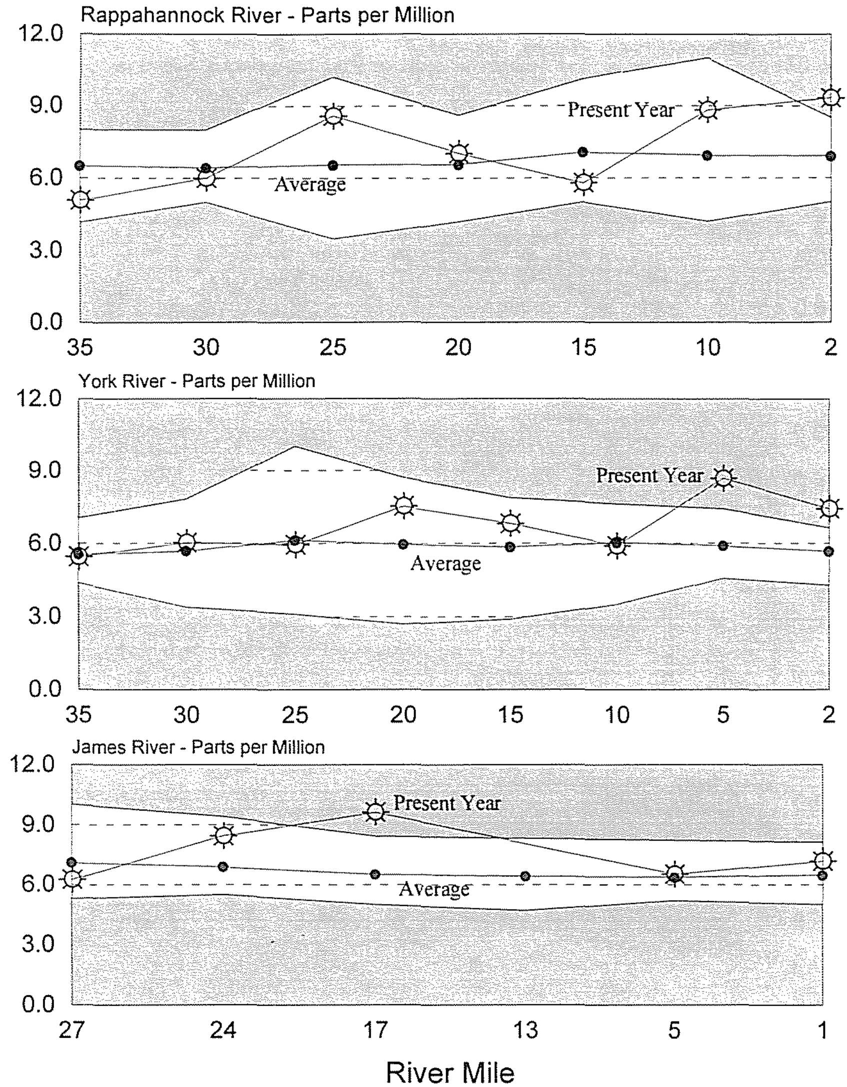

FIGURE 17a-c. Surface dissolved oxygen, July 1995.

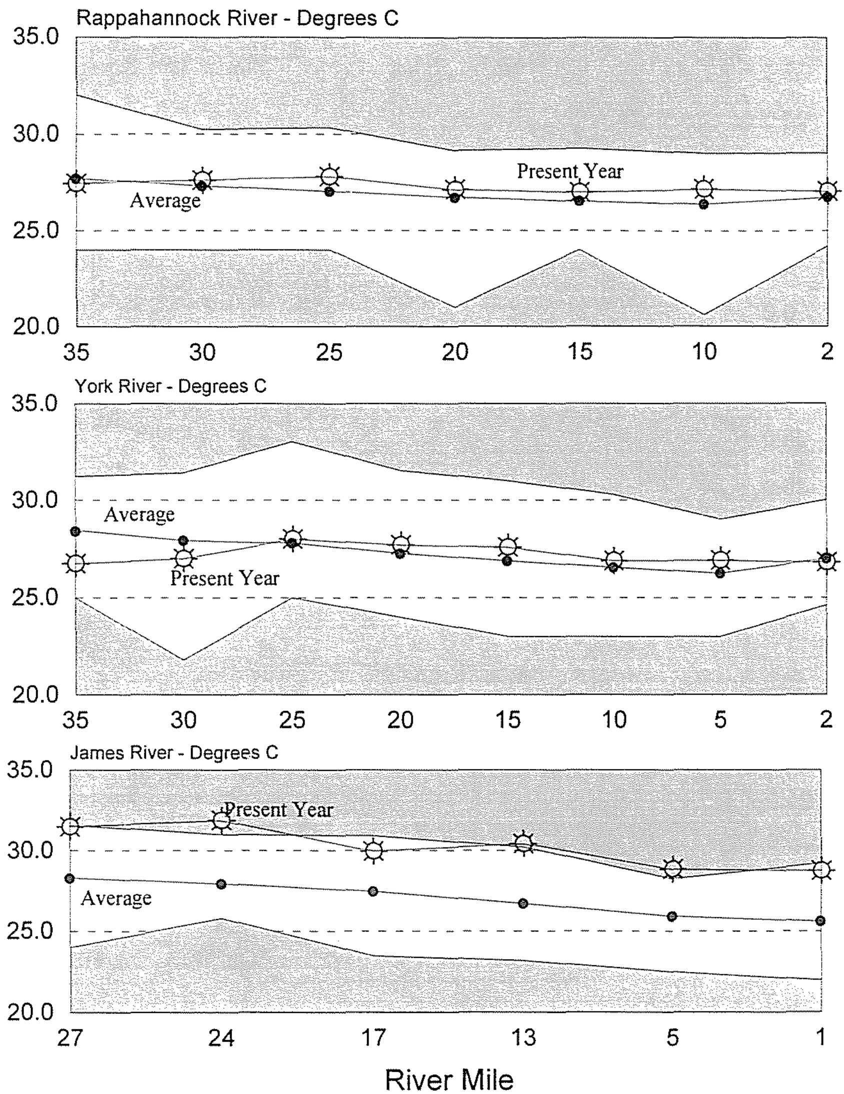

FIGURE 18a-c. Surface water temperature, July 1995.

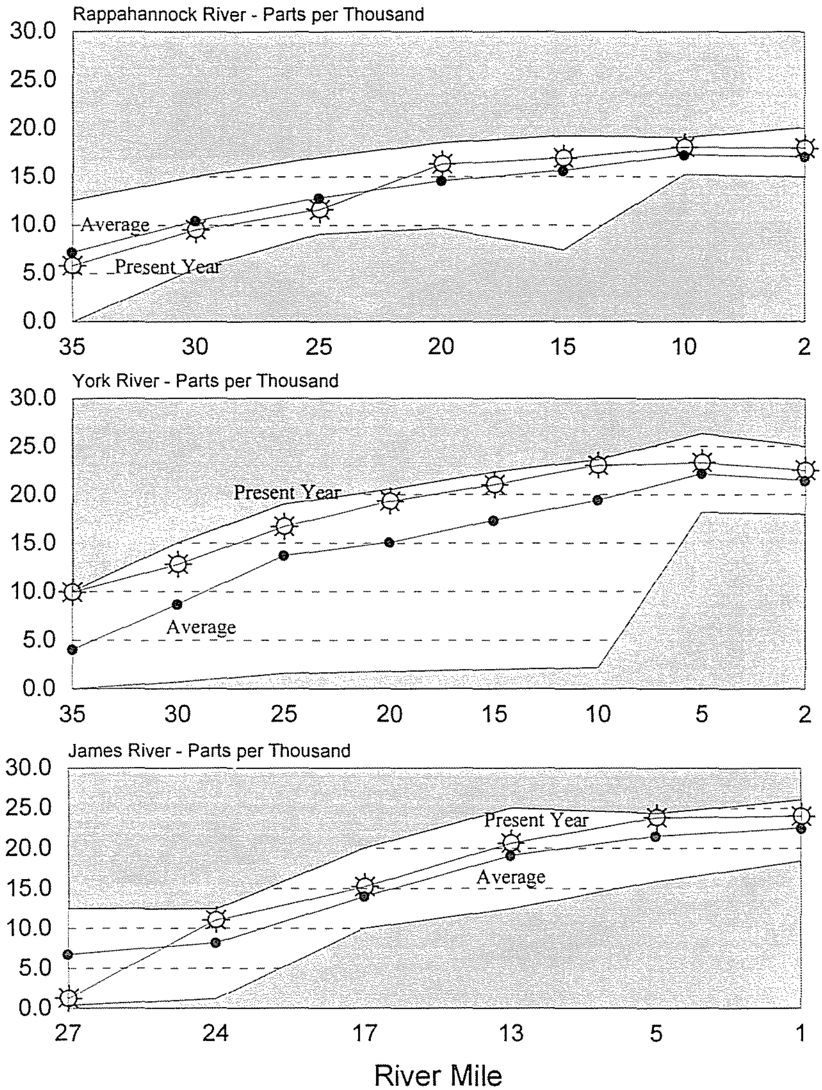

FIGURE 19a-c. Bottom salinity, August 1995.

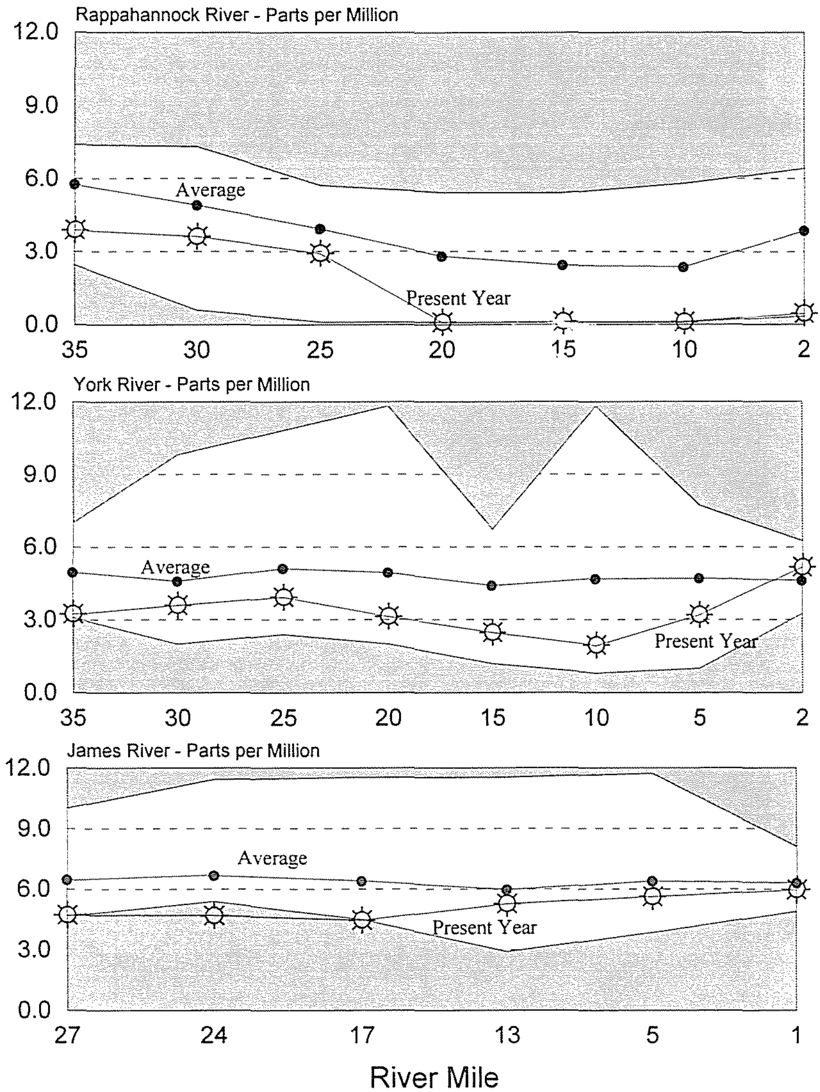

FIGURE 20a-c. Bottom dissolved oxygen, August 1995.

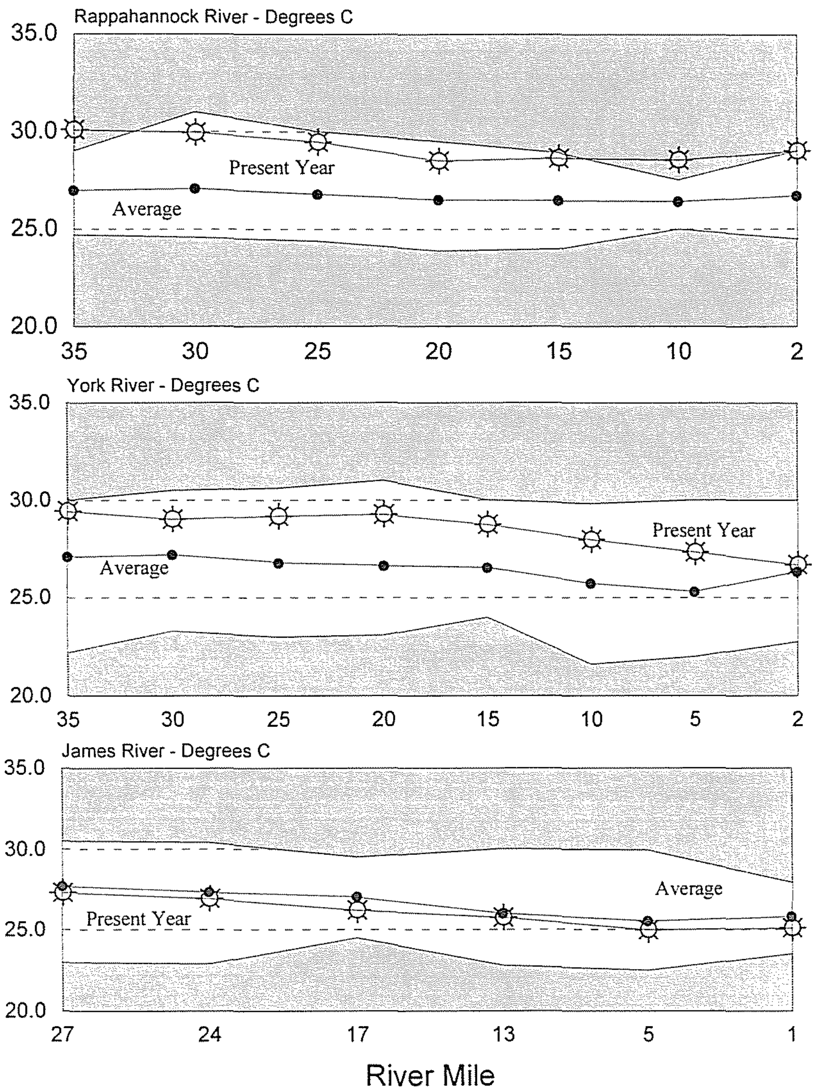

FIGURE 21a-c. Bottom water temperature, August 1995.

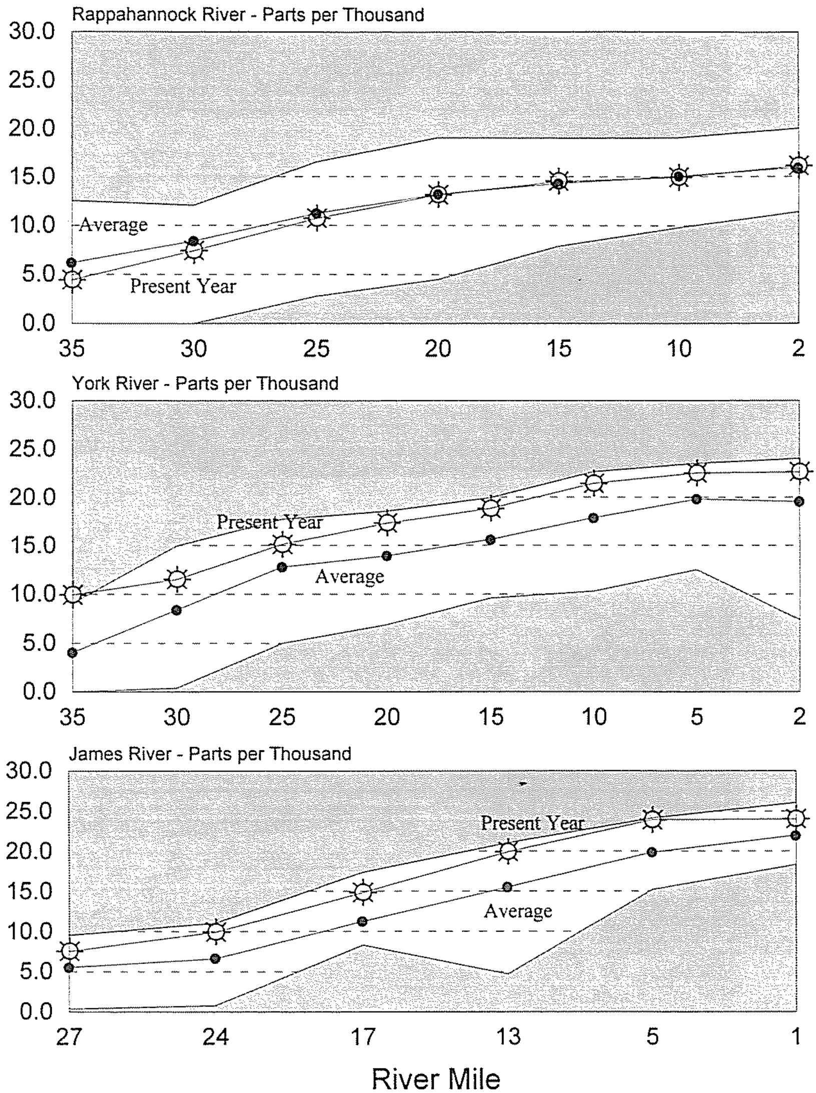

FIGURE 22a-c. Surface salinity, August 1995.

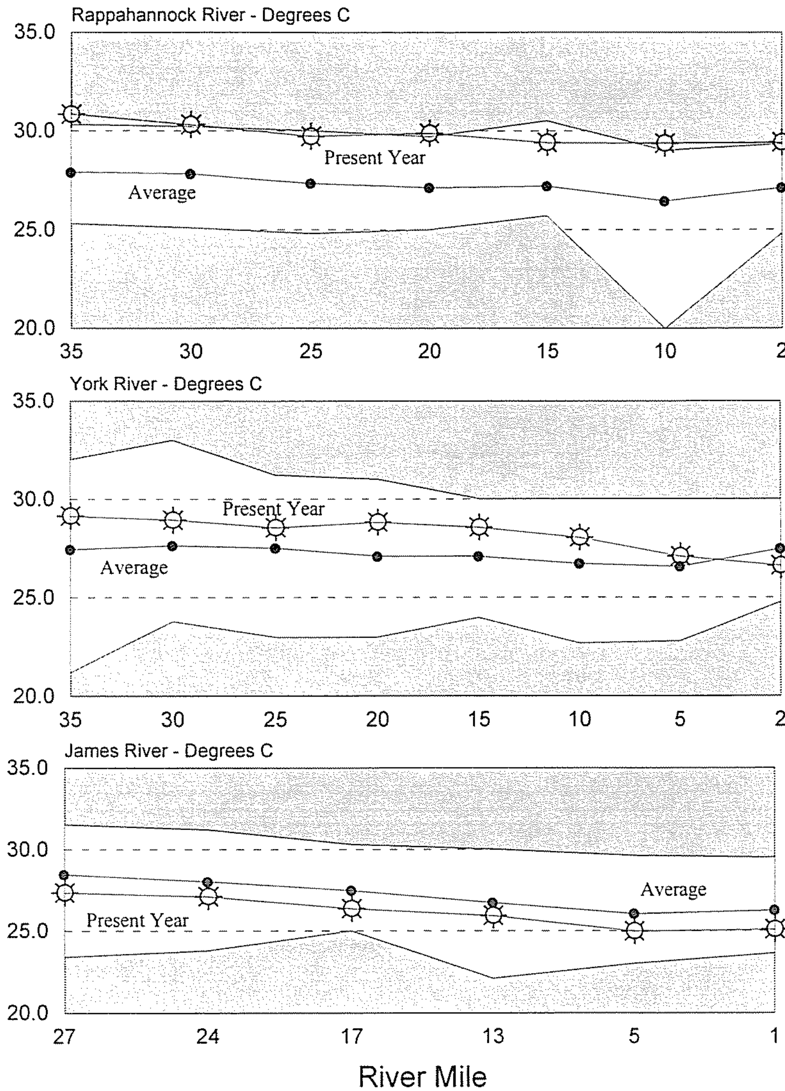

FIGURE 24a-c. Surface water temperature, August 1995.