

New River Estuary Water Quality 2008-2009

UNCW-CMS Report 10-02

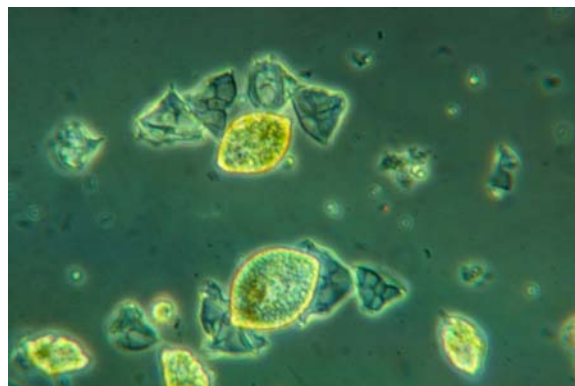
Report to:
Environmental Management Division,
US Marine Corps, Camp Lejeune, N.C.

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Executive Summary

For several years the U.S. Marine Corps at Camp Lejeune has sponsored research efforts by the University of North Carolina Wilmington Center for Marine Science to investigate the water quality in the New River Estuary, North Carolina. Water sampling was conducted at 13 locations during 2008-2009 stretching from the upper estuary above Jacksonville and upper Northeast Creek down to Channel Marker 15 near the Atlantic Intracoastal Waterway. The data indicate that the estuary remains greatly improved since before the USMC and the City of Jacksonville initiated improved wastewater treatment in the late 1990's. However, we note that pulses of nitrate enter the estuary from the New River upstream of Jacksonville, and to a lesser extent from drainages feeding Northeast Creek. These nitrate pulses lead to algal blooms that exceed the North Carolina water quality standard in some of the upper estuary locations. The upper estuary is stratified by salinity differences, which reduces water column mixing. The algal blooms die and become labile organic matter and exert a biochemical oxygen demand (BOD), which contributes to bottom water low dissolved oxygen concentrations (sometimes severe). Thus, while water quality conditions have improved, efforts to control non-point source inputs of nutrients into the river and tributary creeks need to be continued and enhanced.



Heterocapsa triquetra, a common dinoflagellate that blooms in the New River Estuary

Introduction

The University of North Carolina Wilmington has conducted water quality sampling on the New River Estuary since 1995. Funding for this effort has come from a variety of sources, including the Water Resources Research Institute of the University of North Carolina, North Carolina State University, and for the past several years, the United State Marine Corps base at Camp Lejeune. This research has produced published scientific contributions that have combined both basic research and applied research, providing key information on topics such as diverse as the impact of large animal waste spills on rivers and estuaries (Burkholder et al. 1997) to the nutrient chemistry and impact of nutrient loading (Mallin et al. 1997; Dafner et al. 2007) to physical flushing and nitrogen processing in the estuary (Ensign et al. 2004) to the (positive) impact of sewage treatment upgrades to estuarine water quality (Mallin et al. 2005).

The most important occurrence in recent years regarding the New River Estuary has been the strong action taken by the US Marine Corps and the City of Jacksonville to upgrade their sewage treatment plants during the period 1998-1999. Immediate results of these actions included decreased ammonium and phosphate inputs to the estuary, large decreases in the size and persistence of the formerly frequent algal blooms, reductions in turbidity and increases in light penetration, and increases in bottom-water dissolved oxygen (Mallin et al. 2005). We also note that both the City and USMC have taken strong actions to reduce non-point source pollution that may enter the estuary from the base and the immediate urbanized areas. However, we note that the river can bring significant loads of nitrate downstream to the estuary, where it may encourage algal bloom formation. Thus, in 2007-2009 USMC-sponsored UNCW sampling was expanded to include stations in Northeast Creek that are located both upstream and downstream of the highway bridge, as well as a station in the upper New River Estuary downtown near Highway 17, and a station at the border of the lower river/upper estuary which was designed to measure nutrient inputs coming into the estuary from upstream sources.

Methods

Samples were collected ten times during 2008-2009 at the following twelve locations (see map – Figure 1):

- 1) WB – middle of Wilson Bay
- 2) M52 – Channel Marker 52
- 3) M47 – Channel Marker 47
- 4) M39 – Channel Marker 39
- 5) M31 – Channel Marker 31
- 6) 172 – in channel near Highway 172 bridge
- 7) M18 – Channel Marker 18
- 8) M15 – Channel Marker 15
- 9) NR-17 - New River at Highway 17 bridge in Jacksonville
- 10) NR-AJ - New River above Jacksonville
- 11) NEC-AB - Northeast Creek at Highway 24 bridge
- 12) NEC-BB- Northeast Creek below Highway 24 bridge

Field parameters were measured at each site using a YSI 6920 Multi-parameter Water Quality Probe (sonde) linked to a YSI 610 display unit. Individual probes within the instrument measured water temperature, pH, dissolved oxygen, turbidity, salinity, and conductivity. Water samples were collected for nutrient analyses (ammonium, nitrate, orthophosphate) and were analyzed using U.S. EPA protocols. For chlorophyll *a* analysis triplicate water samples were filtered simultaneously through 25 mm Millipore AP40 glass fiber filters (nominal pore size 1.0 micrometer) using a manifold with three funnels. The chlorophyll *a* was extracted and subsequently analyzed using a Turner AU-10 fluorometer, following the method described in Welschmeyer (1994).

Results and Discussion

Salinity: Salinity patterns in the New River Estuary show lowest values on average in the lower river/upper estuary stations, ranging from about 3 ppt at NRAJ to about 12 ppt at M52 (Figure 2). Much of the upper and middle estuary averages “mesohaline” salinities (5 – 15 ppt), while the stations downstream of the Highway 172 bridge are at near-marine salinities (Figure 2). The estuary is only slowly flushed (Ensign et al. 2004) and thus experiences significant salinity stratification most of the way down the estuary. This occurs when fresher water (which is lighter) flows over saltier water, as is shown in Figure 2. Such stratification has water quality impacts because the stratification reduces mixing or dissolved oxygen into lower levels of the water column.

Dissolved oxygen: Average surface dissolved oxygen (DO) concentrations in all areas of the estuary were well above the North Carolina standard of 5 mg/L (Figure 3). Surface water dissolved oxygen fell below the standard 30% of the times sampled at NRAJ and 20% of the time at NECAB. However, bottom water DO concentrations were usually considerably lower than surface water DO concentrations (Figure 3). This disparity between surface and bottom DO was exacerbated by the salinity stratification and slow flushing (Ensign et al. 2004) in the system. Bottom water DO fell below the state standard on 80% of occasions sampled at NRAJ and NR17, 50% of occasions sampled at Wilson Bay (WB) and NECAB, and 40% of the time at M52 and M39. This at times was at particularly stressful levels (for fish and invertebrates) especially when DO fell below 2.0 mg/L. Bottom water DO at WB was not found at particularly stressful levels, possibly due to mechanical aerators placed in that bay. Low DO often results from decomposition of algal blooms into labile organic matter, exerting a BOD (Mallin et al. 2006) and from direct inputs of BOD materials from point or non-point sources. In a system such as the New River Estuary, with low river discharge and low gravitational mixing, DO stratification can be severe when fueled by BOD (Lin et al. 2006). Low bottom water DO thus remains problematic at some sites in the upper estuary, although it has improved in general from pre-sewage upgrade days (Mallin et al. 2005).

Turbidity: Average turbidity concentrations remained well below the North Carolina standard of 25 NTU (nephelometric turbidity units) at all stations (Figure 4). In fact, on no sampling occasion were turbidity values seen in excess of this standard in 2008-2009.

Light attenuation: Light attenuation is a measure of how much solar irradiance is decreased as it passes vertically through the water column. Attenuation of solar irradiance can be caused by

reflection from particulate matter, absorbance by water color, and absorbance by photosynthetic algae. Higher values reflect more attenuation. As a general guide, values greater than 3/m may constrain light availability to phytoplankton. Within the New River Estuary, light is plentiful at almost all stations for algal usage (Figure 5). Light attenuation improved greatly following the sewage upgrades (Mallin et al. 2005).

Ammonium: Ammonium is a reduced inorganic form of nitrogen that is commonly seen in sewage treatment plant discharges, among other sources. Average ammonium concentrations in the estuary were highest at NRAJ, followed by NR17, with another peak at M18 in the lower estuary (Figure 6); however, on no sampling occasion were concentrations of ammonium unusually high in terms of provoking algal blooms or fish kills. Ammonium concentrations in general remained well below concentrations commonly found before the sewage treatment plants were upgraded.

Nitrate: Nitrate as presented here includes nitrite, which usually is only a small fraction of the combined total. Nitrate concentrations were highest at NRAJ, followed in turn by NR17 and JAX (Figure 7). On occasion (mainly during winter and spring – often called the spring freshet in estuaries) nitrate concentrations were high, well in excess of 500 $\mu\text{g-N/L}$. The maximum concentration experienced was 1,174 $\mu\text{g/L}$, at NRAJ in January 2009. Average nitrate concentrations from M52 downstream, including Northeast Creek (Figure 7) were generally low. Thus, the main source of nitrate entering the New River Estuary in 2008-2009 was the New River, and sources in its watershed upstream of Jacksonville. There appears to be a second inflow source of nitrate (as well as ammonium) in upper Northeast Creek (Figure 7). We conclude that the local non-point source control efforts by the Corps and the City appear to be generally effective in reduction of local stormwater-driven nutrient loading, although the drainage into Northeast Creek may need more attention.

Orthophosphate: Orthophosphate is the principal inorganic form of phosphorus in aquatic systems. Orthophosphate concentrations have considerably decreased since before the sewage plant upgrades. The areas presently yielding the highest orthophosphate concentrations include NR17 (downtown Jacksonville), the upper estuary above Jacksonville (NRAJ) and upper Northeast Creek (Figure 8). Orthophosphate concentrations can be described overall as moderate to low in this system.

Chlorophyll *a*: Chlorophyll *a* is a water quality parameter that is an integrative measure of several variables, especially nitrogen loading but also light availability and flushing rate. Average chlorophyll concentrations at all locations were below the North Carolina standard of 40 $\mu\text{g/L}$ (Figure 9). However, algal blooms in 2008-2009 were far more abundant than during 2007, and average chlorophyll *a* was higher in 2008-2009 than in 2007 (Figure 9; see also Mallin et al. 2009). Algal biomass was greatest in the upper estuary as well as in Northeast Creek. Chlorophyll *a* concentrations exceeded the NC standard 50% of times sampled at Wilson Bay, 40% of times sampled at NRAJ and NECAB, and 20% at NR17 and M52. Bioassays conducted by our laboratory and published in the scientific literature (Mallin et al. 1997; Mallin et al. 2005) showed that nitrogen is the principal nutrient controlling phytoplankton growth in the New River Estuary. Thus, we conclude that pulses of stormwater-driven nitrate entering the system are responsible for the algal blooms that still occur.

Conclusions

Water quality in the New River Estuary in 2008-2009 was considerably better than during the period before the sewage treatment plant upgrades. However, from 2007 to the 2008-2009 period there was an increase in algal bloom activity in the upper estuary. The algal blooms mostly occur in the uppermost areas of the estuary from NRAJ upstream of Jacksonville through Wilson Bay, also in Northeast Creek. We also note that bottom-water hypoxia, sometimes severe, still occurs in some locations including NRAJ, NR17, NECAB and M52. While salinity stratification and the slow flushing rate contribute to the bottom-water hypoxia, the hypoxia is ultimately fueled by biochemical oxygen demand (BOD) resulting from algal blooms. The blooms that still occur appear to be the result of nitrate loading entering the estuary from the river, primarily from sources within the watershed upstream of Jacksonville, although drainage into Northeast Creek appears to be somewhat problematic as well.

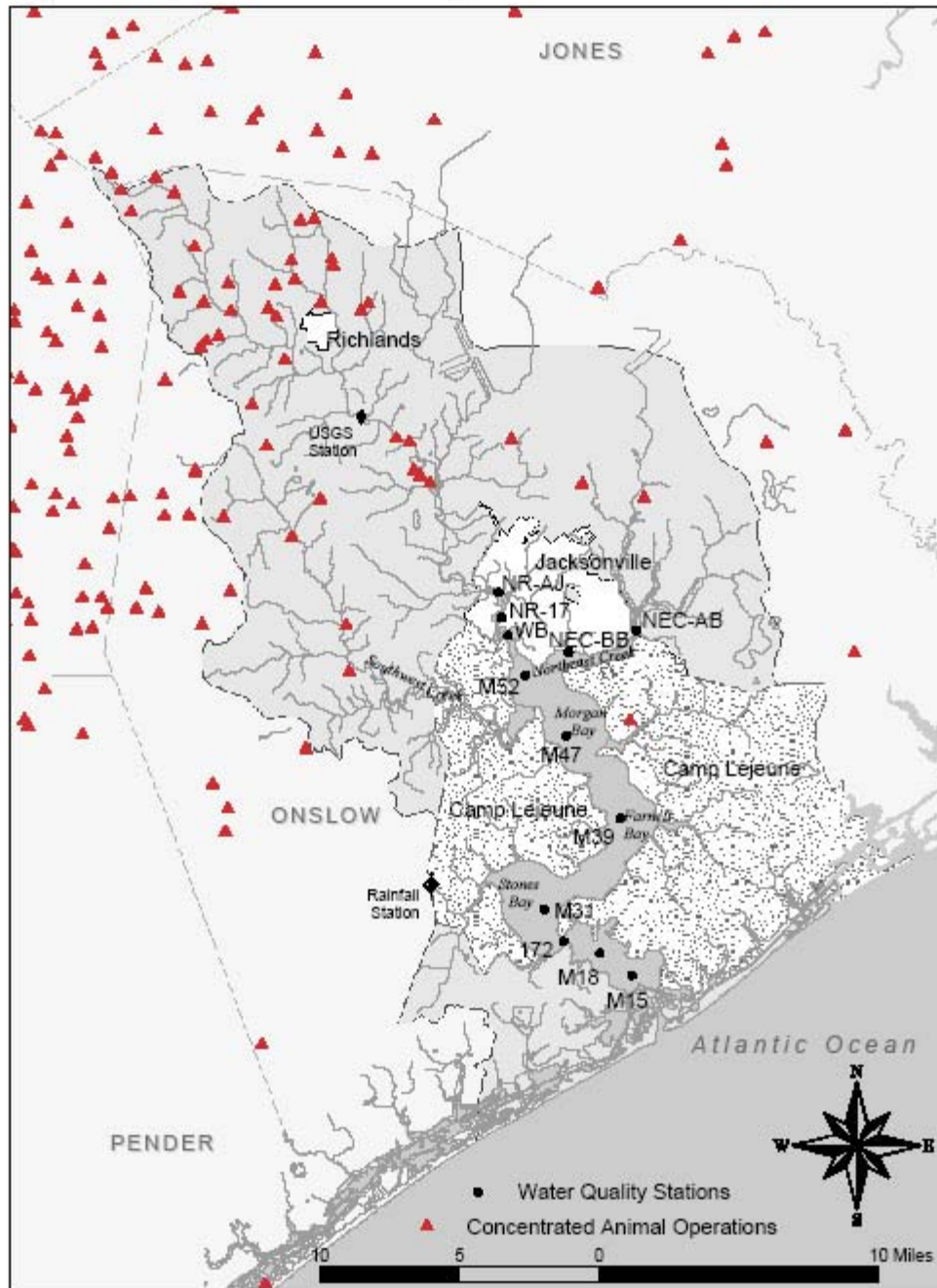
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Welschmeyer, N.A. 1994. Fluorometric analysis of chlorophyll *a* in the presence of chlorophyll *b* and phaeopigments. *Limnology and Oceanography* 39:1985-1993.

Figure 1. Map of the New River Estuary and Watershed



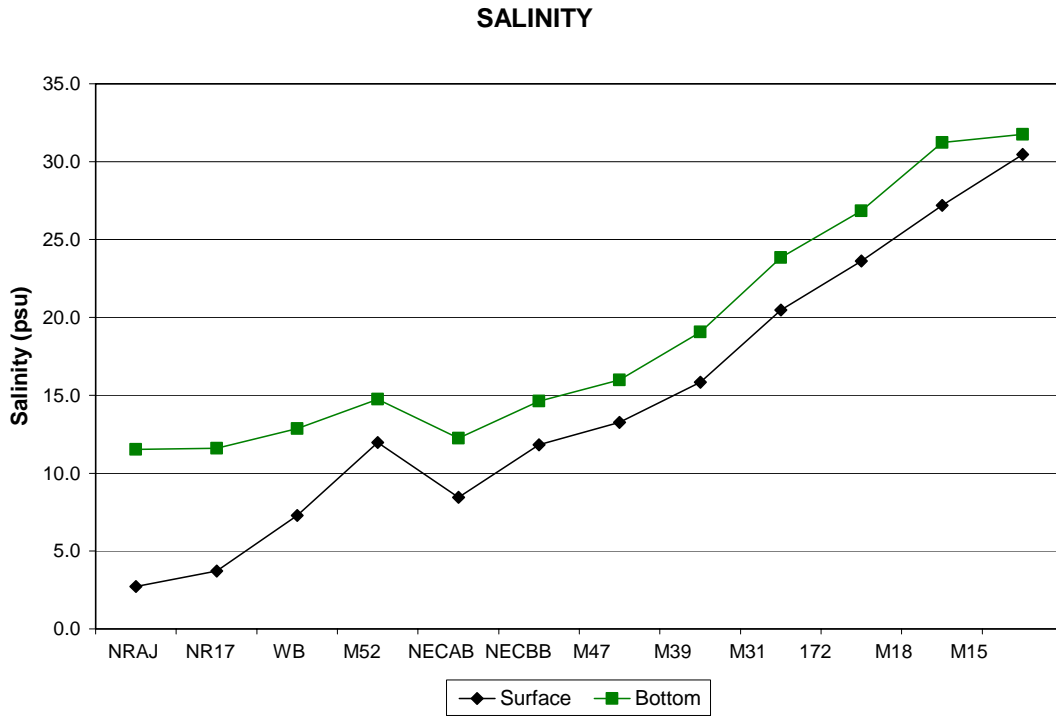


Figure 2. Average surface and bottom salinity, New River Estuary, 2008-2009.

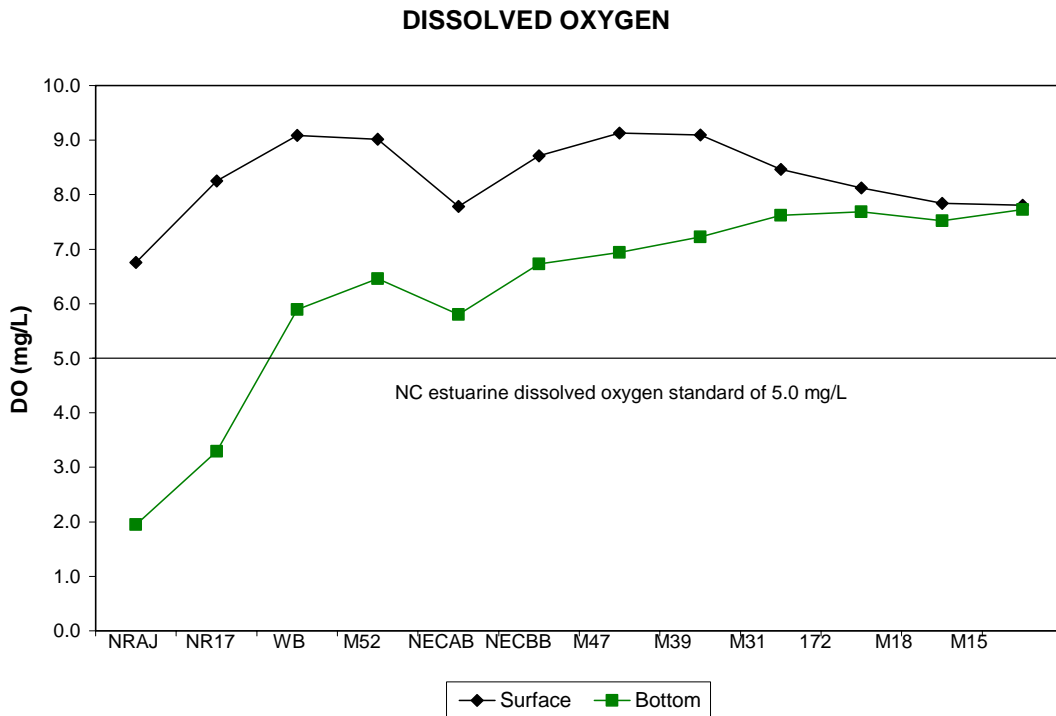


Figure 3. Average surface and bottom dissolved oxygen, New River Estuary, 2008-2009.

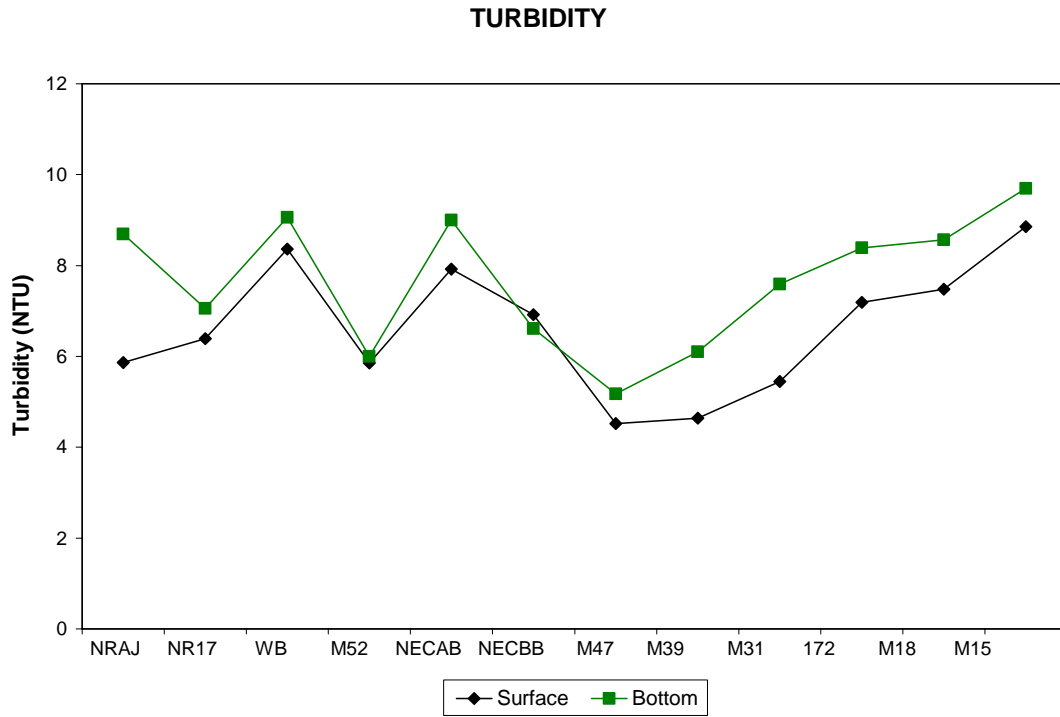


Figure 4. Average surface and bottom turbidity, New River Estuary, 2008-2009.

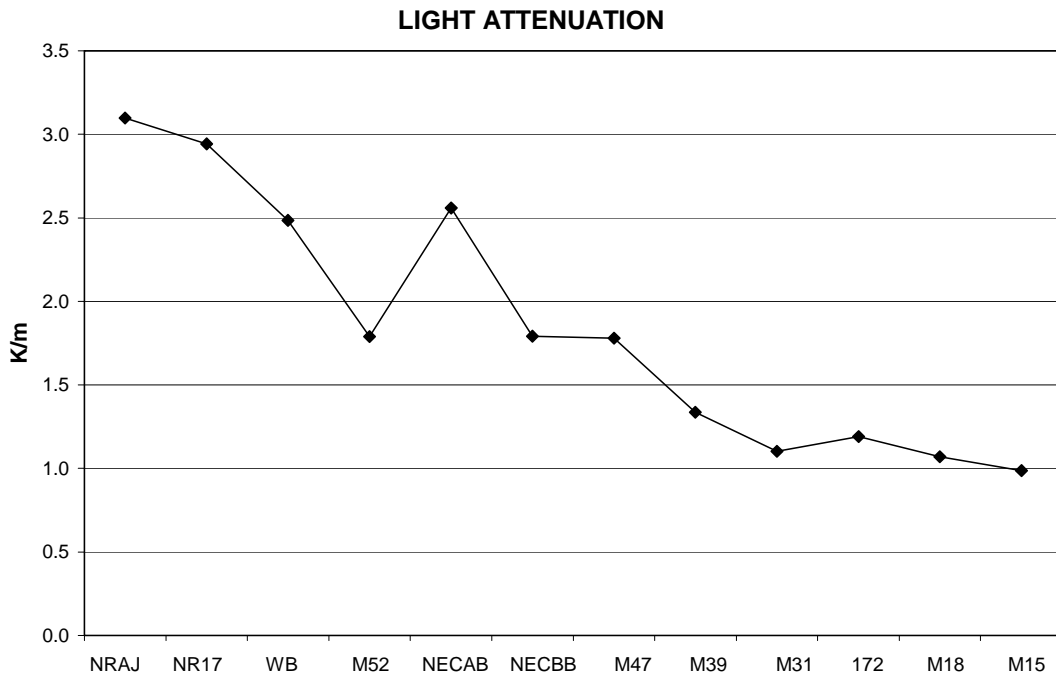


Figure 5. Average light attenuation in the New River Estuary 2008-2009.

AMMONIUM

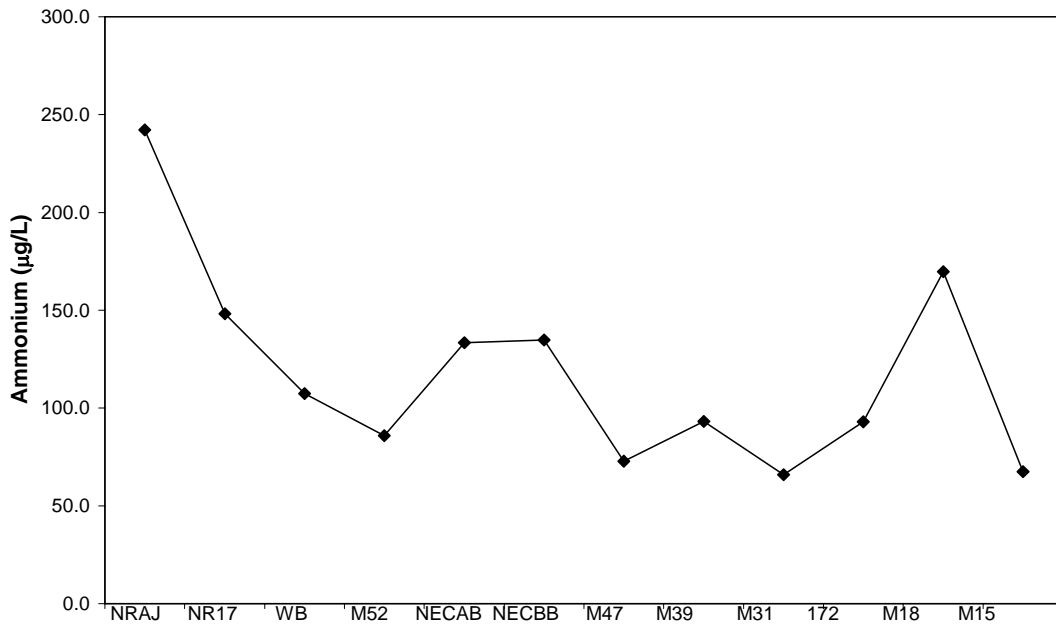


Figure 6. Average ammonium concentrations in the New River Estuary, 2008-2009.

NITRATE

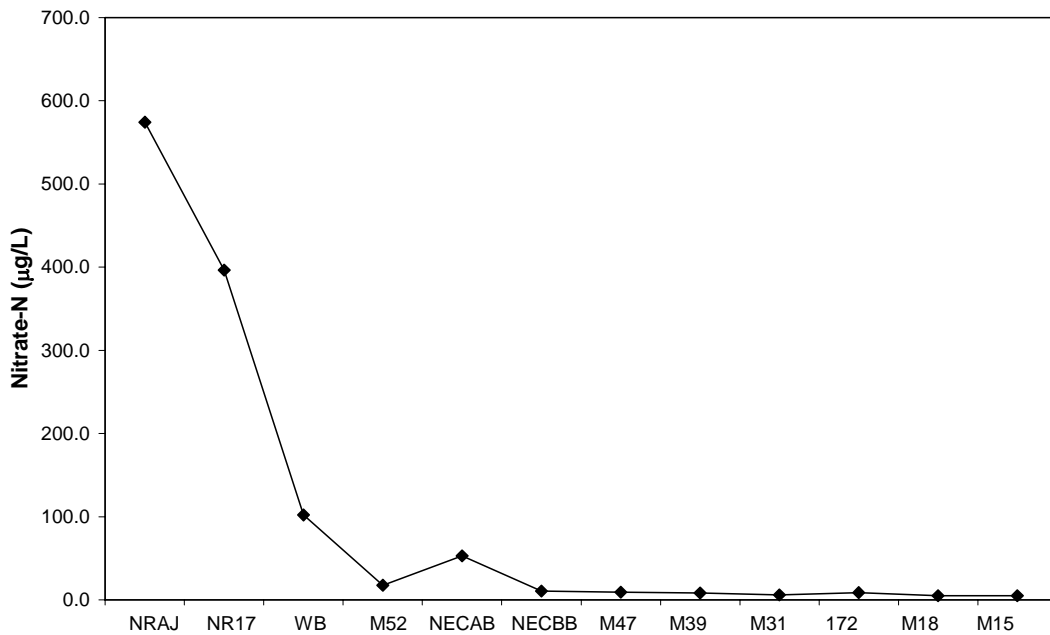


Figure 7. Average nitrate concentrations in the New River Estuary, 2008-2009.

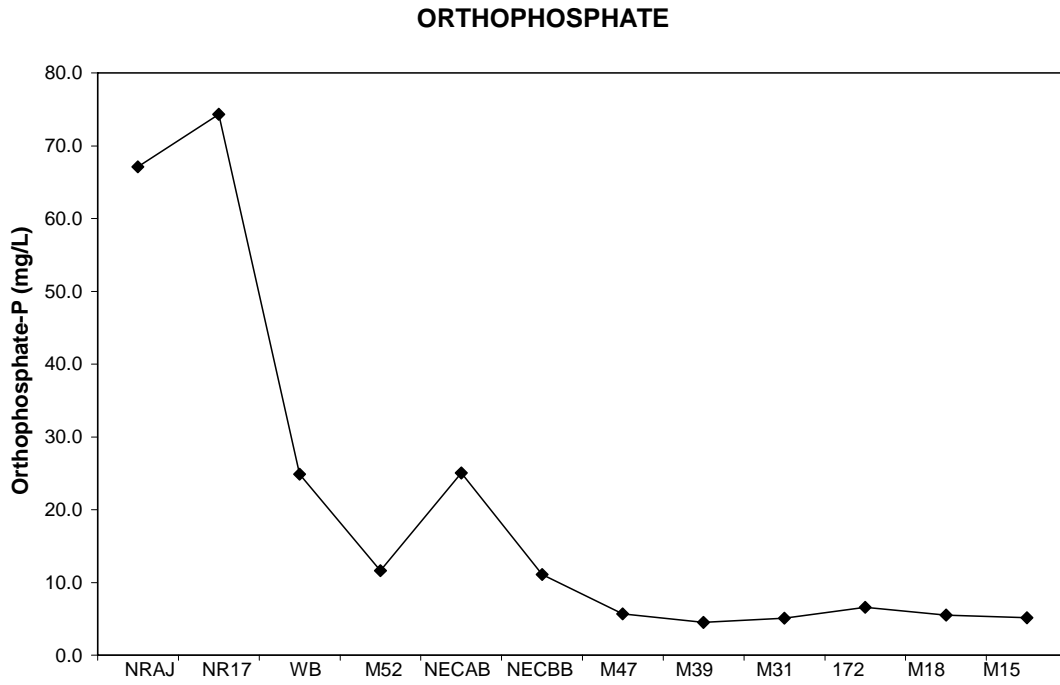


Figure 8. Average orthophosphate concentrations in the New River Estuary, 2008-2009.

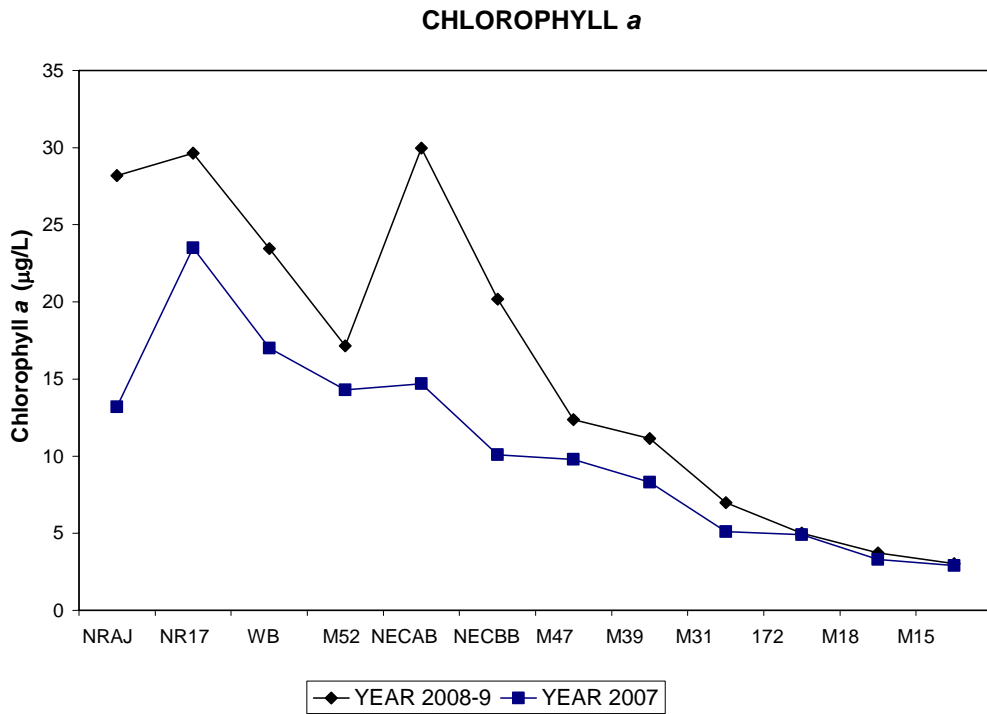


Figure 9. Average chlorophyll *a* concentrations in the New River Estuary, 2008-2009 versus 2007.