Town of Hempstead Water Quality Report

1975 – 2012

Department of Conservation and Waterways

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1975 – 2012

Town of Hempstead

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Department of Conservation and Waterways

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1.1 Executive Summary

The Town of Hempstead, Department of Conservation and Waterways, began monitoring the condition of its bays in 1968. This effort consisted of a one-year study focused primarily on the effects of treated sewage discharge on the quality of bay water. The results of this study were published as the "Water Quality Study, Hempstead Bay Estuary, 1968."

After the 1968 report, a monitoring program was initiated which incorporated monthly water sampling at 28 stations throughout Hempstead Bay. The number of sampling stations eventually increased to 36 for more complete coverage. At first, fourteen water quality parameters were tested, although two have since been dropped and three new parameters added. The sampled area begins in the East Rockaway Inlet in the West and extends to the Oyster Bay town line in the East. Because of the size of the region, the bay is split into 3 regions: West, Middle, and East. West Bay contains Stations 1-10, Middle Bay contains Stations 11-18, and East Bay contains Stations (-147).

The analysis of water parameters in this report focused on representative sampling stations within each section of the bay (Figure 1). The representative stations varied in tandem for each of the parameters. In addition, we looked for differences within the eastern section of the bay by comparing parameter trends in eastern-Middle Bay (14, 16, 17) and eastern-East Bay (22, 23, 26, 27). Stations 2 and 2A were examined for differences within West Bay. We investigated nitrogen levels at Station 4, the location of a treated effluent outfall, and looked at parameter values at the ocean inlets (1 and 18). We also separated out trends in several parameters through time by month for station 4, the inlet stations 1 and 18, high nutrient station 10 and low nutrient station 28.

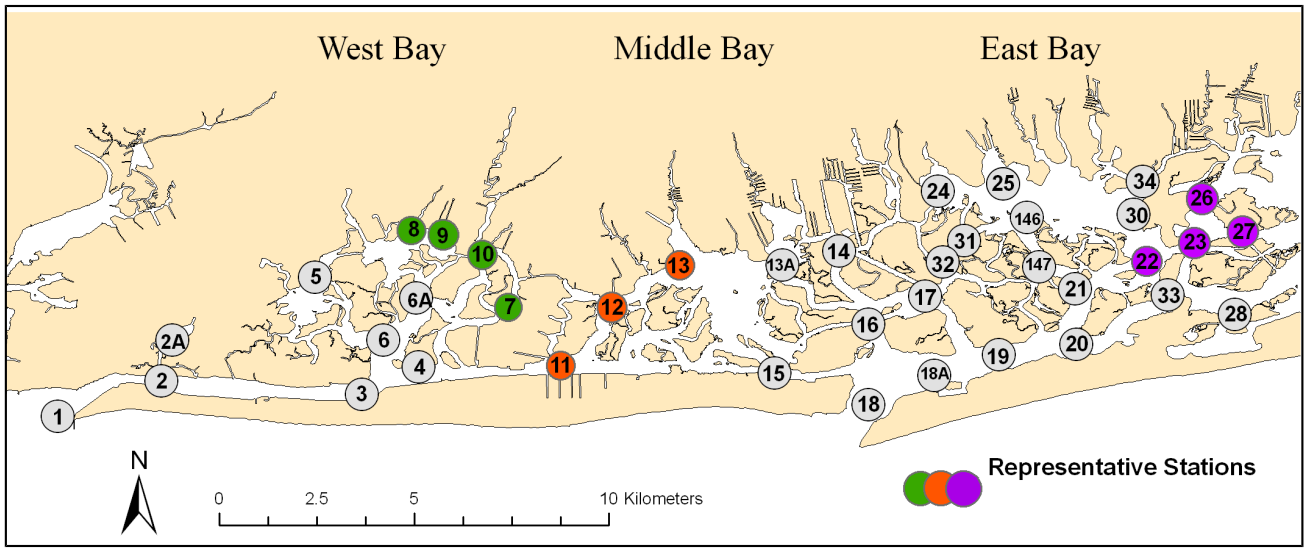


Figure 1. Locations of stations used to collect water quality data during the length of the study. West, Middle, and East Bays are identified, as well as representative stations for each bay. Hempstead Bay, 1975-2011.

1.2 Introduction

The south shore of Long Island, New York, is characterized by a series of shallow estuaries that are separated from the Atlantic Ocean by a series of sandy barrier beach islands. Starting from the east, these include Shinnecock Bay, Moriches Bay, and the South Shore Estuary that together comprise the South Shore Estuary reserve. Jamaica Bay is the last and most westward of the south shore estuaries and the Hudson River Estuary lies just west of Long Island. The South Shore Estuary is often subdivided for administrative reasons into Great South Bay, South Oyster Bay, and Hempstead Bay, but are contiguous water bodies. This report focuses on the water quality results within Hempstead Bay (Figure 2) that comprises the western 19,500 acres of the South Shore Estuary. This wetland contains approximately 7,000 acres of tidal salt marsh, the most extensive single concentration within New York State. It is populated by a diversity of estuarine creatures. Large numbers of waterfowl, wading birds shore birds and other species nest and raise their young here. Additional species of birds and seals spend the winter in Hempstead Bay as well as neighboring estuaries. Many local residents and visitors spend their free time fishing, crabbing and clamming in our waters and we retain an active group of commercial clammers and crabbers. We are committed to the understanding and maintenance of the diverse community of species in our part of the estuary.

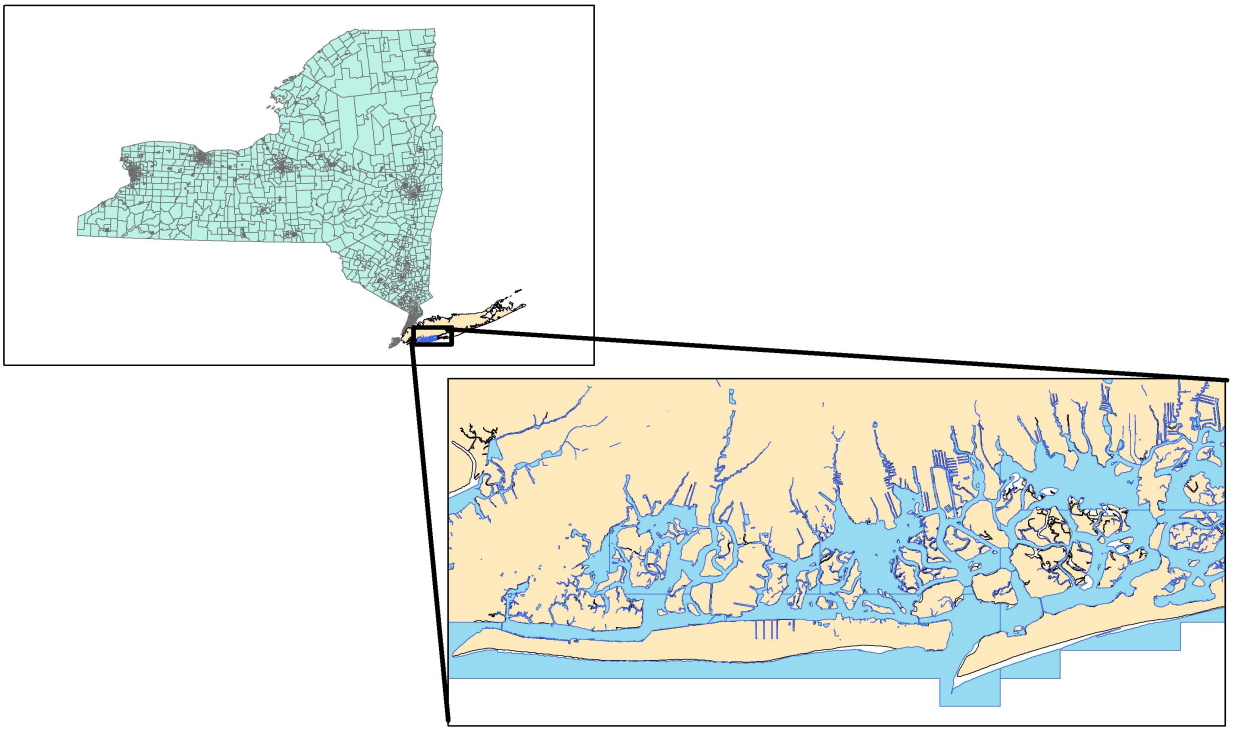


Figure 2. A map of Long Island, New York, showing the location of Hempstead Bay.

1.3 The Bay and Surrounding Urban Neighborhood

Hempstead Township, through its Department of Conservation and Waterways, manages Hempstead Bay (the western bays) within the South Shore Estuary Reserve. Densely populated urban areas surround these bays. Hempstead Township has a population of approximately 760,000, The City of Long Beach just south of the estuary has approximately 33,000, and approximately 550,000 live within the watersheds that lead to the bays monitored in this study. The bays occur behind barrier beaches (Long Beach Island and Jones Beach Island) and contain over 6,000 acres of salt marsh and over 12,000 acres of channels and flats.

The West Bay is the smallest of the Hempstead Bays and approximately 38% of the surface area is covered with *Spartina* marsh. Urban and suburban development completely surrounds this bay, with the city of Long Beach to the south, the village of Island Park to the East and several other incorporated villages to the north and west. This bay is influenced by discharge from four wastewater treatment plants, potentially by ground water discharge, and Mill River. There is tidal input from the East Rockaway ocean inlet in the southwest.

The Middle Bay is larger, extending from Island Park to the Meadowbrook State Parkway (Meadowbrook). While there are no large sources of treated water currently, this bay has thermal input from the Barret power plant located in Island Park. In addition, there are indications that Middle Bay receives nutrients from the West Bay. Less than 33% of the surface area is covered by *Spartina* marsh and a significant amount of surface runoff enters this bay from the north. The edges are somewhat less developed than West Bay, with undeveloped parts of census-designated place Lido Beach to the south and a vegetated border to the East created by the Meadowbrook. Tidal flushing is provided by Jones Inlet in the southeast.

East Bay is the largest of the bays extending from the Meadowbrook to the Oyster Bay town line. The neighborhoods draining into the bays once had individual septic systems, but were sewered during the late 1960s as part of Nassau County's Cedar Creek Treatment Plant construction. Cedar Creek was designed with an ocean outfall at the time. The Jones Beach treatment plant was the only seasonal treated effluent water source found in this area and now discharges treated sewage into the ocean through a connection to the Cedar Creek outfall. Several creeks and many storm water systems discharge into the northern edge of East Bay. The northern edge also the only part of this bay with high-density suburban development. The Meadowbrook, Wantagh State Parkway, and Jones Beach State Park provide large tracts of varied vegetation and wildlife habitat along the East Bay.

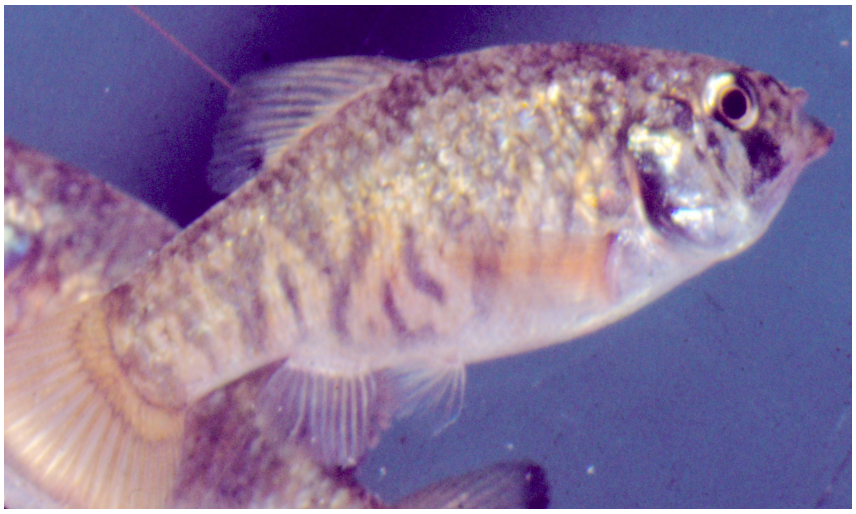
1.4 Ecological Context

Hempstead Bay, consisting of open water, salt marsh islands, and intertidal mudflats, contains great ecological diversity. Salt marsh and dredge islands constitute a large percentage of the bay ecosystem as well as extensive offshore mud and sand flats which are exposed at low tide. The tidal marshes are dominated by cordgrasses (*Spartina* spp.) and estuarine plants like marsh elder (*Iva frutescens*). Vegetation on dredge spoil islands includes Groundsel-bush (*Baccharis halimifolia*), Bayberry (*Myrica pensylvanica*), Poison Ivy (*Toxicodendron radicans*), Cottonwood (*Populus deltoides*), Red Cedar (*Juniperus virginiana*), Grey Birch (*Betula populifolia*) and Black Cherry (*Prunus serotina*).

This large area of open water and tidal saltmarsh contains regionally significant fish and wildlife habitat. Nesting colonies of wading birds occur throughout the bay with sizable breeding concentrations of Snowy Egret (*Egretta thula*), Great Egret (*Casmerodius albus*), Glossy Ibis (*Plegadis falcinellus*), Little Blue Heron (*Egretta caerulea*), Tricolored Heron (*Egretta tricolor*), Black-crowned Night-herons (*Nycticorax nycticorax*), and Yellow-crowned Night-herons (*Nyctanassa violacea*). In 1989, the Hempstead Bay rookeries were the only known Long Island nesting sites for Yellow-crowned Night-herons, although they have since expanded westward.

The Hempstead Bay marsh ecosystem sustains colonies of Common Tern (*Sterna hirundo*), the locally rare Gull-billed Tern (*Sterna nilotica*), and Forester's Tern (*Sterna forsteri)*. Other nesting birds include American Oystercatcher (*Haematopus palliates*), Green Heron (*Butorides virescens*), Laughing Gull (*Larus atricilla*), Seaside Sparrow (*Ammodramus maritimus*), Osprey (*Pandion haliaetus*), and Black Skimmer (*Rynchops niger*). From 2011 through 2013, Hempstead Bay supported two of only four black skimmer colonies on Long Island, with the others nesting on the Rockaway Peninsula.

The bay provides essential habitat for overwintering waterfowl and migrating shorebirds. Waterfowl species common in the winter months include Brant (*Branta bernicla*), American Black Duck (*Anas rubripes*), scaup (*Aythya spp.)*, and Red-breasted Merganser (*Mergus serrator*). The invertebrate-rich tidal flats attract shorebirds such as Sanderling (*Calidris alba*), Dowitchers (*Limnodromus* spp.), Red Knot (*Calidris canutus*), plovers (*Charadrius spp*.), including the endangered Piping Plover, and many species of sandpipers (Scolopacidae).



Sheepshead Minnow (Cyprinodon varegatus)

Hempstead Bay also provides important habitat for a high diversity of fish. The following species rely upon the bay as a spawning ground: Atlantic Menhaden (*Brevoortia tyrannus*), Weakfish (*Cynoscion regalis*), Winter Flounder (*Pseudopleuronectes americanus*), American Sand Lance (*Ammodytes americanus*), Killifish (*Fundulus* spp.), and Atlantic Silverside (*Menidia menidia*). Young Bluefish (*Pomatomus saltatrix*), Striped Bass (*Morone saxatilis*), Summer Flounder (*Paralichthys dentatus*), and Blackfish (*Tautoga onitis*) use the bay as a nursery ground. American Eel (*Anguilla rostrata)* are still found in Hempstead Bay, where they feed and prepare for their migration to their spawning grounds in the Sargasso Sea. Hemsptead Bay also serves as an important feeding area for herring (*Clupea* spp.).

Harbor Seals (*Phoca vitulina*) frequent the bay during winter months along with Grey Seals (*Halichoerus grypus*), Ringed Seals (*Pusa hispida)* and Harp Seals (*Pagophilus groenlandicus)*.

Great Egret

2. Methods/Results for Parameters

2.1 Description of Water Quality Parameters

All sample collection and laboratory analysis were performed in accordance with the contemporaneous edition of Standard Methods for the Examination of Water & Wastewater or with Environmental Protection Agency (EPA) approved variations, recommended by the manufacturers of the instrumentation. Samples were obtained monthly throughout the bays starting in 1975 at 28 separate stations. Water quality parameters sampled at this time included: water temperature (°C), salinity (parts per thousand - ppt), chlorophyll 'a' (mg/m3), nitrate (μM), nitrite (μM), ammonia (μM), particulate organic matter (mgC/m3), dissolved oxygen (mg/L), biological oxygen demand, Secchi transparency (m), orthophosphates (μM), coliforms (MPN), and fecal coliforms (MPN). Sampling currently occurs at 36 stations and now includes urea (μM), silicate (μM), and total chlorophyll in place of particulate organic matter and biological oxygen demand (BOD).

Salinity (1975 - present)

Salinity is a measure of the salt concentration of water. It is usually expressed in parts per thousand (ppt). Many estuarine organisms, notably the eastern oyster (*Crassostrea virginica*), survive better at lower salinity (22.5-28 ppt), while many predators and parasites of estuarine species prefer salinity closer to the 32 ppt that is typical of the ocean. Increased salinity may have a potential negative influence on the estuary.

Water Temperature (1975 - present)

Fluctuations in water temperature influence where bay grasses grow and when fish, crabs and oysters feed, reproduce and migrate. Warmer water holds less dissolved oxygen, and can lead to hypoxic events.

Dissolved Oxygen (1975 - present)

Dissolved oxygen concentration is one of the most universal indicators of overall water quality and is critical for respiration by aquatic life. It is measured in milligrams of oxygen per liter of water (mg/L). Adequate dissolved oxygen (approximately 2 mg/L or more) is necessary for good water quality.

Particulate Organic Matter (1975 - 2001)

Particulate organic matter is the amount of material of plant or animal origin that is suspended in water. Generally, higher particulate organic values can indicate the severity of the water pollution problem.

Orthophosphate (1975 - present)

Orthophosphate is the dissolved inorganic form of phosphate found in aquatic systems. Most of the phosphate is incorporated into organic compounds or bound into plant and animal tissues. Orthophosphate values indicate the

portion of phosphate that is available to plants and animals. Phosphate becomes insoluble and is lost to sediments in ecosystems with very low productivity.

Ammonia (1975 - present)

Ammonia is a simple inorganic nitrogen compound that is typically excreted by marine invertebrates and fishes. It is also the main form of nitrogen produced by anthropogenic sources like treated wastewater and cheap fertilizers. Ammonia is readily utilized by many forms of algae, is absorbed directly by the leaves of saltmarsh cordgrass (*Spartina alterniflora*), and converted to nitrites by bacteria. Because it is readily utilized, ammonia normally does not last long (has a short half-life) in oxic conditions. However, ammonia can also be toxic to fishes and aquatic organisms, even in low concentrations.

Recent electronic

Nitrite (1975 - present)

Nitrite ($NO2^-$) is formed when bacteria oxidize ammonia. Although it is less toxic than ammonia, elevated levels of nitrite are still a threat to aquatic life, especially fishes. In open waters, nitrites are usually oxidized to nitrates in a short time.

Nitrate (1975 - present)

In the next stage of the nitrogen cycle, bacteria oxidize nitrites ($NO2^-$) to nitrates ($NO3^-$), a less toxic form of nitrogen. Nitrate is a nutrient for plants and is necessary for supporting marine life. However, high concentrations can cause excessive unconsumed growth of algae and other plants. This growth can lead to accelerated eutrophication and loss of dissolved oxygen.

Dissolved Inorganic Nitrogen (1975-present)

Dissolved inorganic nitrogen is the sum of ammonia, nitrite and nitrate. This parameter is often used in studies instead of its components. It is an important parameter because nitrogen is usually the limiting factor of ecosystem productivity in marine systems.

Chlorophyll 'a' (1975 - present)

Chlorophyll 'a' is the primary green pigment that allows plants to capture energy from sunlight and produce organic compounds, and is the predominant type of chlorophyll found in algae. High levels of chlorophyll 'a' indicate nutrient loading because excess nutrients fuel the growth of algae. Areas with lower algal levels have clearer water and fewer harmful blooms, but insufficient levels (or the wrong species) of phytoplankton can negatively impact filter feeding species and other herbivores. Ideal levels of chlorophyll 'a' indicate that there is enough algae to fuel the food web, but not so much that hypoxic conditions are prevalent.

Total Coliform (1975 - present)

Some coliform bacteria are not directly an indication of contamination by raw fecal matter, so these readings are taken in combination with fecal coliform to judge the likelihood of such contamination and potential presence of organisms that can affect human health. Counts are measured as most probable number (MPN) per 100ml.

Fecal Coliform (1975 - present)

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other warm-blooded animals. The source water may also have been contaminated by pathogens, disease-producing bacteria or viruses, which can exist in fecal material. The presence of fecal coliform(s) is an indicator of potential health risks, most notably waterborne gastroenteritis.

Secchi Transparency (1975 - present)

The clarity of water is estimated using a Secchi disc. High Secchi transparency, associated with clear low-productivity water, is typically when the disk is visible to depths of 5 feet or more. Low Secchi transparency of 3 feet or less, is indicative of turbid or light limiting conditions. Low Secchi readings are often associated with degraded waters because transparency decreases as suspended sediments or algal abundance increases. Clear water can indicate a healthy bay, though high Secchi readings are also found in with waters devoid of marine life.

Silicate (2007 - present)

Silicates are important primarily for the production of protective structures on many plants. It can be a limiting nutrient for diatoms, a useful group of algae, and the production of their external frustules.

Urea (2007 - present)

Urea is a simple organic nitrogen compound. Elevated levels often indicate untreated waste from anthropogenic sources or excretion from mammals. Some fertilizers are urea based and may contribute to elevated urea levels.

Early electronic sensors

Fluorometric Chlorophyll (2007 - present)

Fluorometric chlorophyll readings are now being collected in conjunction with chlorophyll 'a' using a YSI 6600 SONDE. This parameter measures algae by using different biological chemistry than the chlorophyll “a” test.

Biological Oxygen Demand (1975 - 1999)

Biological oxygen demand (BOD) is a measurement of the oxygen utilized by organisms in a water sample when incubated without light. Because of the inherent inconsistencies incorporated into the method used to determine BOD, we no longer evaluate this parameter.

2.2 State Water Quality Standards

The New York State Department of Environmental Conservation (NYS DEC) uses water parameters as indicators of ecosystem health or degradation. NYS DEC standards reflect a range of acceptable water quality conditions corresponding to the State-designated "best usage" of the water body. These are being reviewed at the time of this printing. The relevant classes are summarized below. For a complete description, visit: http://www.dec.ny.gov/regs/4590.html

NYS DEC Classification for Saline Waters	
Class	**Usage**
SA	Shellfishing and all other recreation and use
SB	Primary and secondary contact recreation and fishing
SC	Suitable for fish, shellfish, and wildlife propagation and survival
I	Secondary contact recreation and fishing
SD	Suitable for fish, shellfish, and wildlife survival

For phosphorus and nitrogen, the NYS DEC suggests that none should occur in amounts that result in growths of algae, weeds and slimes that impair the waters for their best usages. For information on how Hempstead Bay is used, see http://www.estuary.cog.ny.us. The values for coliform, fecal coliform and dissolved oxygen standards are listed below, and are implemented at the discretion of the NYS DEC:

NYS DEC Water Standards		
Parameter	**Classes**	**Standards**
Coliform	I	The monthly geometric mean, from a minimum of five examinations, shall not exceed 10,000 MPN/100ml.
Fecal Coliform	SB, SC	The monthly geometric mean, from a minimum of five examinations, shall not exceed 200 MPN/100ml.
	I	The monthly geometric mean, from a minimum of five examinations, shall not exceed 2,000 MPN/100ml.
Dissolved Oxygen	SA, SB, SC	Chronic: Shall not be less than a daily average of 4.8 mg/L

2.3 Salinity

Salinity is a measure of the salt concentration of water. It is usually expressed in parts per thousand (ppt). Many estuarine organisms, notably the eastern oyster (*Crassostrea virginica*), survive better at lower salinity (22.5-28 ppt), while many predators and parasites of estuarine species prefer salinity closer to the 32 ppt that is typical of the ocean. Increased salinity has the potential to negatively influence the estuary.

Salinity values were higher in the East Bay compared to the Middle or West Bays, with no significant difference between the sections of East Bay (Fig. 3). Seasonally, values were highest in the winter months and lowest in May and June in all three bays (Fig 4). Stations 2 and 2A in lower West Bay had higher salinity values than upper West Bay, a pattern likely reflecting the influx of freshwater into the northern edge of this bay (Figure 3).

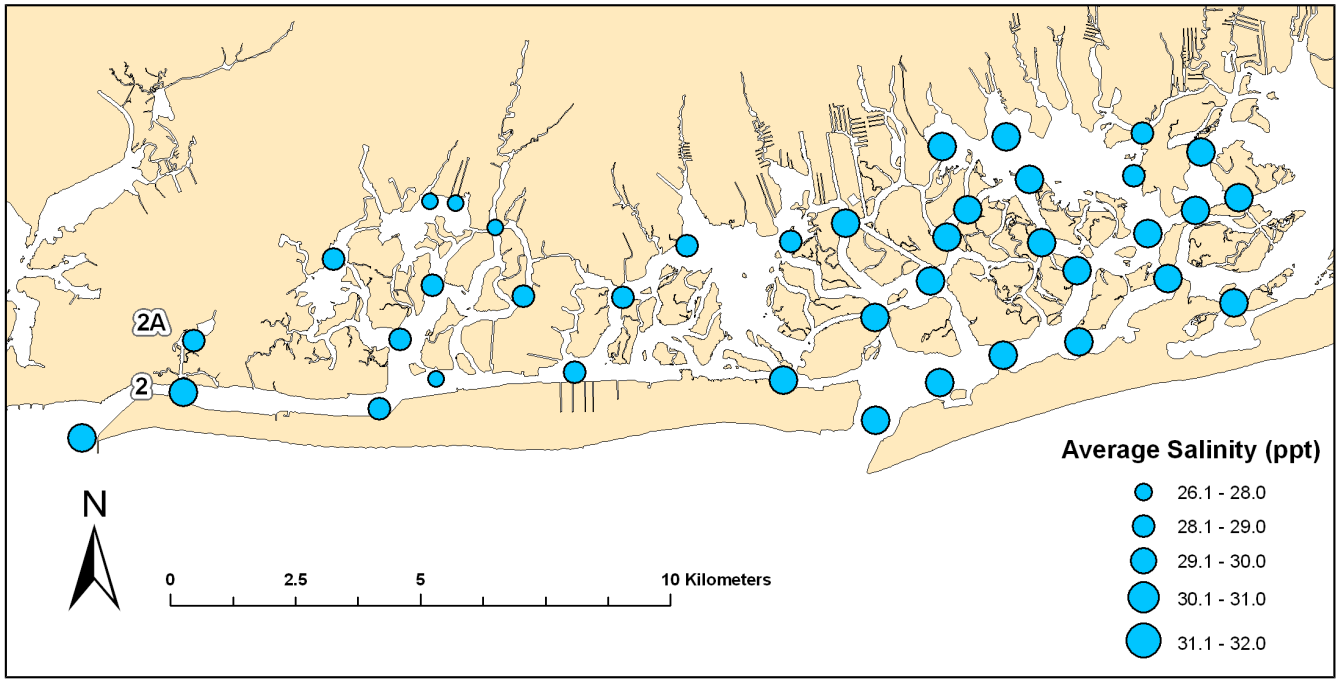


Figure 3. Salinity values averaged for each sampling station. Hempstead Bay, 1975-2011.

Salinity *continued*

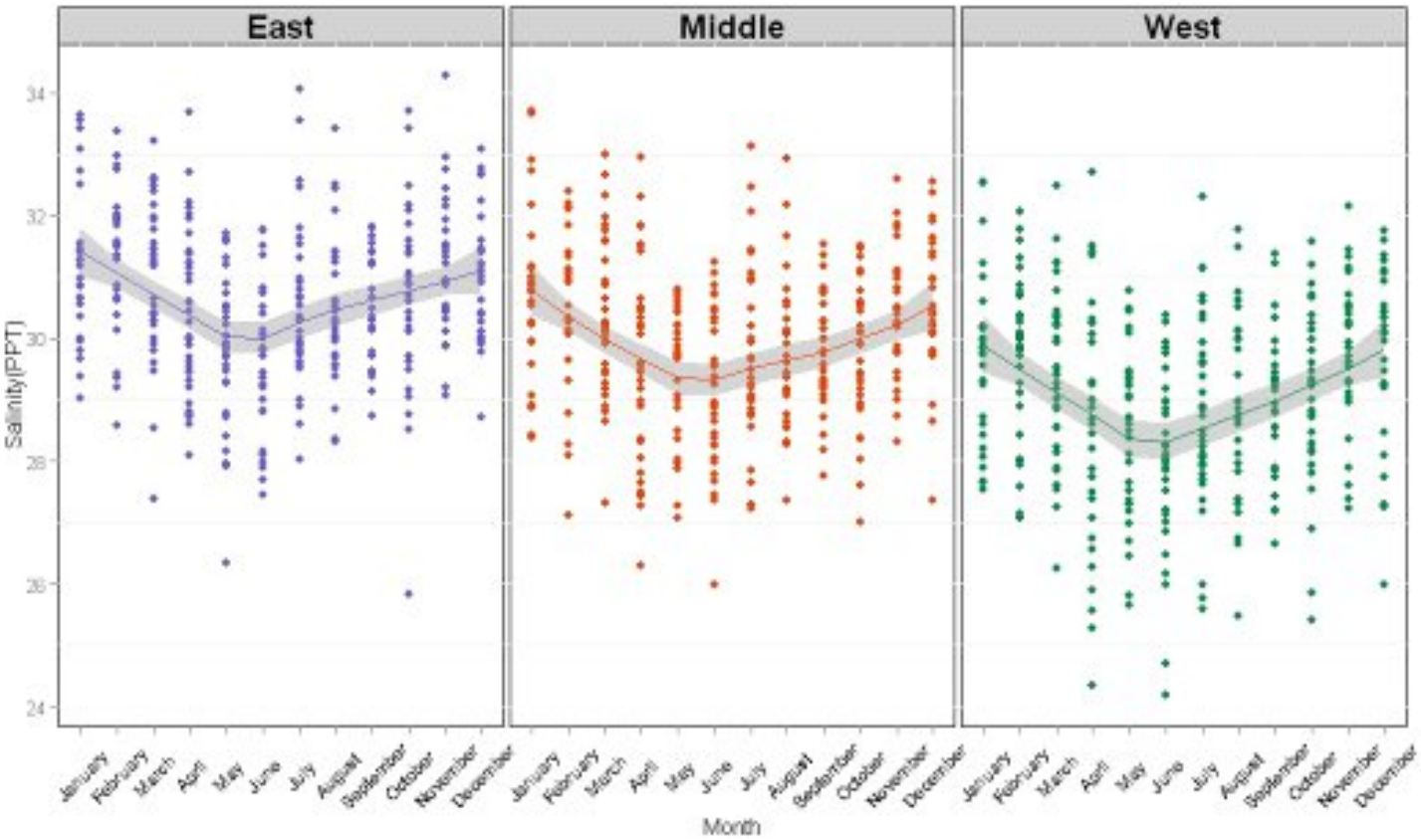


Figure 4. Seasonal salinity values for West, Middle and East Bay fit with loess curves and 95% confidence regions. Hempstead Bay, 1975-2011.

2.4 Water Temperature

Fluctuations in water temperature influence where bay grasses grow and when fish, crabs and oysters feed, reproduce or migrate. Warmer water holds less dissolved oxygen, and can lead to hypoxic events.

Bay water temperatures showed typical seasonal variation with high temperatures in summer months and low in winter months. Because of this seasonal trend, averaging together all months to examine temporal changes yielded much variation. Instead, a monthly examination revealed that different months exhibit varying trends. January, September and November showed increasing temperatures through time while some months (July and March) showed little change. Water temperatures in May decreased, though this trend was most apparent at West Bay sampling stations (Figure 5).

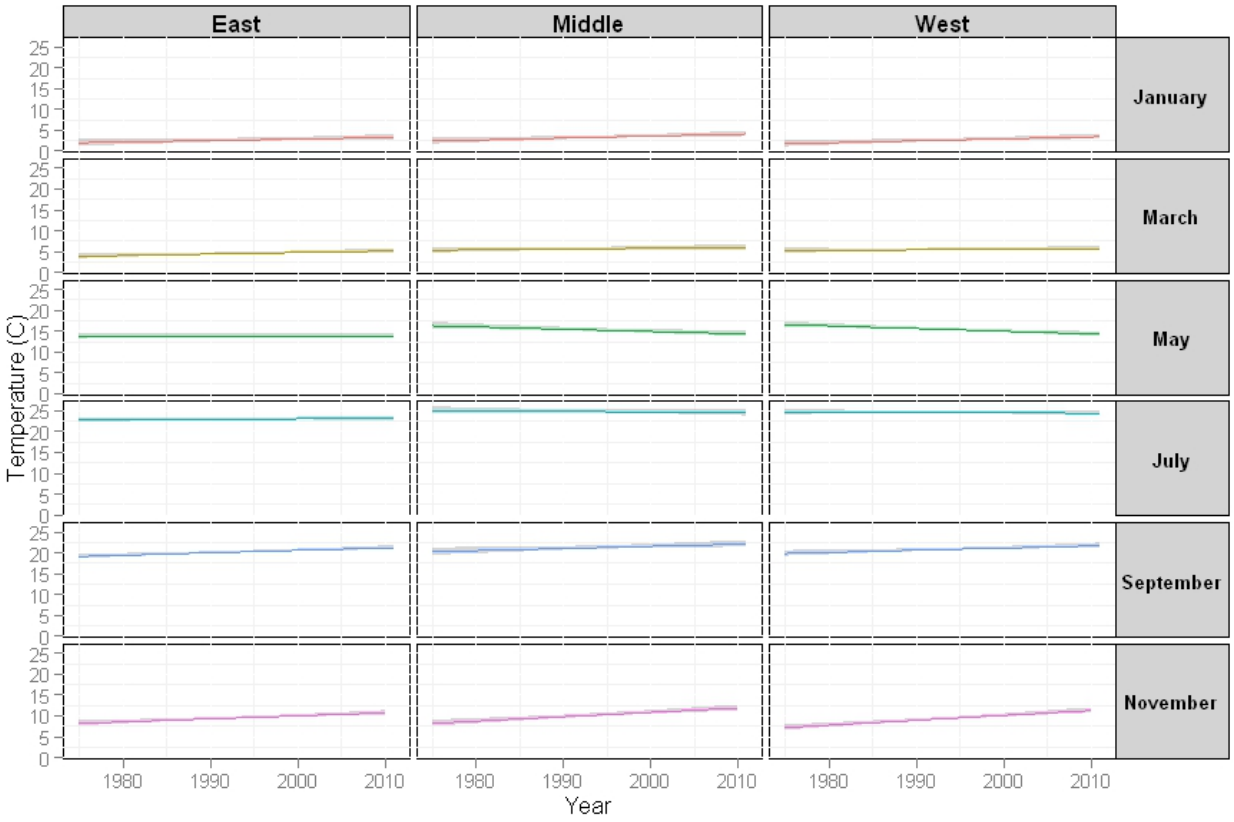


Figure 5. Yearly water temperatures of East, Middle, and West Bays in January, March, May, July, September, and November. Hempstead Bay, 1975-2010.

2.5 Dissolved Oxygen (O_2)

Dissolved oxygen (DO) concentration is one of the most universal indicators of overall water quality and is critical for respiration by aquatic life. Adequate dissolved oxygen is necessary for good water quality and is measured in milligrams of oxygen per liter of water (mg/L).

Monthly dissolved oxygen values for East, Middle, and West Bays showed a strong seasonal trend throughout the bay with the lowest oxygen readings in summer months and the highest in the winter (Fig. 6). This trend is expected because warmer water holds less oxygen, therefore we see dissolved oxygen (DO) values near the the NYS DEC chronic standard (4.8 mg/L) during warmer months. Values below the chronic standard can result in negative effects on aquatic life, including reduced survival in shellfish and other economically important species. Oxygen saturation is the maximum amount of oxygen the water can hold per unit of temperature and salinity. It appears that in all parts of the bay, the saturation levels were lower than the measured DO in February-April (the period of high chlorophyll levels when excess oxygen is released into the air; Fig. 6). Through time, DO values in the bay have remained relatively stable (Fig. 7).

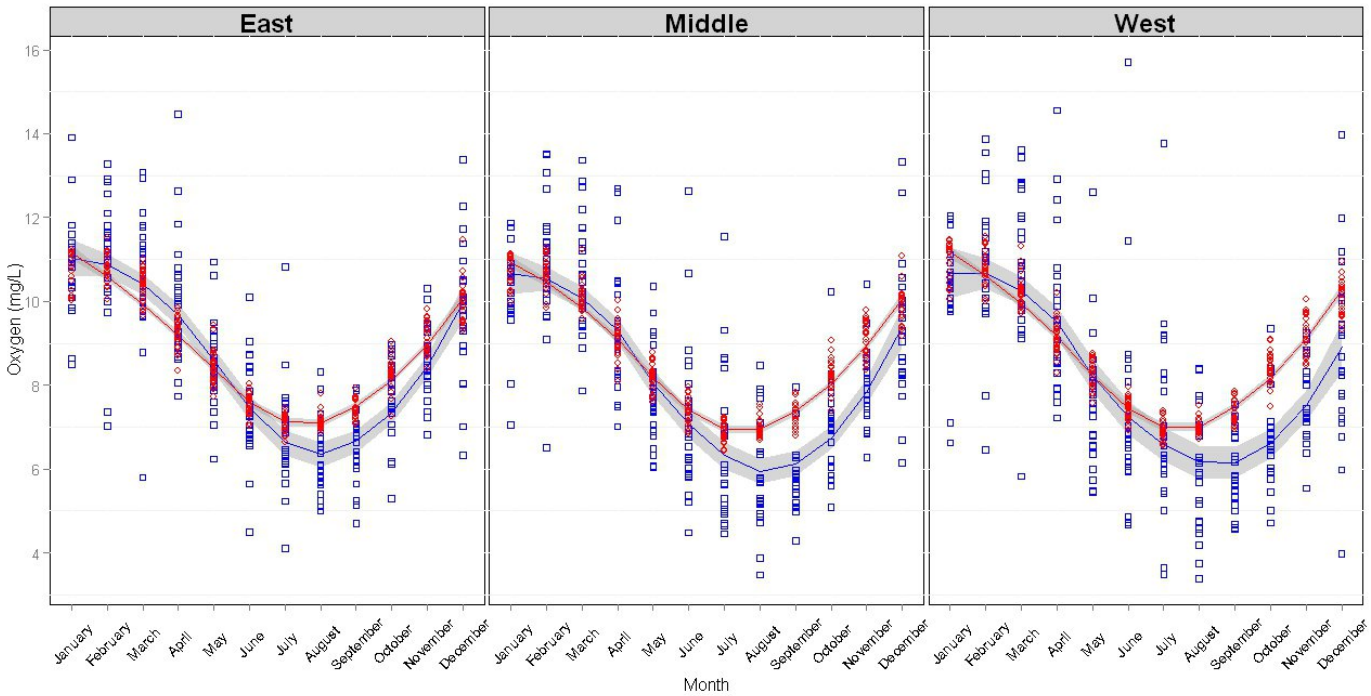


Figure 6. Monthly dissolved oxygen values and calculated oxygen saturation values of East, Middle, and West Bays from 1975 – 2011 fit with loess curves and 95% confidence regions. Questionable dissolved oxygen data from 1988-1991 and 1998 – 2003 were removed.

Dissolved Oxygen (O_2) *continued*

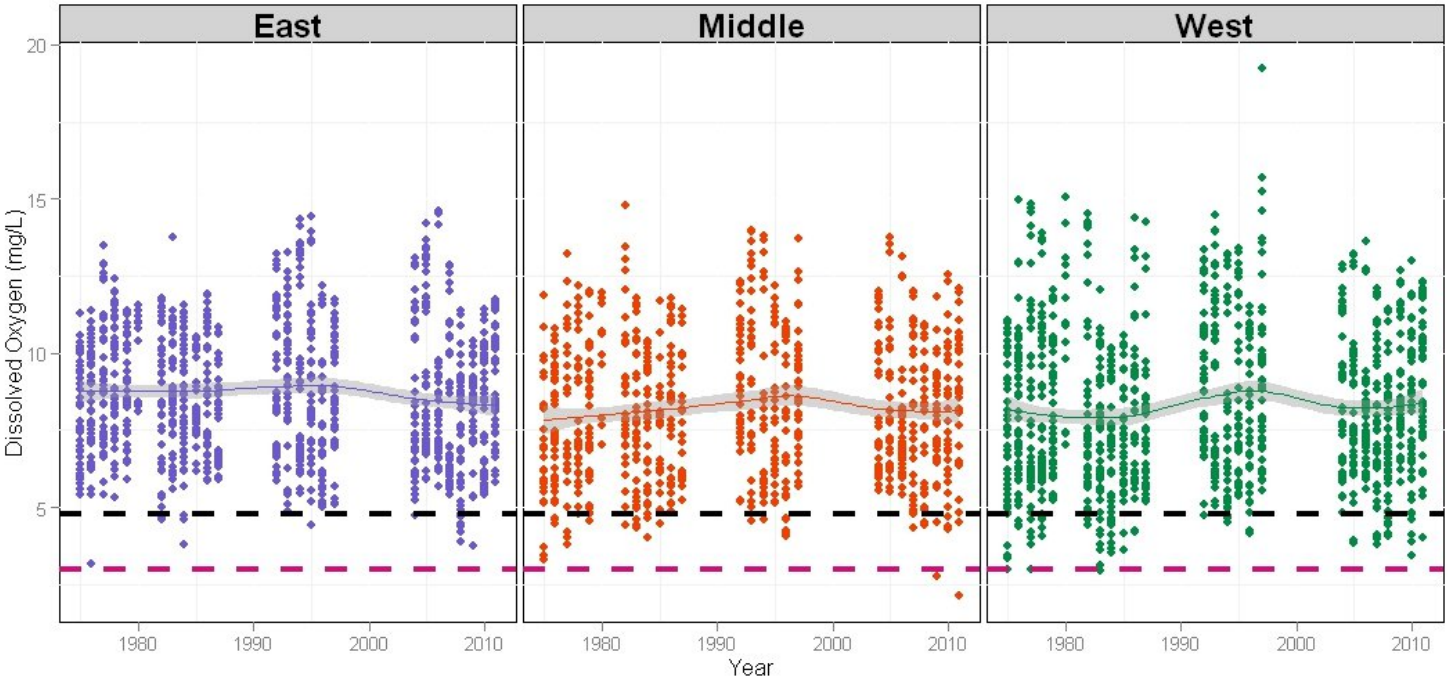


Figure 7. Yearly dissolved oxygen values of East, Middle, and West Bays from 1975-2011 fit with a loess curves and 95% confidence regions (oxygen data from 1988-1991 and 1998 – 2003 removed). NYS DEC dissolved oxygen standards are represented by the higher black (chronic, 4.8 mg/L) and lower purple (acute 3.0 mg/L) dashed lines.

Water quality testing at the Town of Hempstead Laboratory.

2.6 Particulate Organic Matter

Particulate organic matter is material of plant or animal origin that is suspended in water. Generally, higher particulate organic values indicate the severity of the water pollution problem.

Particulate values significantly declined throughout the bay (Figures 8 and 9). This decline was most evident in the East Bay and was reflected in the slope values for linear regression (m=-41.78 East, m=-35.93 Middle, and m=-34.37 West, Fig. 9). Spatially, East Bay had lower particulate values than the West Bay though the difference was most prominent in the final years (1989-2001) of collection (Fig. 8). From 1975-1988, particulate values at Station 4 near the Bay Park outfall were drastically higher than the rest of the bay. Although values at Station 4 were still high in 1989-2001, the readings were lower as were the readings at all stations. Particulate values in the West Bay showed a slight seasonal trend with the highest readings occurring between March and June, possibly reflecting phytoplankton productivity (Fig. 10).

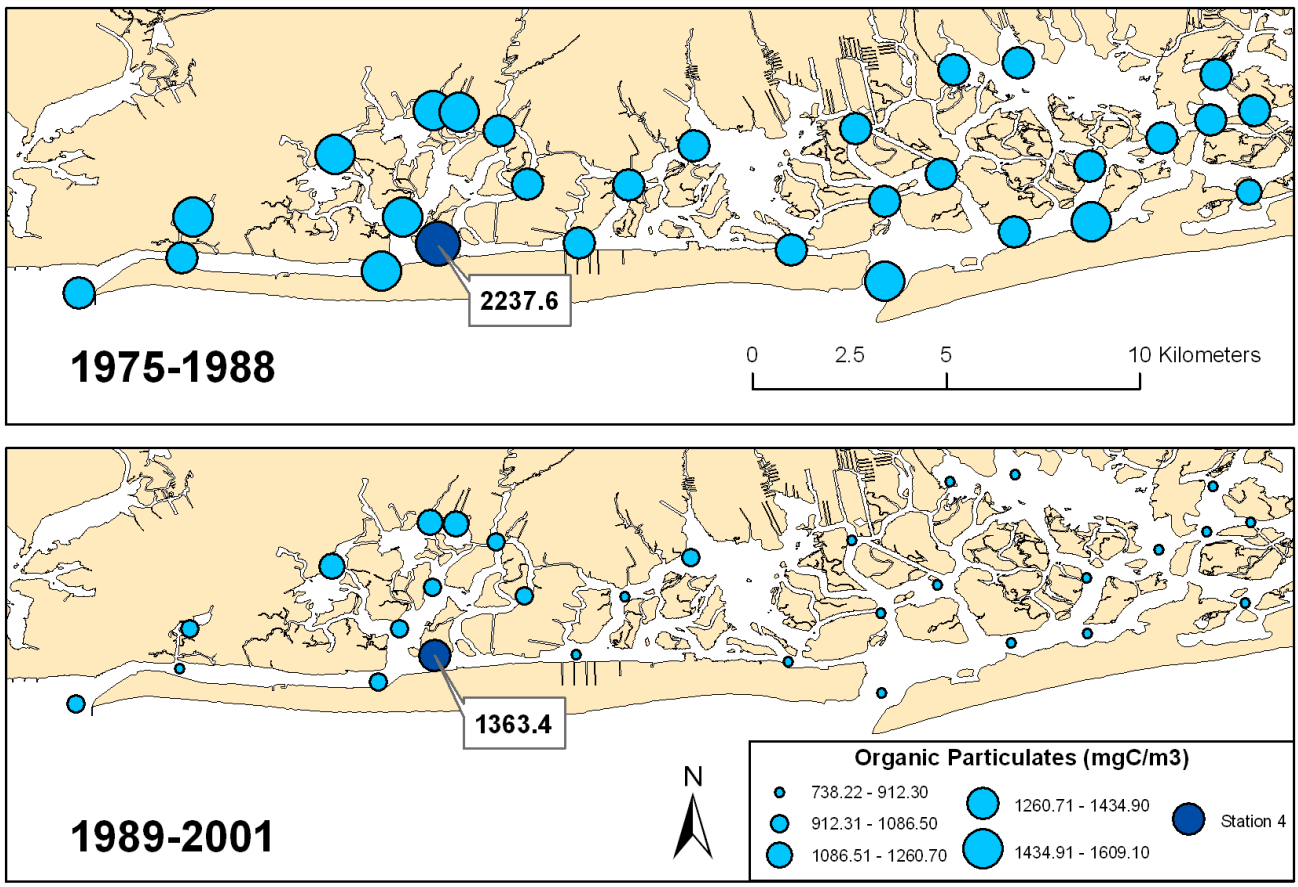


Figure 8. Average particulate values at sampling stations for two time periods. The Bay Park outfall, Station 4 (dark blue), particulate values are displayed for 1975-1988 and again from 1989-2001 when it deviated greatly from the other stations and could not be shown to scale without loosing comparisons between the rest of the stations. Hempstead Bay, 1975-2001

Particulate Organic Matter *continued*

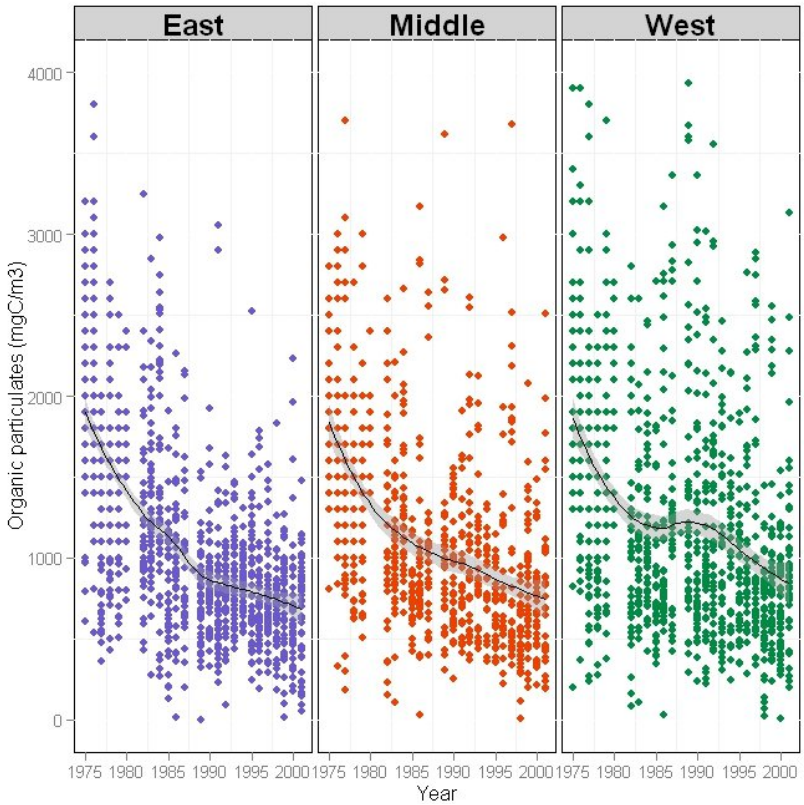


Figure 9. Particulate values for West, Middle and East Bays fit with loess curves and 95% confidence regions. Hempstead Bay, 1975-2001.

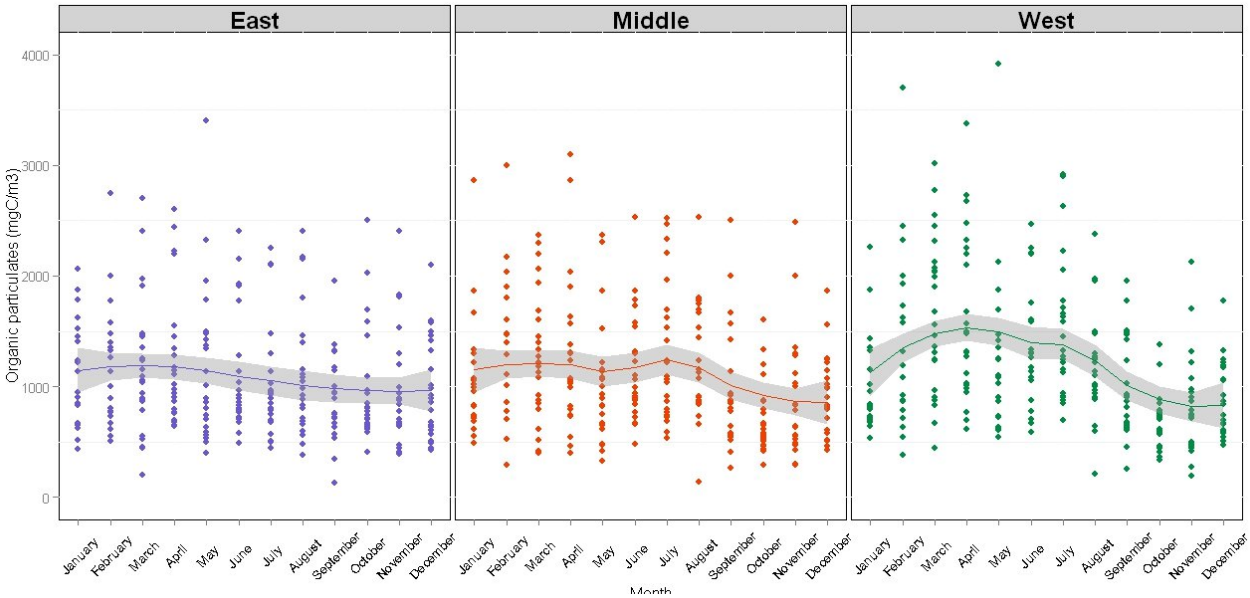


Figure 10. Monthly particulate values of East, Middle, and West Bays fit with loess curves and 95% confidence regions. Hempstead Bay, 1975-2011

2.7 Orthophosphate

Orthophosphate is the dissolved inorganic form of phosphate found in aquatic systems. Most of the phosphate is incorporated into organic compounds or bound into plant and animal tissues. Orthophosphate values indicate the portion of phosphate that is available to plants and then animals. Phosphate becomes insoluble and is lost to sediments in ecosystems with very low productivity.

Orthophosphate values decreased slightly since 1975 but spatially, values in the West Bay, especially at Upper West Bay stations, were higher than in other parts of West Bay stations (2, 2A) were significantly lower than northern West Bay (Figure 11). Orthophosphate levels in East Bay showed little seasonal variation while values in Middle and West Bays showed seasonal variation with levels highest between June and September (Fig 12). Orthophosphate levels in eastern-Middle Bay were significantly higher than those in eastern-East Bay, though this difference was small compared to the higher values found in Middle and West Bays.

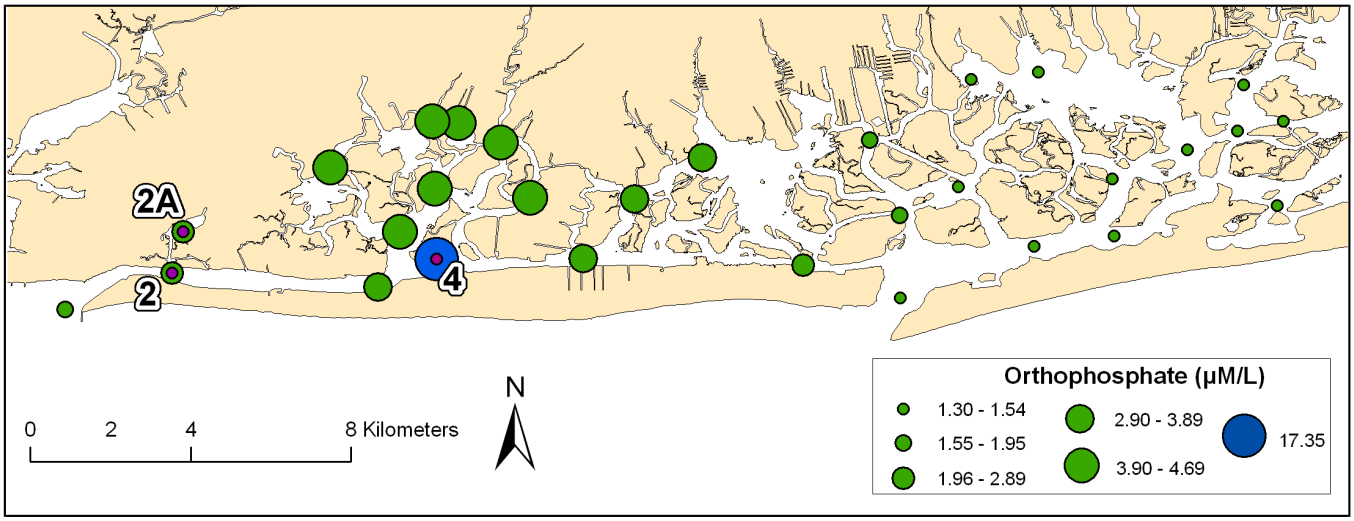


Figure 11. Orthophosphate values averaged for each sampling station. Hempstead Bay, 1975-2011. Station 4 (blue) orthophosphate values are not displayed to scale because the values deviate greatly from the rest of the bay and would obscure differences between other station if scaled.

Orthophosphate *continued*

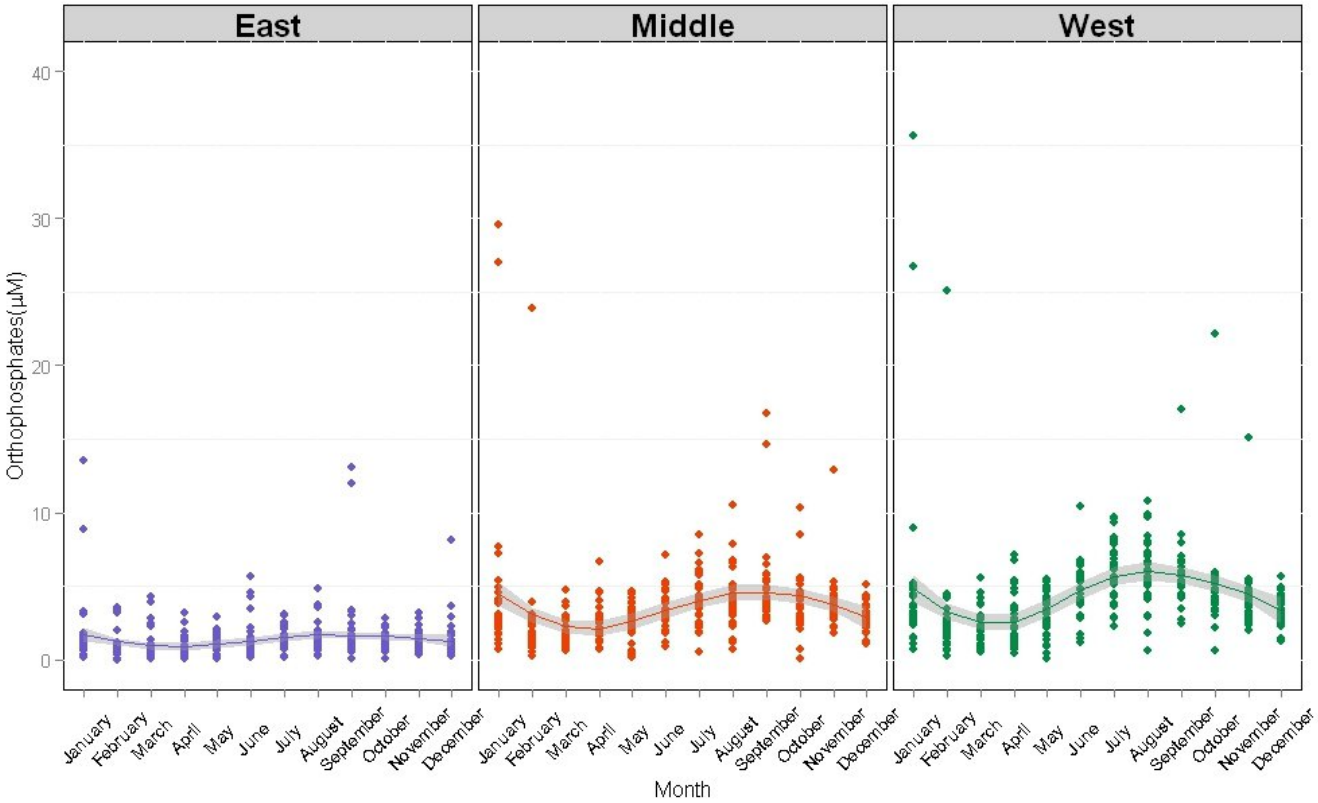


Figure 12. Monthly orthophosphate values of East, Middle, and West Bays from 1975-2011fit with loess curves and 95% confidence regions.

Black skimmer

2.8 Ammonia

Ammonia is a simple inorganic nitrogen compound that is typically excreted by marine invertebrates and fish, often comprising the bulk of ammonia even in estuaries with heavy human influence. Ammonia is readily utilized by many forms of algae and converted to nitrites by bacteria. Because it is readily utilized, ammonia normally has a short half-life in oxic conditions. However, ammonia can be toxic to fish and aquatic organisms, even in low concentrations. It is the main form of nitrogen cycled naturally in marine systems but also introduced by some anthropogenic sources like treated wastewater and cheap fertilizers.

Spatially, ammonia values were highest in the Middle and West Bays. Ammonia values at Stations 2 and 2A were significantly lower than those in upper West Bay. West and Middle Bay ammonia values showed seasonal trends with peaks in April and May and again in December. The annual cycle of East Bay values remained stable and low relative to Middle and West Bays (Fig. 13). Values increased through time (1980-2009) though this trend was most evident at West Bay sampling stations (Fig. 14). Though eastern Middle Bay had significantly higher ammonia values compared to the eastern East Bay representative stations, this difference was nominal compared to the higher values found in Middle and West Bays. Station 4, located at the Bay Park Treatment Plant outfall, yielded substantially higher ammonia values compared to the rest of the bay (Fig 14).

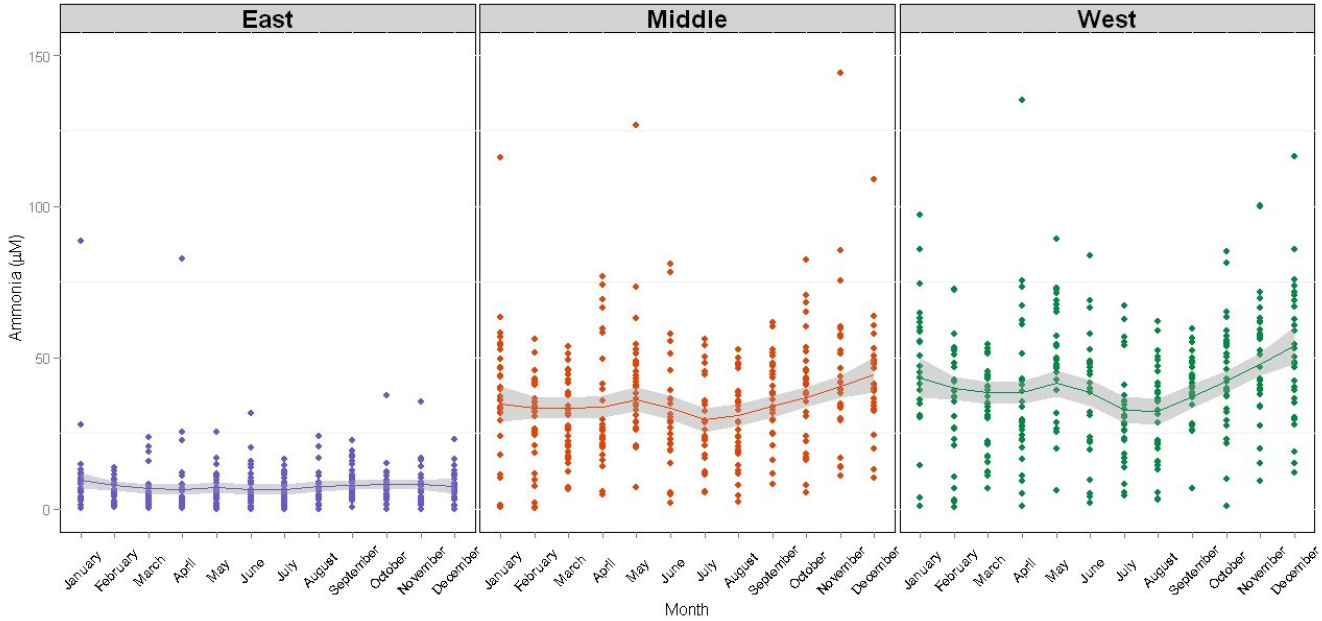


Figure 13. Monthly ammonia values for West, Middle and East Bays fit with loess curves and 95% confidence regions. Questionable data from 1997-1999 have been removed. Hempstead Bay, 1975-2011.

Ammonia *continued*

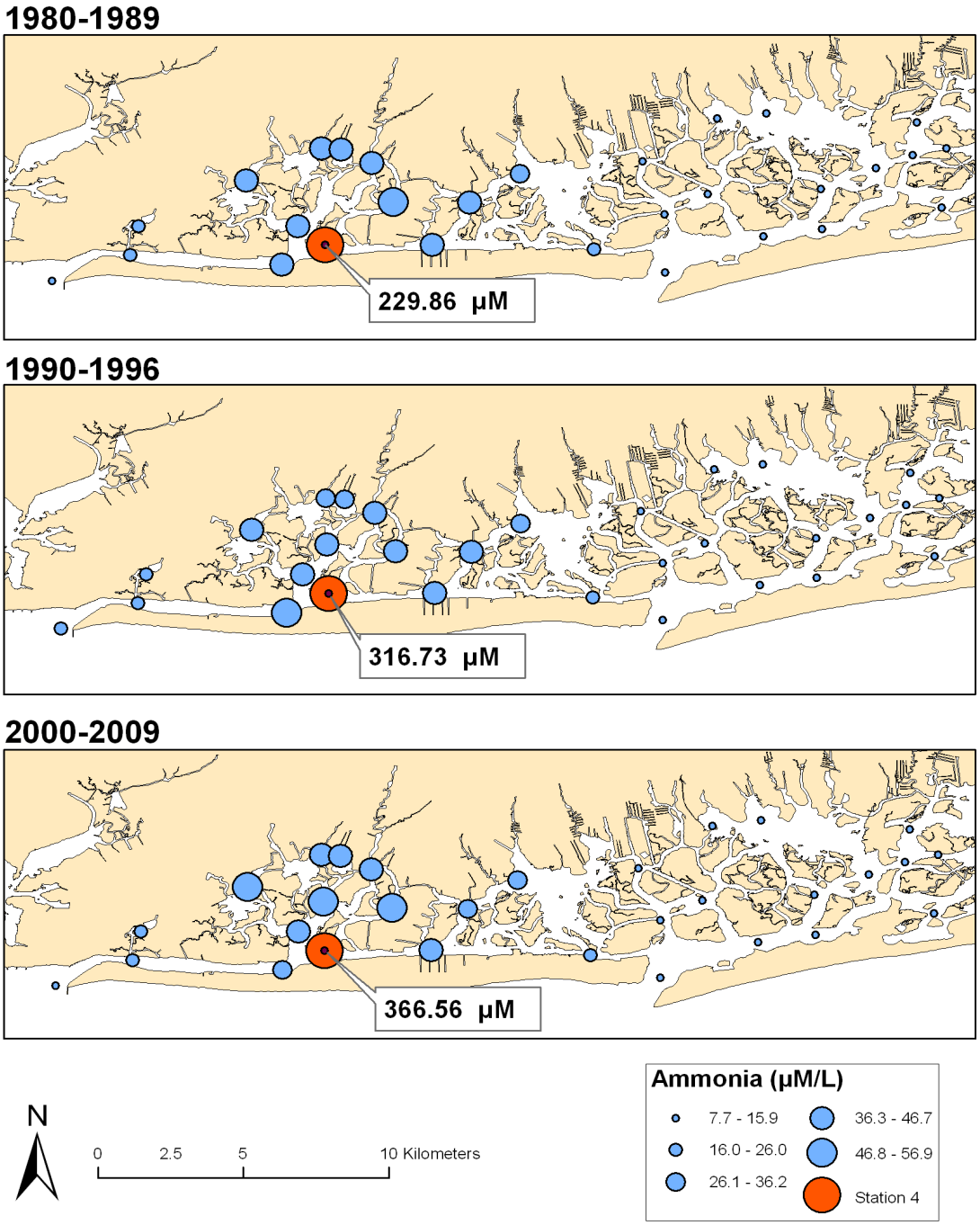
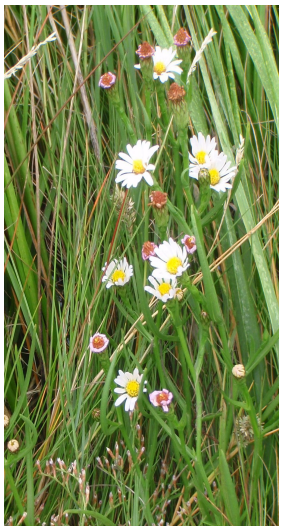


Figure 14. Ammonia values for Hempstead Bay for three decades. Station 4 (orange) ammonia values are not displayed to scale due to the large difference between Station 4 values and the rest of the bay. Questionable data from 1997-1999 have been removed.

2.9 Nitrite

Nitrite ($NO2^-$) is formed when bacteria oxidize ammonia. Although it is less toxic than ammonia, elevated levels of nitrite are still a threat to aquatic life, especially fish. In open waters, nitrite is usually oxidized to nitrate in a short time.



West Bay nitrite values increased since 1975 with the highest values at upper West Bay stations and at Station 4. Nitrite values at stations 2 and 2A were significantly lower than the rest of West Bay. East Bay nitrites remained stable month to month while West and Middle Bays showed highest nitrite values between August and November (Fig. 15). Eastern Middle Bay values were significantly higher than eastern East Bay nitrite values though both were consistently lower than those in the West and Middle Bays (Fig. 16). Station 4 nitrite values followed the increasing trend though the disparity between the readings at this station and the rest of the bay were most evident in the most recent decade (Fig.16).

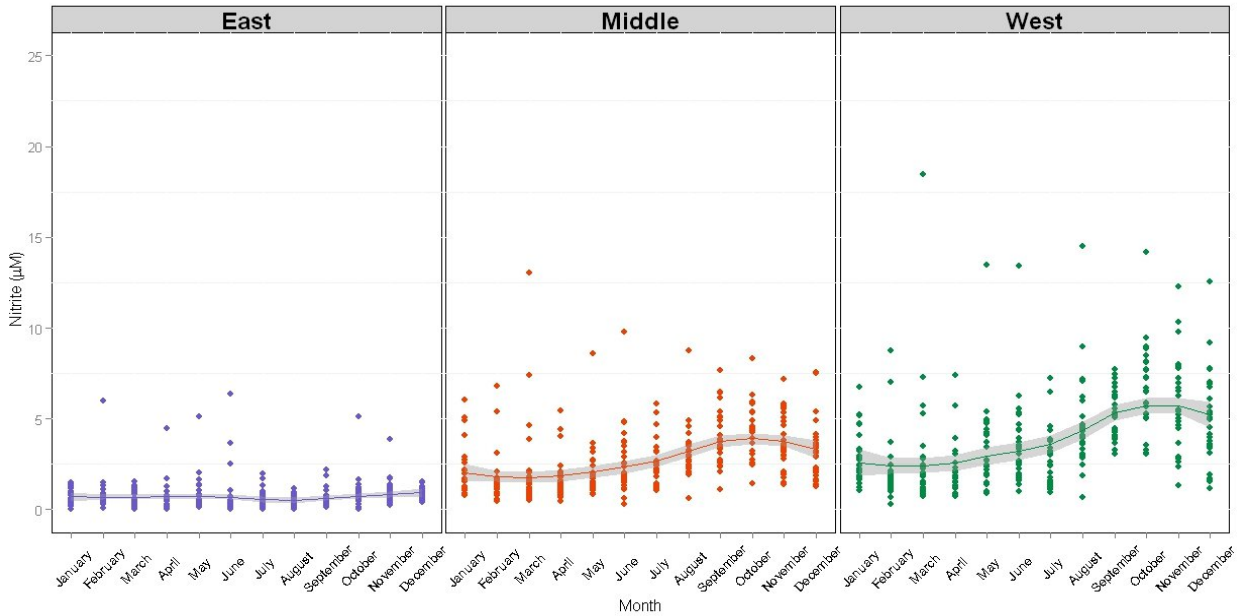


Figure 15. Monthly nitrite values for West, Middle and East Bays fit with loess curves and 95% confidence regions. Data from 1997-1999 have been removed Hempstead Bay, 1975-2001.

Nitrite *continued*

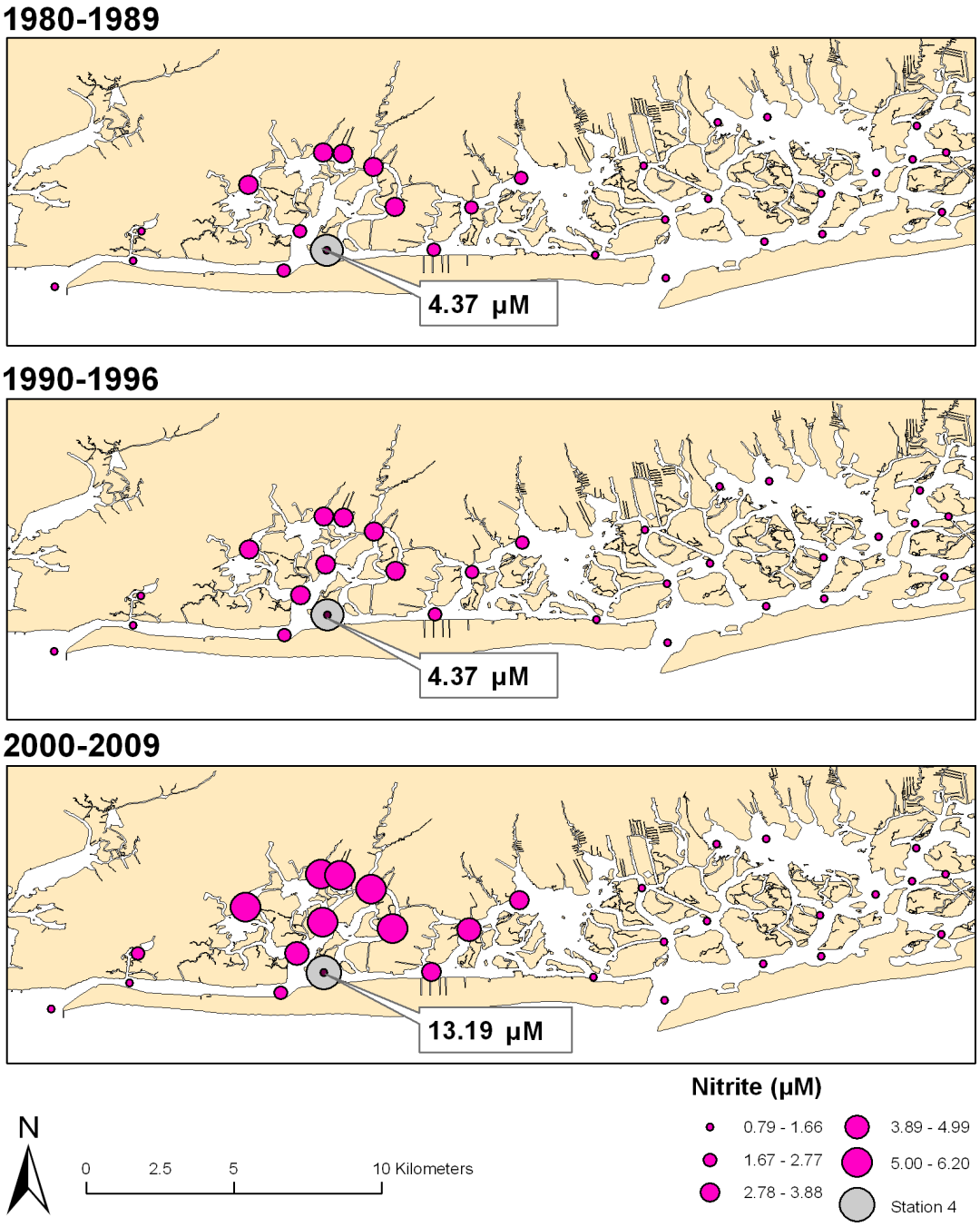


Figure 16. Nitrite values for three decades. Station 4 (gray) nitrite values are not displayed to the same scale as the symbols because the values deviate greatly from the rest of the bay. Questionable data from 1997-1999 have been removed.

2.10 Nitrate

In the next stage of the nitrogen cycle, bacteria oxidize nitrite ($NO2^-$) to nitrate ($NO3^-$), a less toxic form of nitrogen. Nitrate is a nutrient for plants and is necessary for supporting marine life. However, high concentrations can cause excessive unconsumed growth of algae and other plants. This growth can lead to accelerated eutrophication and loss of dissolved oxygen.

Nitrate values decreased throughout the bay after a peak in the late 1980's (Fig.17). Spatially, nitrate levels were lowest in the East Bay (Fig. 18) though readings at these stations followed similar temporal trends to the rest of the bay. Values at Stations 2 and 2A were significantly lower than those at the other representative stations of West Bay. Eastern Middle Bay had higher nitrate values compared to the East Bay representative stations, though this difference was nominal compared to the higher values found in the rest of Middle and West Bays. Unlike the other two nitrogen parameters (ammonia and nitrite), nitrate values at Station 4 were within the range of the other stations across the bay. Nitrate values were highest in winter months and lowest between April and June (Fig. 19).

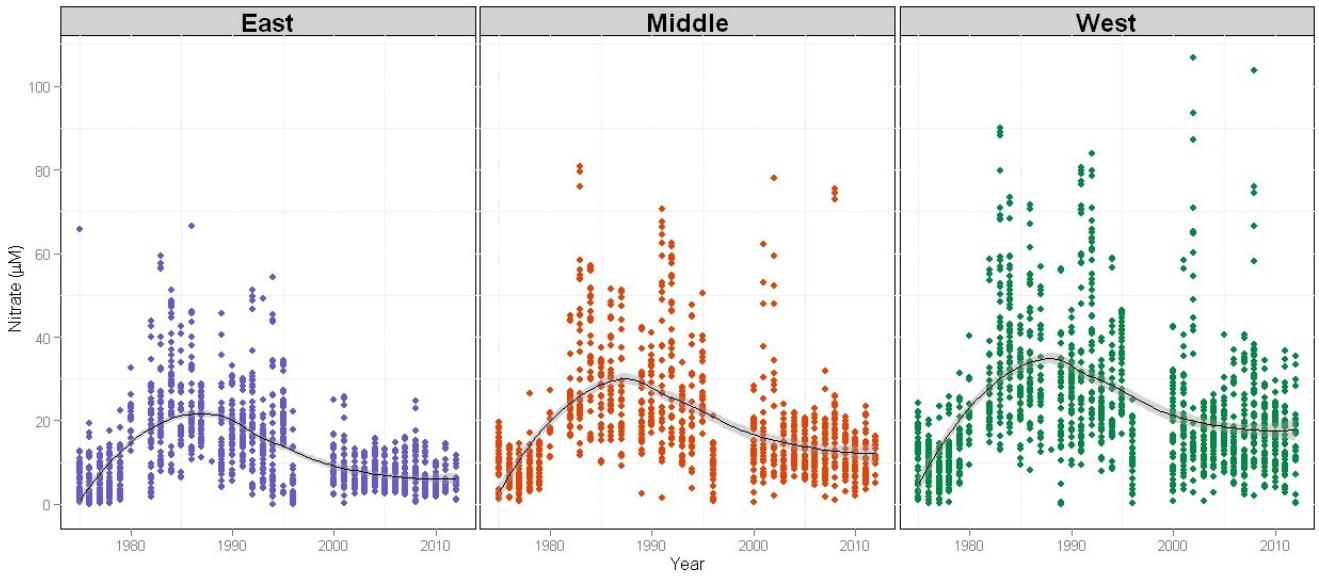


Figure 17. Yearly nitrate values for West, Middle and East Bays, 1975-2011, fit with loess curves and 95% confidence regions. Questionable data from 1997-1999 have been removed.

Nitrate *continued*

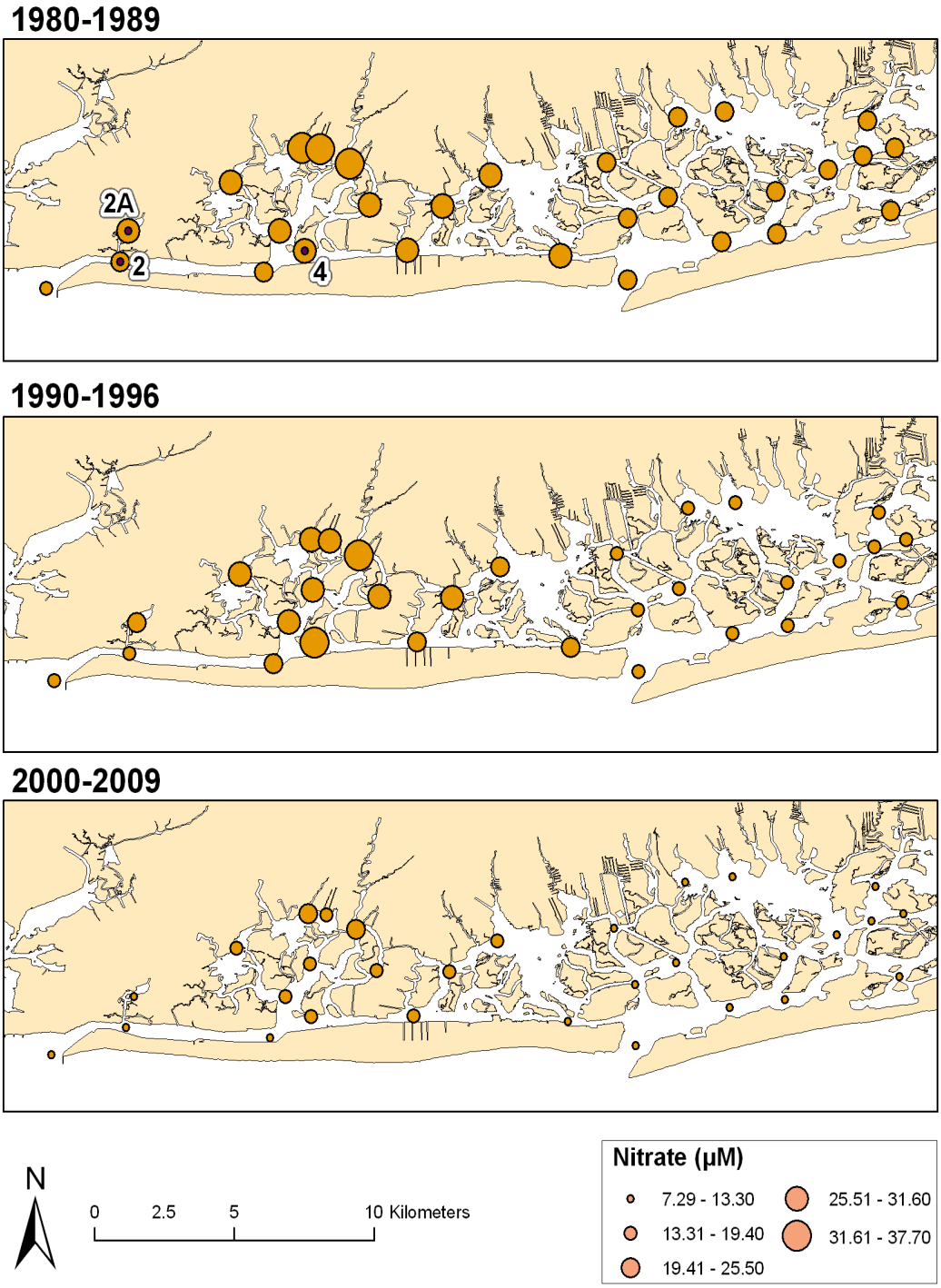


Figure 18. Nitrate values for three decades, 1980-2009. Questionable data from 1997-1999 have been removed.

Nitrate *continued*

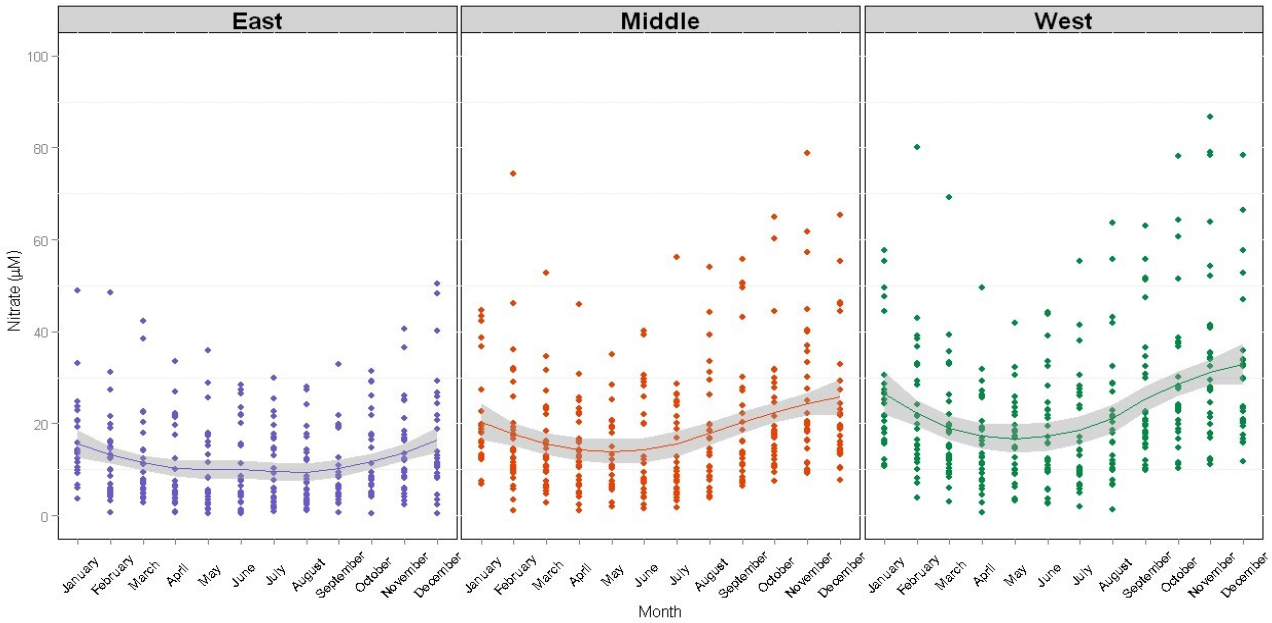
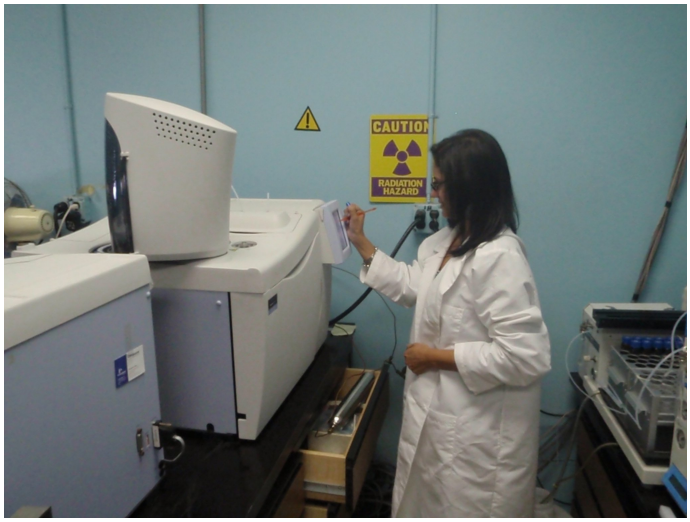


Figure 19. Monthly nitrate values, 1975-2011, for West, Middle and East Bays fit with loess curves and 95% confidence regions. Questionable data from 1997-1999 have been removed.



Water quality testing at the Town of Hempstead Laboratory.

2.11 Dissolved Inorganic Nitrogen

Dissolved inorganic nitrogen (DIN) is the sum of ammonia, nitrite and nitrate. This parameter is often used in studies instead of its components. It is an important parameter because nitrogen is usually the limiting factor of ecosystem productivity in marine systems.

Nitrogen levels were highest in West Bay and lowest in East Bay (Fig. 20). Stations 2 and 2A had lower nitrogen levels than the rest of West Bay. Station 4 was removed from the interpolation due to its disproportionately high nitrogen levels but the value was displayed for comparison. Removal of significant outliers is required for proper *spline* interpolation (see glossary).

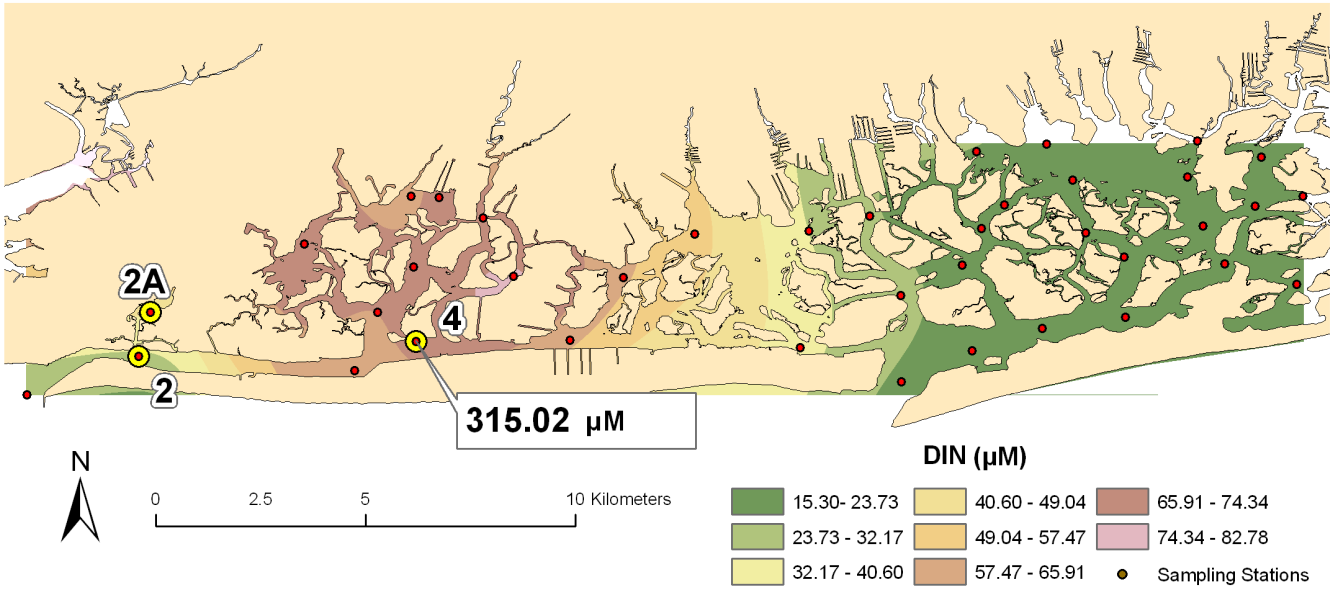


Figure 20. Interpolation of DIN values. Hempstead Bay, 1975 - 2011. The Station 4 value was not included in the interpolation, but is included for comparison. Questionable data from 1997-1999 have been removed.

2.12 Chlorophyll ‘a’

Chlorophyll 'a' is the primary green pigment that allows plants to capture energy from sunlight and produce sugars, proteins, and other organic compounds, and is the predominant type of chlorophyll found in algae. High levels of Chlorophyll 'a' indicate nutrient loading because excess nutrients fuel the growth of algae. Areas with lower algal levels have clearer water and fewer harmful blooms, but insufficient levels of phytoplankton, or the wrong species, can negatively impact filter feeding species and other herbivores. The ideal levels of Chlorophyll 'a' indicate that there is enough algae to fuel the food web, but not so much that hypoxic conditions are prevalent.

Chlorophyll 'a' levels were highest at upper West Bay stations and lowest in the East Bay (Fig. 21). Station 2A, site of the Village of Lawrence Wastewater Treatment Plant, had levels similar to upper West Bay though Station 2 showed much lower values. Eastern Middle Bay had significantly higher Chlorophyll 'a' values compared to the East Bay representative stations, but this difference was nominal compared to the higher values found in Middle and West Bays. Seasonally, Middle and West Bay Chlorophyll 'a' values spiked with warmer temperatures in early spring and then again in June and July (Fig. 22). Inter-year examination of this seasonal trend throughout the years showed that the timing and magnitude of the chlorophyll 'a' spike varied drastically (Fig. 23). In 2011, Chlorophyll 'a' values peaked earlier in the year, while the peak occurred around July or August in many other years. Warmer spring and winter temperatures may have caused shifts in the timing of when chlorophyll values were the highest.

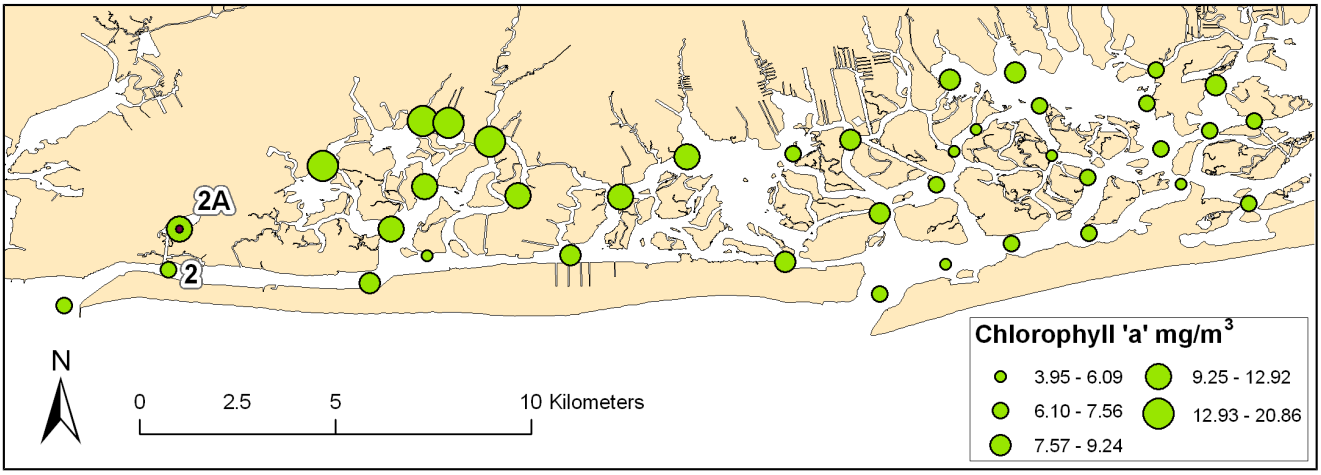


Figure 21. Chlorophyll 'a' values averaged for each sampling station. Hempstead Bay, 1975-2011.

Chlorophyll 'a' *continued*

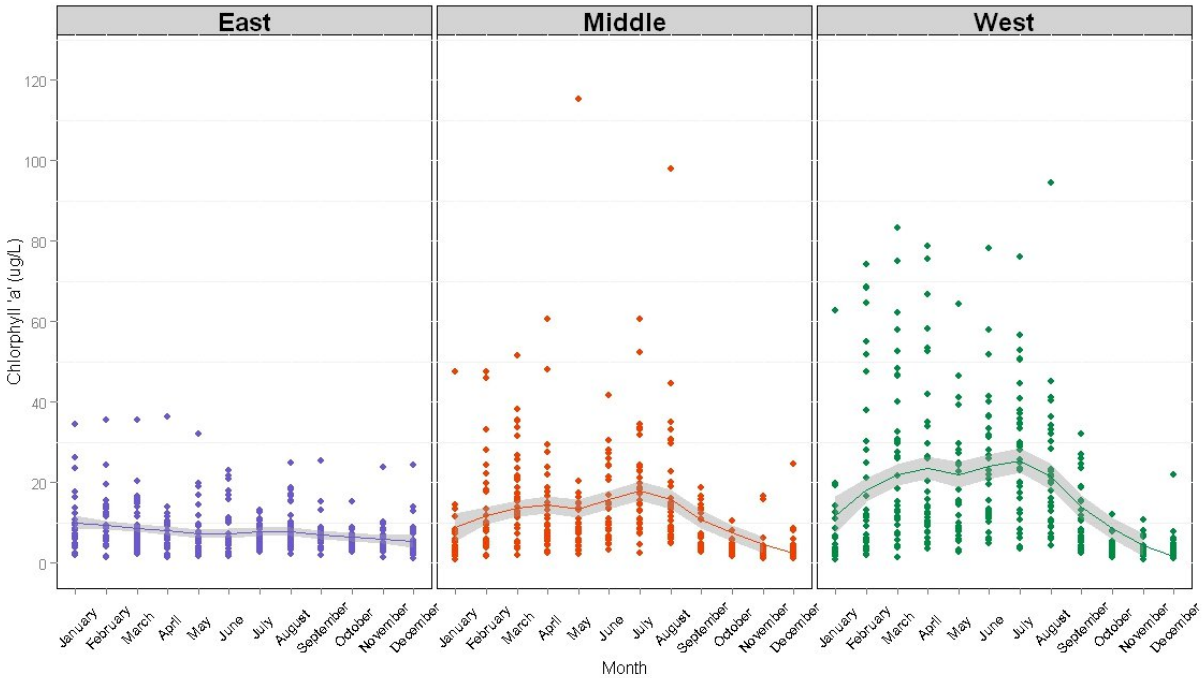


Figure 22. Monthly chlorophyll 'a' values from East, Middle, and West Bays from 1975-2011, fit with loess curves and 95% confidence regions.

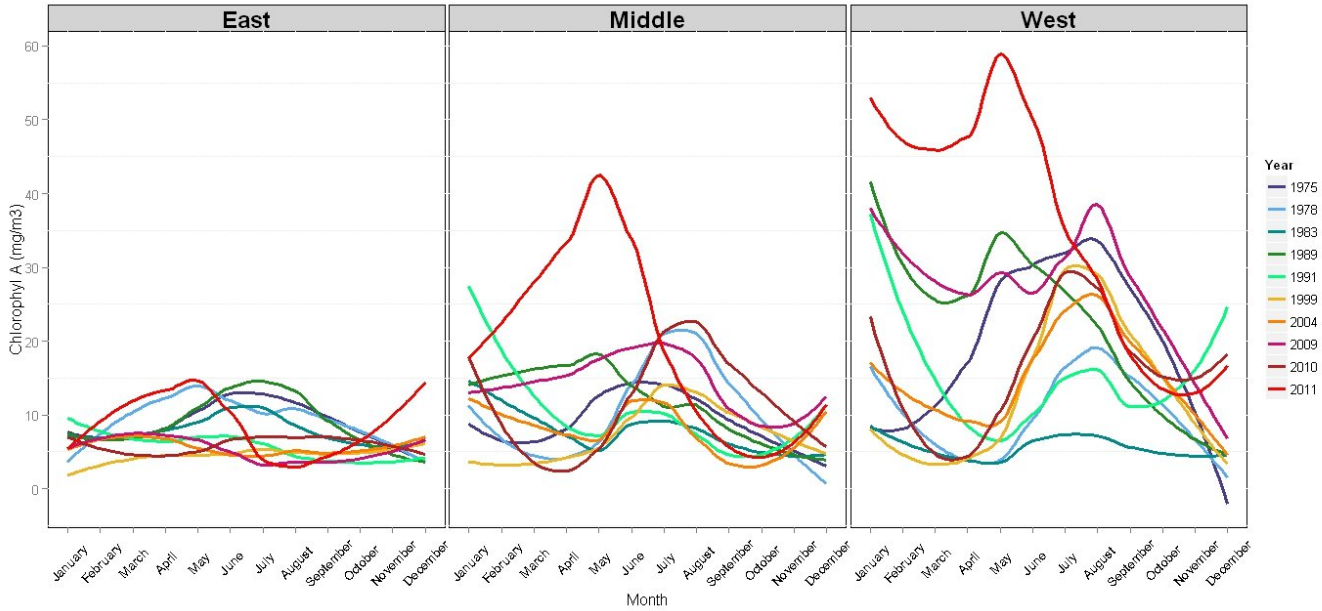


Figure 23. Chlorophyll 'a' loess curves for each year and plotted separately for East, Middle, and West Bays, 1975-2011.

2.13 Total Coliform

Total coliform bacteria tests record the general prevalence of bacteria similar to the types that may be associated with contamination by using a most probable number method (MPN) as described by the Federal Environmental Protection Agency (EPA) standard methods. The most probable number readings are not actual bacteria counts, therefore simple means and standard deviations are not used. A change in the chart used for the interpretation and recording of laboratory results was mandated by the NYS DEC around 2000, adding to the difficulty of correctly interpreting trends through time. Use of the earlier chart resulted in the reporting of some higher readings that would unduly exaggerate subsequent declines. In order to facilitate realistic interpretations of changes over time in the estuary, readings were reevaluated to estimate a consistent reporting in line with the more recently mandated chart. To facilitate comparisons, the accepted methods of interpreting the results were used to determine trends, e.g. the federal and state standard's use of the geometric means and number of events exceeding the standards for shellfish lands. New York State has used total coliforms for the management of shellfish lands in this area, so this section is analyzed in detail.

Overall, total coliform values decreased through time in all parts of the estuary that were studied, with West and Middle Bay stations usually reporting the highest readings (Figure 24; next page). Comparisons between eastern-Middle Bay (Stations 15, 16, 17) and northern-East Bay (24, 25, 26, 34; see Figure 1; page ii) revealed that northern-East Bay had significantly higher values than southern Middle Bay. Overall, the East Bay region reported low coliform readings. After calculating the geometric mean for each station for each of the three decades shown in Figure 24, we determined that no stations exceed the NYS DEC total coliform water standard of 10,000 MPN/100 ml for fishing and an increasing number seem to meet the 70 MPN/100 ml needed for the certification of shellfish lands.

Harbor seals, winter visitors to the bay

Total Coliform *continued*

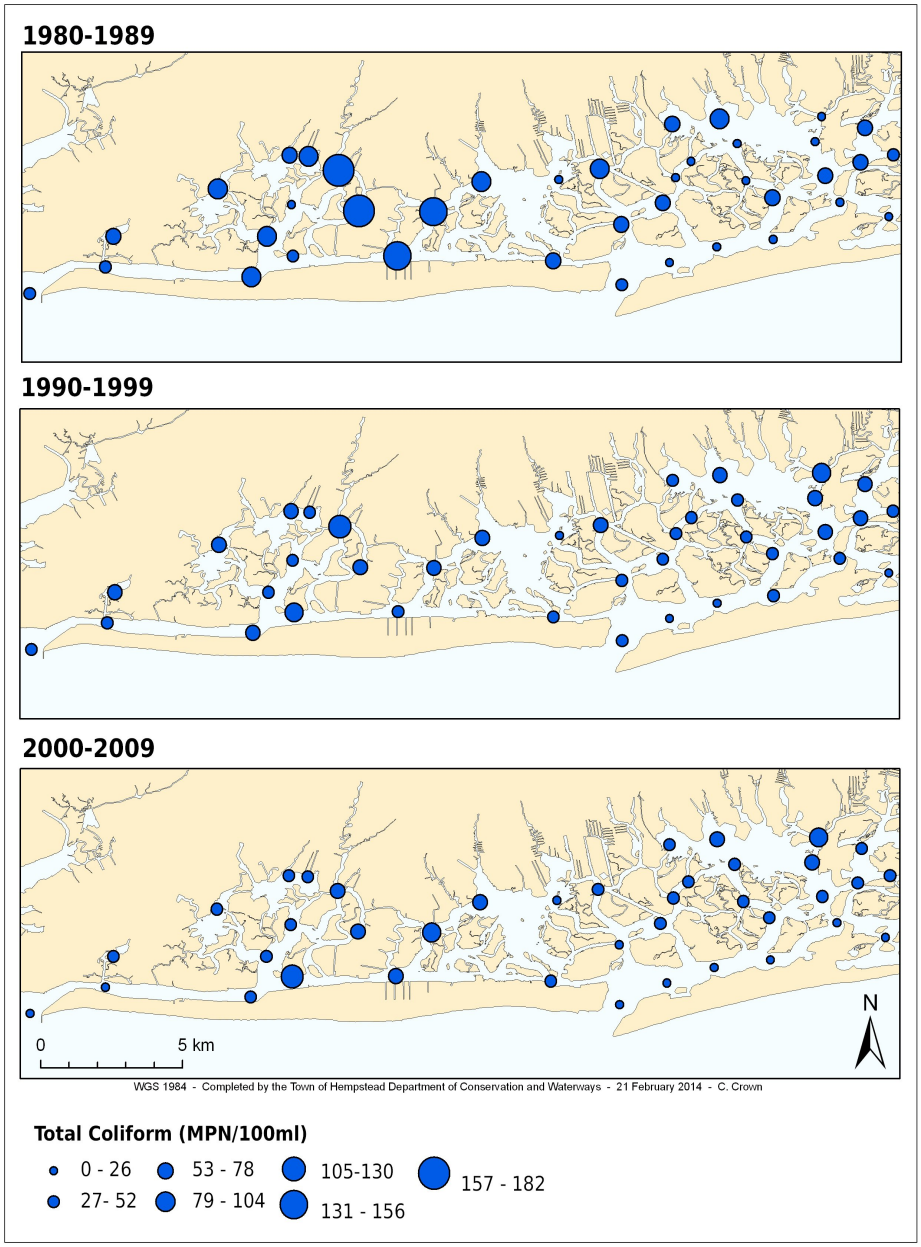


Figure 24. Total coliform readings for three decades averaged at each sampling station in Hempstead Bay, 1980-2009.

Time trends are easily seen in plots that include all stations, even in the reevaluated readings that potentially de-emphasize them (Figures 25 and 26). Two periods of coliform reduction appear to occur in the data that do not relate to the timing of methodological changes. Starting in the early 1990s, a gentle decline is seen that may be be related to the introduction and increasing acceptance of the pooper-scooper laws that were instituted in the 1980s. The reduction in the amount of dog waste in the streets was obvious at the time, and is potentially reflected in the coliform data. A second abrupt drop in counts, particularly noticeable in East Bay, occurred in 2008 (Figure 27), and may be the result of the Town of Hempstead's (TOH) purchase and operation of two pump-out boats. The bay is a no discharge zone, but some parts of the bay did not have ready access to on-shore pump-out facilities such as the TOH run facilities in Guy Lombardo Marina in Freeport and the East Marina in Point Lookout. The two TOH pump-out boats can travel to and service the boating public who may otherwise be tempted to release “black water” into the bay.

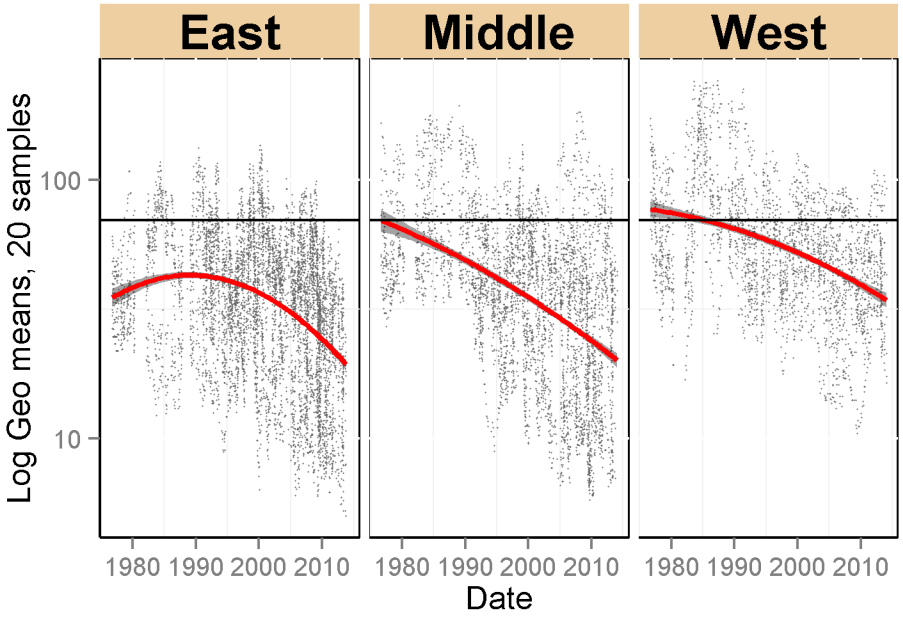


Figure 25. The 20-sample moving geometric means of Total Coliform MPN/100 ml data were plotted to log scale for each station over time. Generalized additive model (GAM) curves are included that show the trends in the geometric means for each bay.

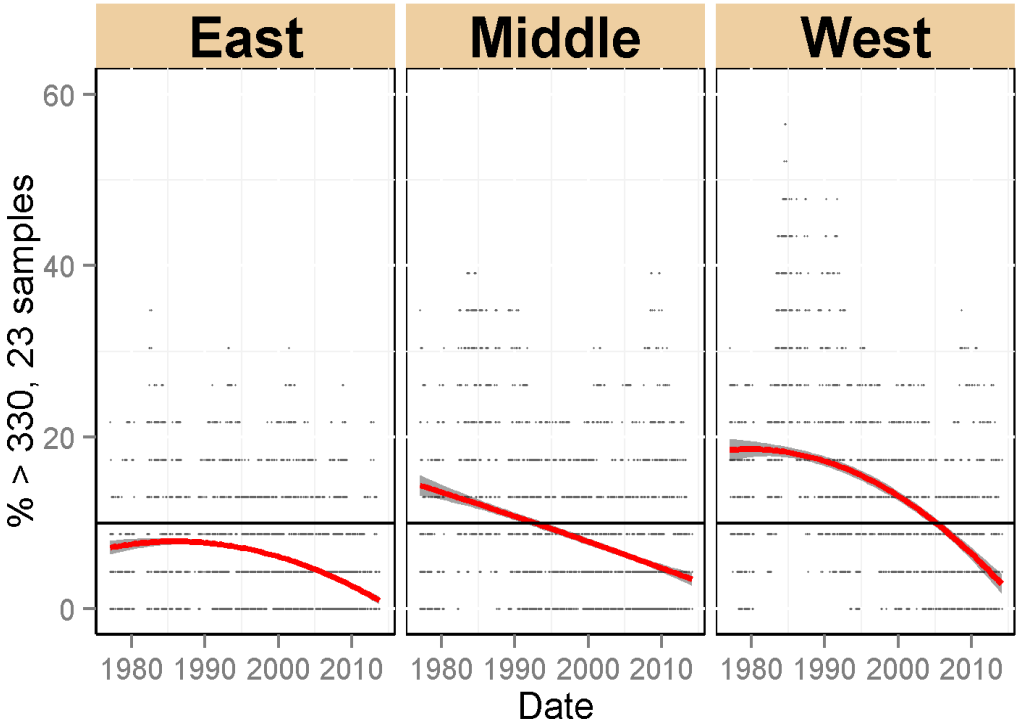


Figure 26. The moving 23 sample percent of Total Coliform data exceeding 330 MPN/100 ml for each station that was sampled for the entire time interval being reported and generalized additive model (GAM) curves showing the trends over time for each bay.

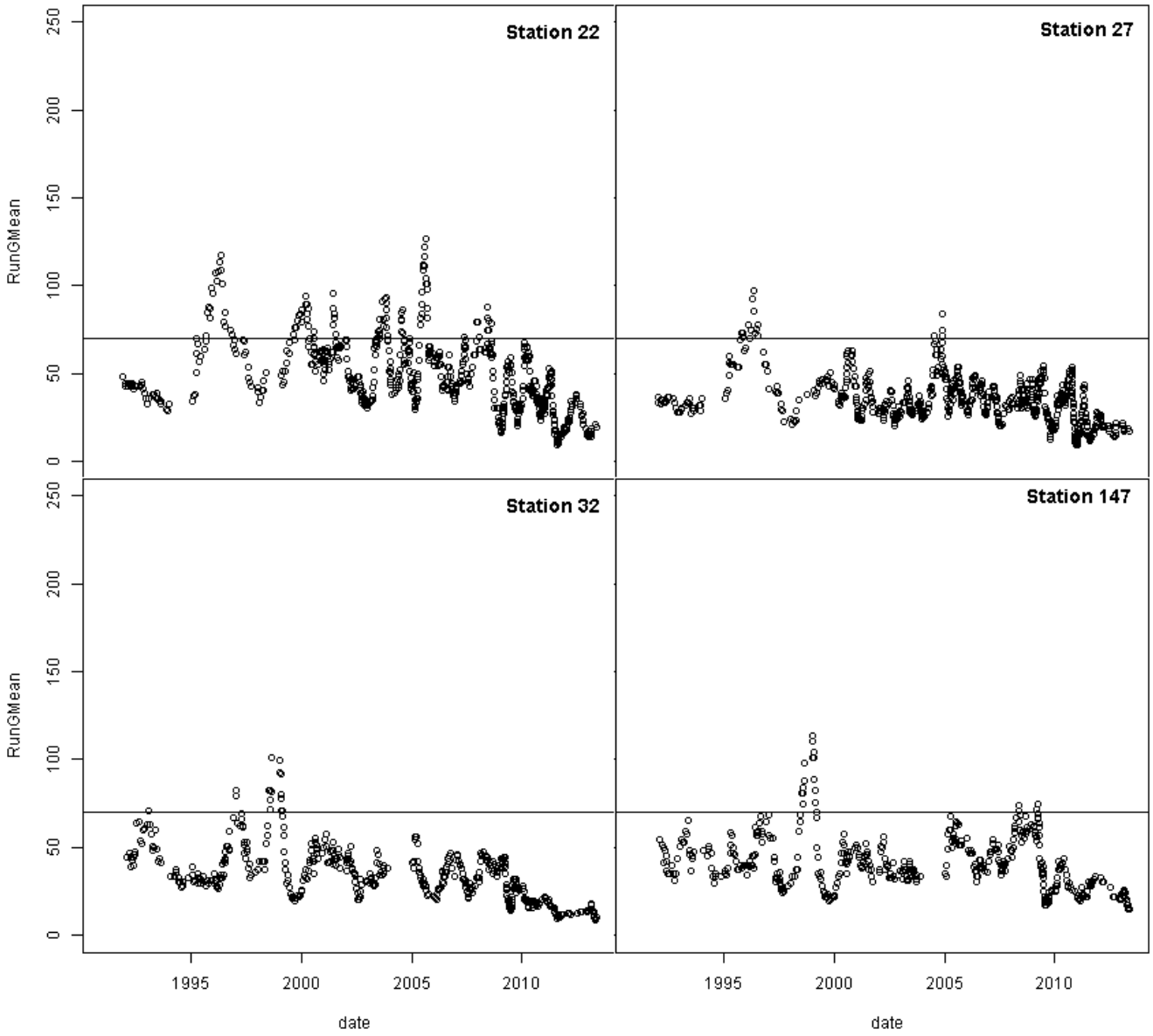


Figure 27. Moving geometric means of four typical stations in East Bay showing an apparent drop in total coliforms after 2008.

One of two exceptions to the general decline in the coliform readings is Station 34 which showed a general increase up until the 2008 decline (Figure 28). The other exception was at Station 4 discussed separately below.

Seasonal variations at each station can be important for regulatory uses. The overall variations for all the years and all the bays is shown in Figure 29. The bar graphs start with January on the left and the geometric means for each month in order from 1 to 12. It can be seen that some locations had higher counts during the summer months (the center of the graphs) and others had higher counts during the winter. This graph includes all data and therefore does not adequately reflect the more recent periods of decline.

Seasonal variations in the East Bay and eastern Middle Bay after the pump-out boats started their work (Figure 30) show a tendency toward higher winter total coliform readings through most of the bay. Only two inland stations, 14 by Freeport and 34 near Seaford, showed high late spring and summer readings while other stations on the northern part of the bays showed August and September spikes. The origins of these patterns are under investigation. The remaining stations showed higher winter readings, likely from overwintering wildlife.

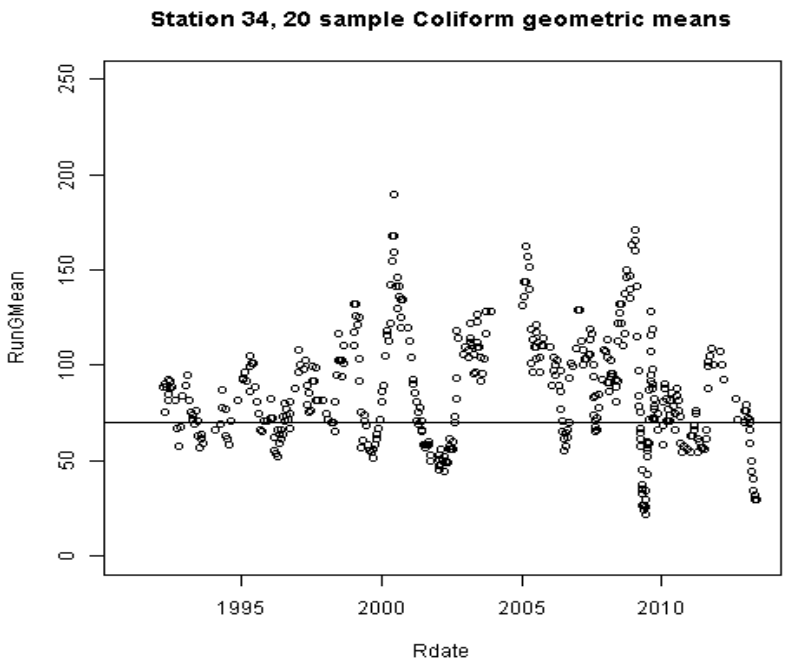


Figure 28. Station 34 from upper East Bay, showing an increase in the MPN/100 ml readings until about 2009.

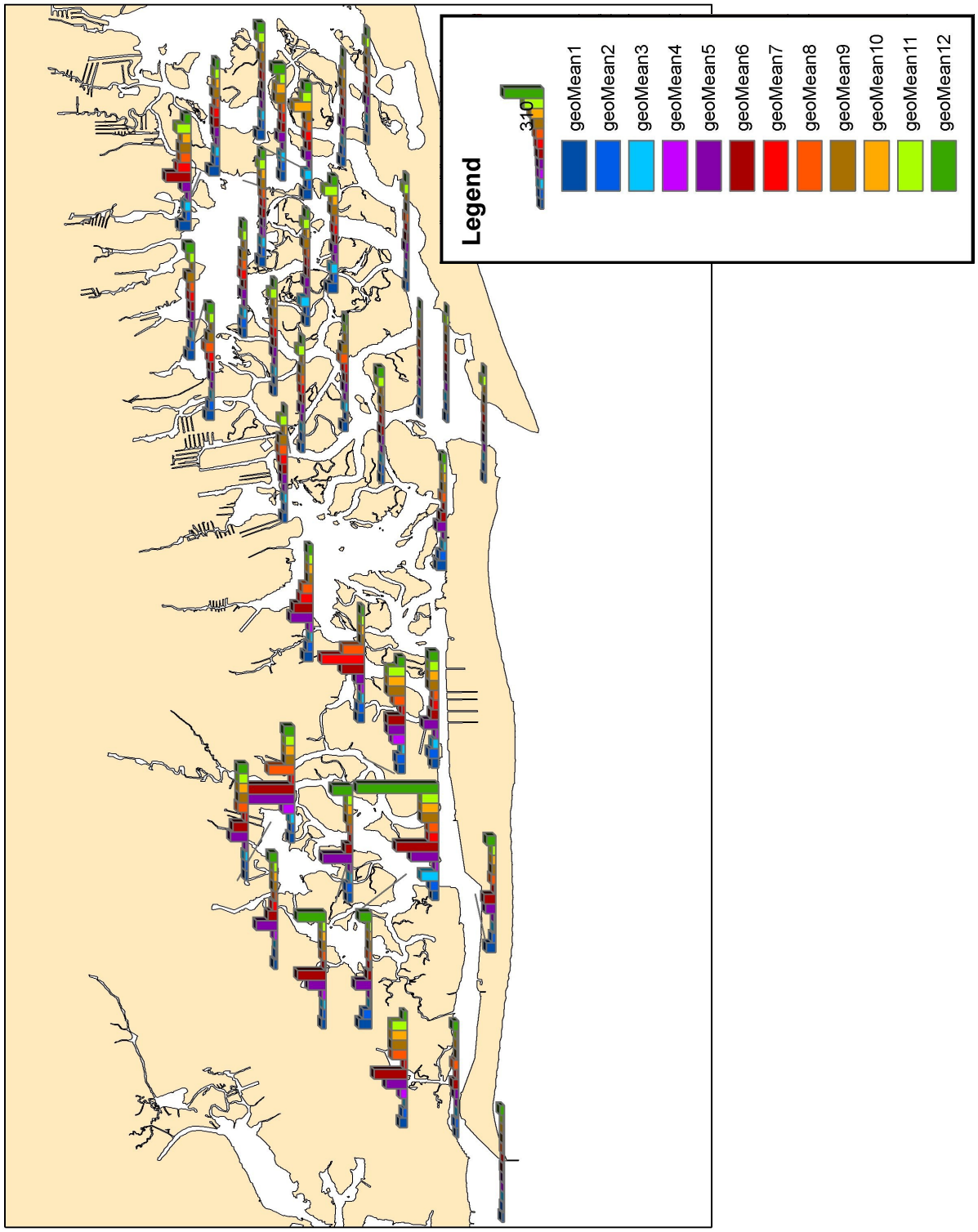


Figure 29. The geometric means of the MPN readings for the entire 1975-2013 time period calculated separately for each month to show the seasonal variation at each station.

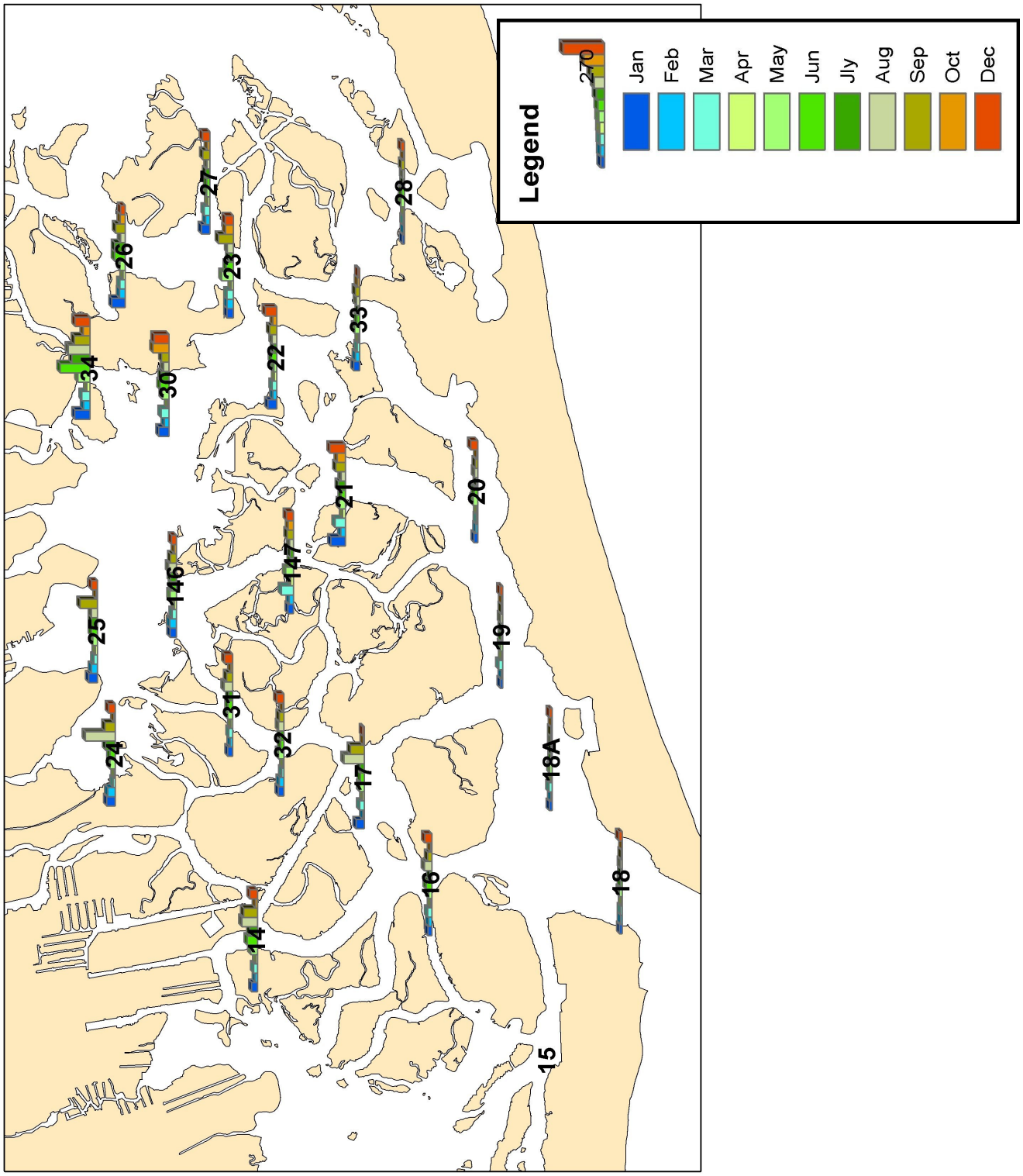


Figure 30. The East Bay geometric means of the MPN readings for the 2008-2013 time period calculated separately for each month to show the seasonal variation at each station after the pumpout boats started operating.

2.14 Fecal Coliform

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other warm-blooded animals. This implies that the water source may have also been contaminated by pathogens (disease-producing bacteria or viruses) that can exist in fecal material. The presence of fecal coliform(s) is an indicator of potential health risks, most notably waterborne gastroenteritis.

Fecal coliform values mostly fluctuated through time in Hempstead Bay, showing an overall trend that is less clear than that of Total Coliforms. In the most recent decade West Bay showed a decline while some Middle and East Bay stations reveled increases in fecal coliform values (Fig 31). No single location consistently reported higher fecal coliform values than the others. Station 2A, next to the Lawrence outfall, had levels similar to upper West Bay, although the nearby Station 2 reported lower values. The Bay Park outfall in the lower West Bay produced mid-level results and is not a major source. Based on these results and the existence of sewering in locations near high readings, additional sampling is being implemented to determine the precise sources that may include illicit discharge or valuable and protected wildlife. After calculating the geometric mean for each station for the recent decades, we determined that no stations exceeded the NYS DEC fecal coliform water standard of 200 MPN/100 ml for fishing (SB, SC; see State Water Quality Standards, page 7).

Osprey

Fecal Coliform *continued*

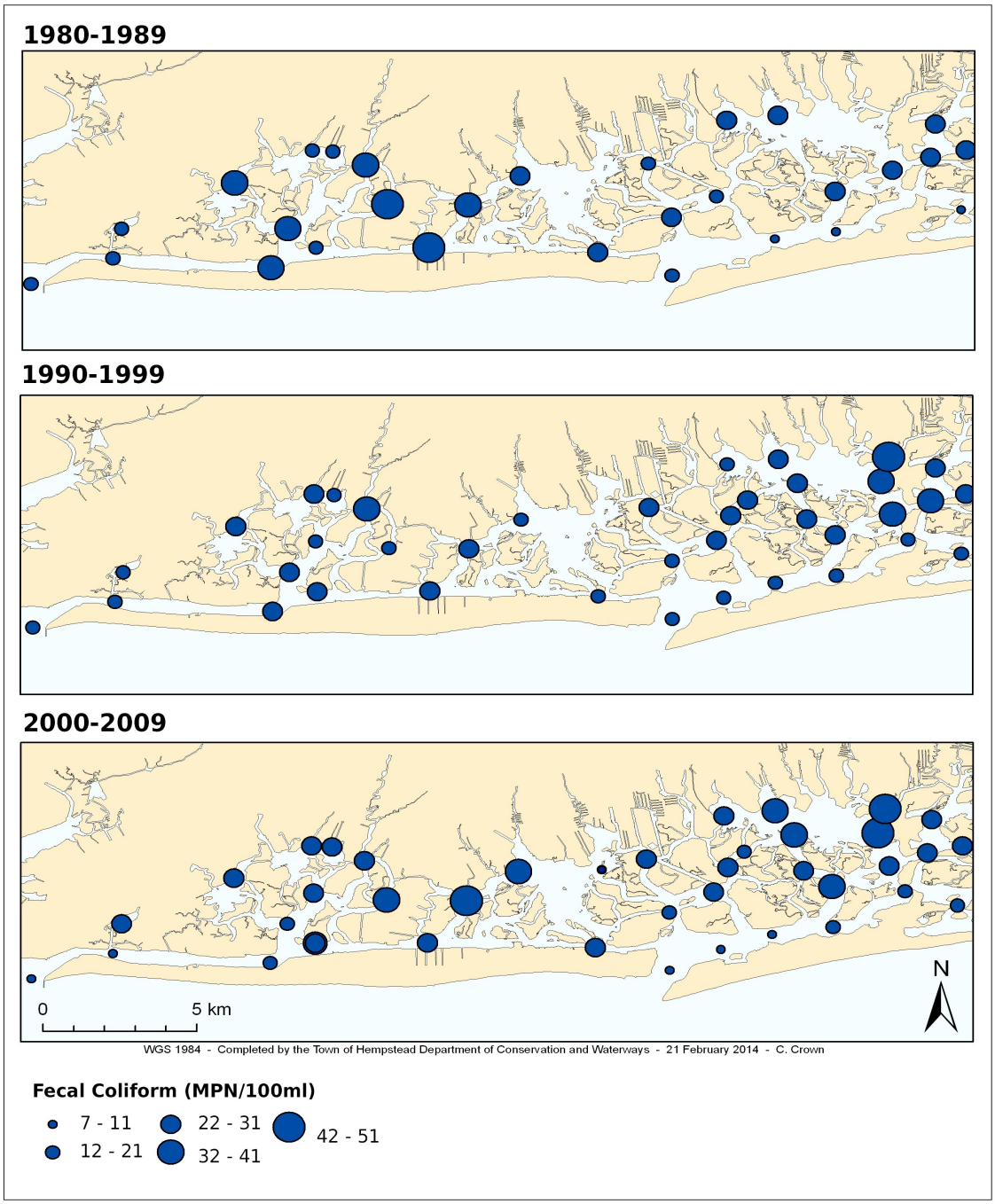


Figure 31. Fecal coliform readings for three decades averaged at each sampling station. Hempstead Bay, 1980-2009.

2.15 Secchi Transparency

A Secchi disk is used to estimate the clarity of surface waters and is estimated using a Secchi disc. High Secchi transparency, associated with clear water, is typically depths of 5 feet or greater. Low Secchi transparency, 3 feet or less, are is typically indicative of turbid or light limiting conditions. Low Secchi readings are often associated with degraded waters because transparency decreases as suspended sediments or increased algal abundance, but can indicate high productivity. Clear water is often indicative of a healthy bay though high Secchi readings can also be correlated with waters mostly devoid of marine life.

Secchi values were highest and most stable in the East Bay. Middle and West Bay displayed seasonal trends in Secchi readings and were coincidental with chlorophyll 'a' fluctuations. Higher chlorophyll 'a' values were paired with lower Secchi readings and vice versa (Fig. 32). Chlorophyll “a” values may be used as a qualifier of Secchi values. Stations 2 and 2A had higher Secchi readings than the upper West Bay stations.

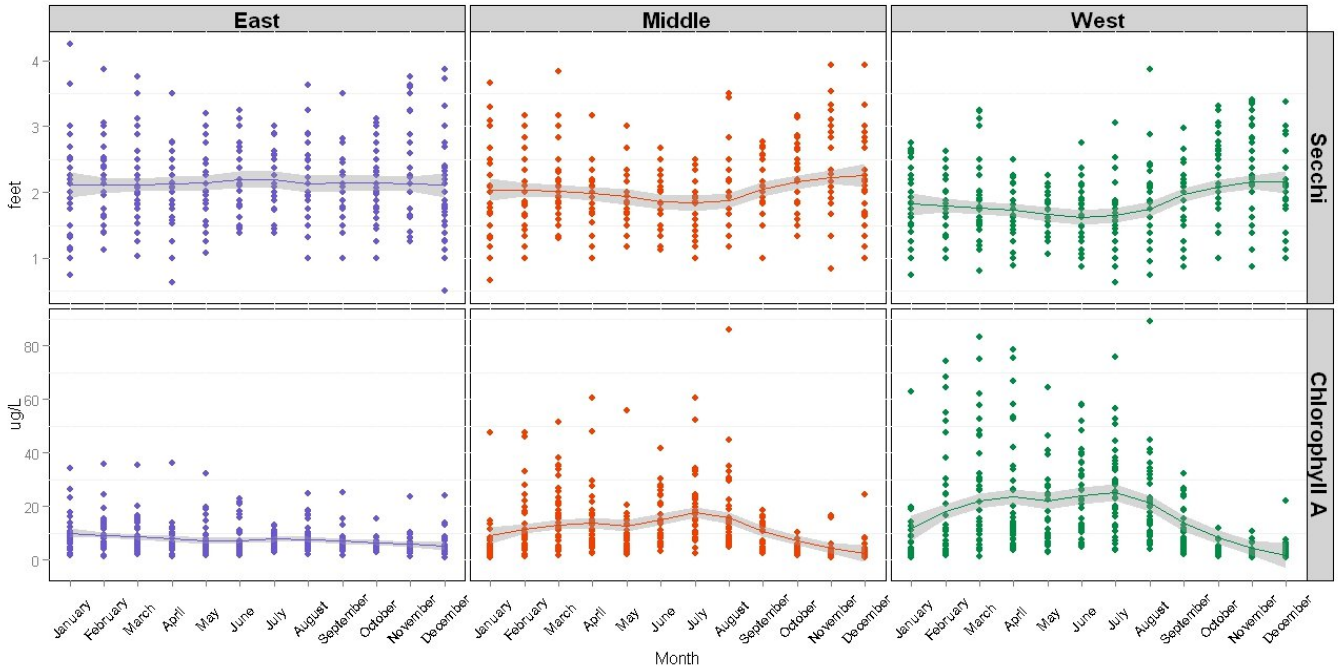


Figure 32. Monthly Secchi clarity and Chlorophyll “a” values from East, Middle, and West Bays fit with a loess curves and 95% confidence regions. Hempstead Bay, 1975-2011.

2.16 Silicates

Silicates are important primarily for the production of protective structures on many plants. It can be a limiting nutrient for diatoms, a useful group of algae, that require silica for the production of their external frustules. Available silicates can be an indicator of useful rather than harmful phytoplankton.

Silicate levels were highest in the West and Middle Bays, with disproportionately high values at station 4 (Figure 33). All three sections of the bay followed a seasonal trend with the lowest values occurring in the late winter months (Figure 34), indicating the timing of the spring diatom blooms. Stations 2 and 2A had significantly lower values than the upper West Bay.

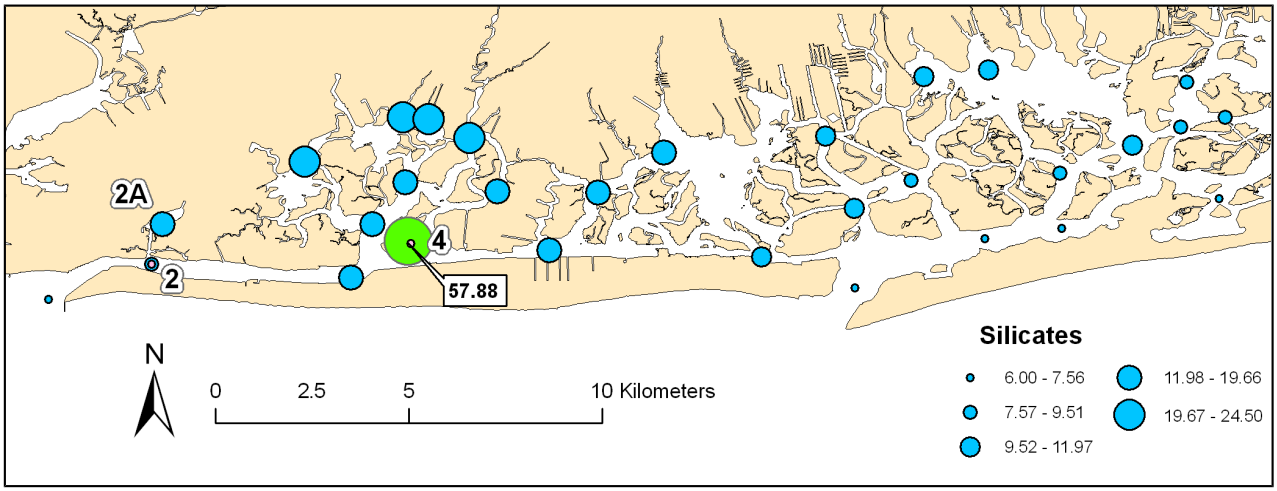


Figure 33. Silicate readings (μM) averaged at each sampling station. Hempstead Bay, 2007-2011.

Silicates *continued*

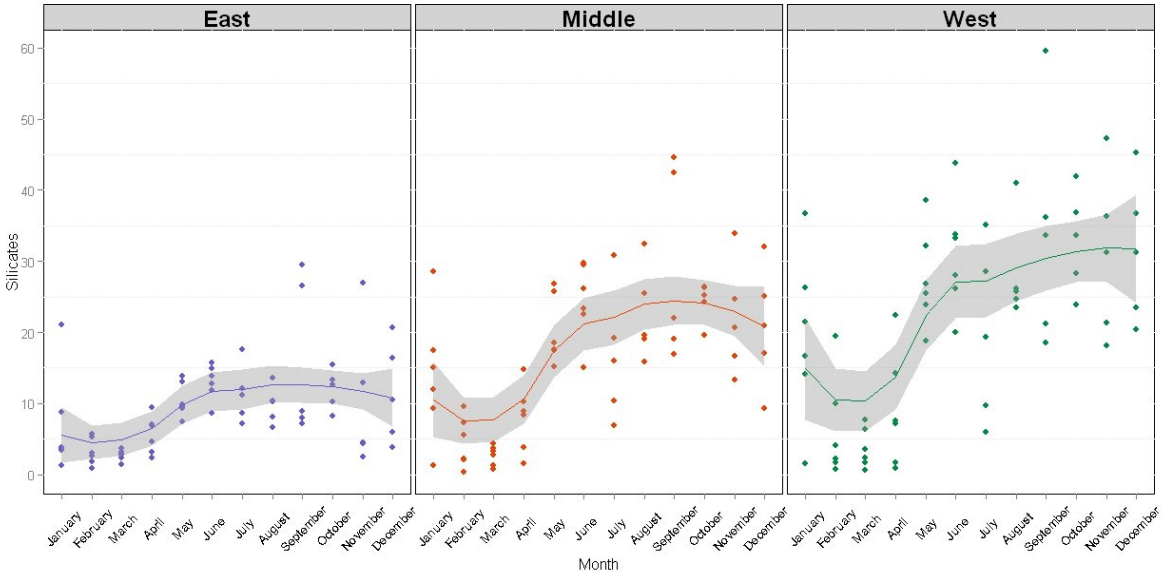
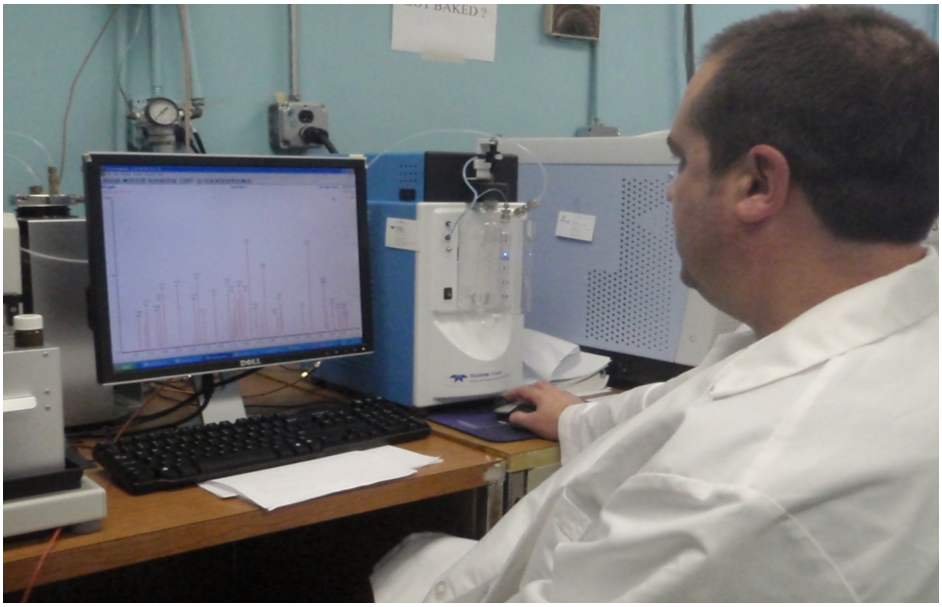


Figure 34. Monthly silicate values (μM) of East, Middle, and West Bays from 2007-2011 fit with loess curves and 95% confidence regions.



Water quality testing at the Town of Hempstead Laboratory

2.17 Urea

Urea is a simple organic nitrogen compound. Elevated levels often indicate untreated waste from anthropogenic sources or excretion from mammals. Some fertilizers are urea based and may contribute to elevated urea levels.

High urea values were reported in the West and Middle Bays. Specifically, the highest values were found at Station 5 in West Bay (Fig. 35 and36). Stations 2A and 2 had significantly lower urea values than upper West Bay. Yearly trends indicate that urea has decreased in all three bays though additional years of data are needed to confirm this finding (Fig. 37). Comparisons of urea values in eastern Middle Bay (Stations 14, 16, and 17) and eastern East Bay (22, 23, 26, and 27) revealed that eastern East Bay had higher readings in the north and east when compared to values in the southwestern part of that bay.

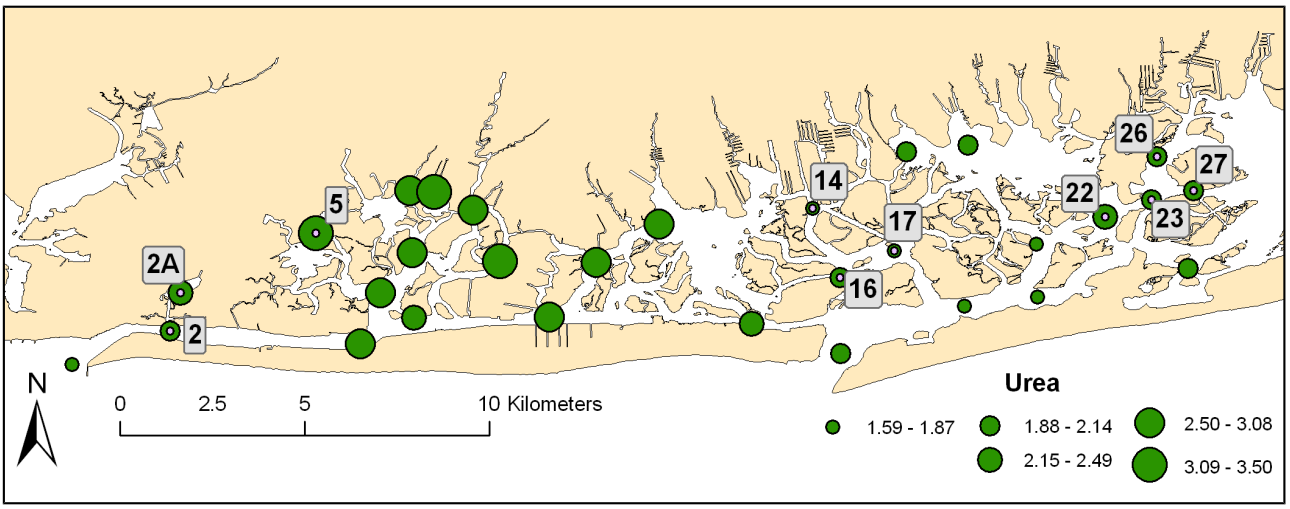


Figure 35. Urea values (μM) averaged for each sampling station, Hempstead Bay, 2007-2011.

Urea *continued*

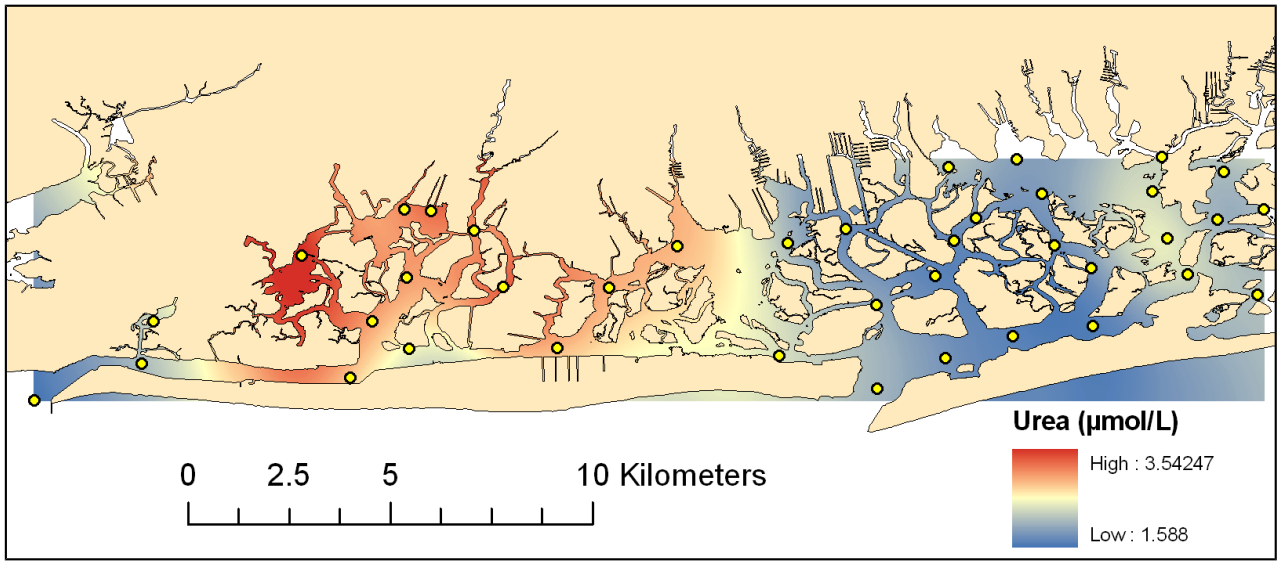


Figure 36. Interpolation of urea values in Hempstead Bay, 2007-2011.

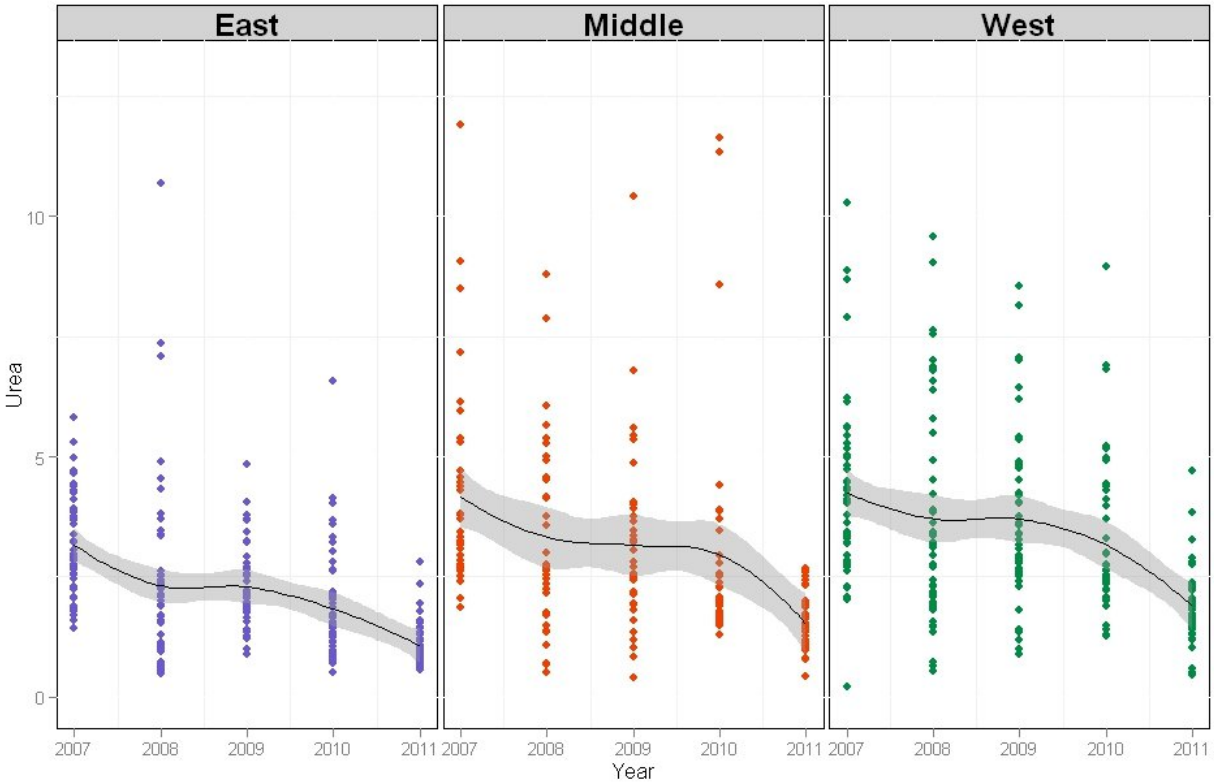


Figure 37. Yearly urea values (µM) of East, Middle, and West Bays fit with loess curves and 95% confidence regions. Hempstead Bay, 2007 – 2011.

2.18 Fluorometric Chlorophyll

Fluorometric chlorophyll readings are now being collected in parallel with Chlorophyll 'a' using a YSI 6600 SONDE (see glossary). This parameter measures algae but uses a different mix of biological pigments than the Chlorophyll “a” test.

Fluorometric chlorophyll values were highest in the West and Middle Bays, with the highest averages recorded in upper West Bay stations (Stations 5, 8, and 9). The lowest readings occurred at stations near the ocean (Fig. 38). All three sections of the bay followed a seasonal trend with highest values occurring in mid- to late summer (Fig. 39).

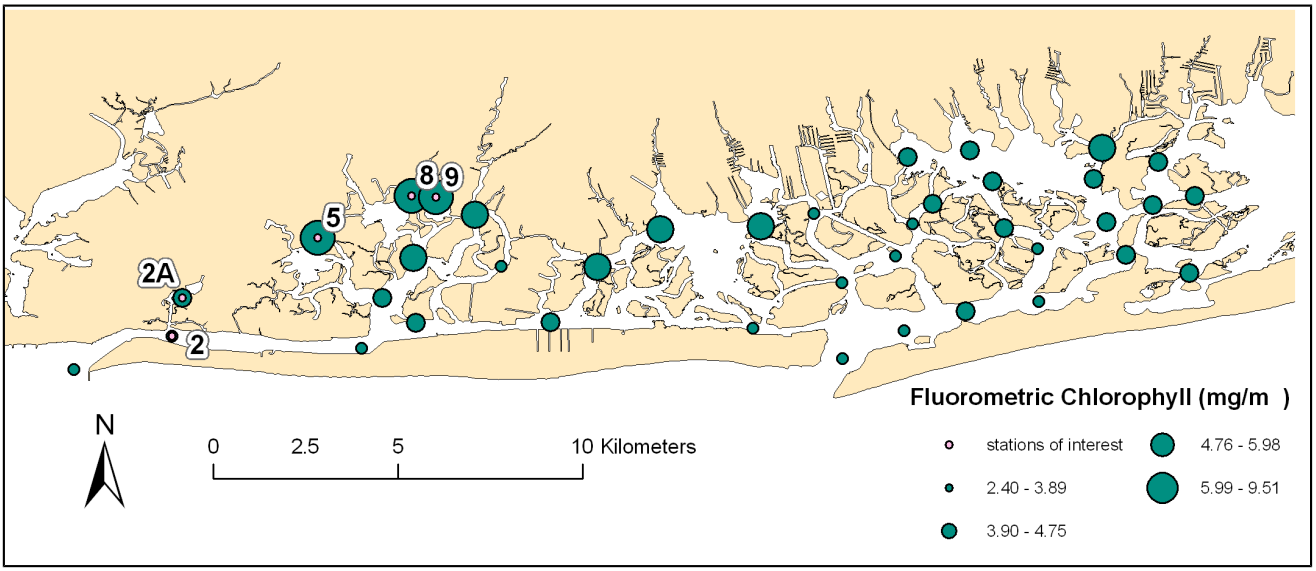


Figure 38. Fluorometric chlorophyll values averaged for each sampling station, Hempstead Bay, 2007-2011.

Fluorometric Chlorophyll *continued*

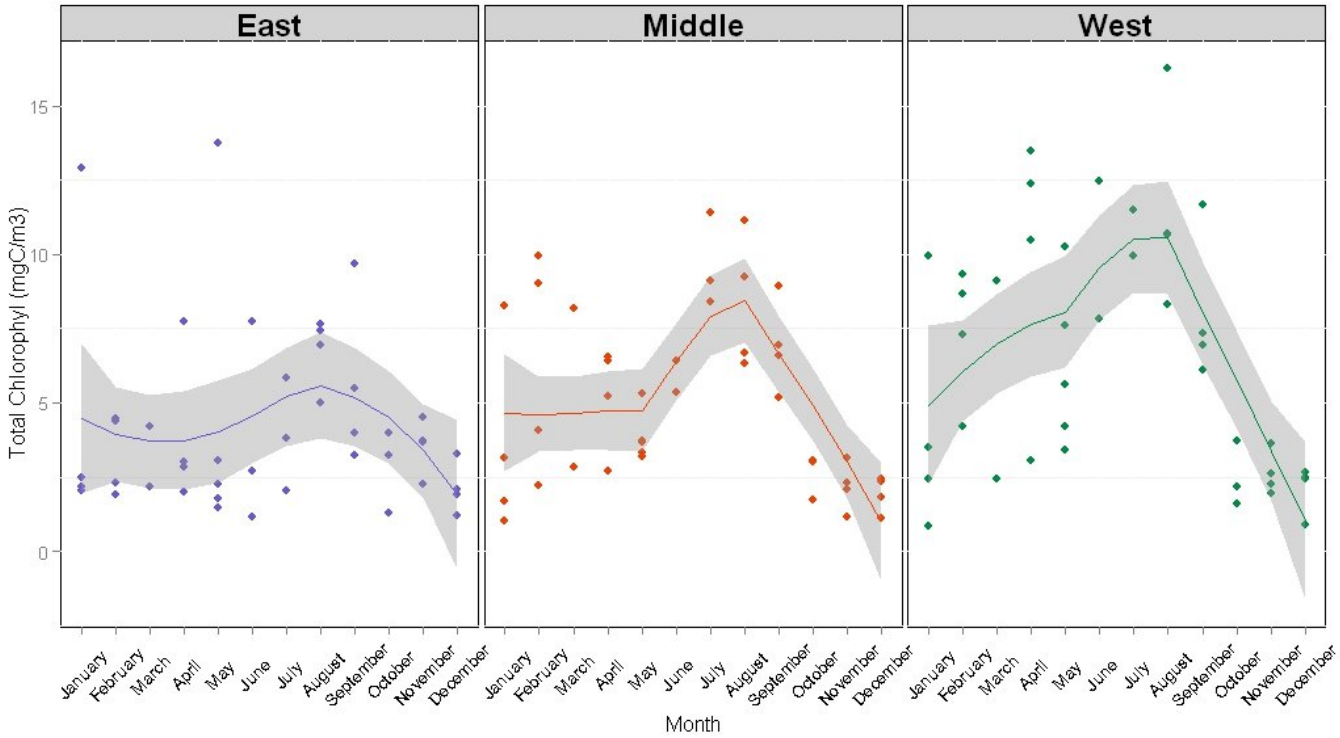


Figure 39. Monthly fluorometric chlorophyll values of East, Middle, and West Bays from 2007-2011 fit with a loess curve and 95% confidence regions.

2.19 Biological Oxygen Demand

Biological oxygen demand (BOD) is one of the older water quality indices and measures the oxygen utilized by organisms in a water sample when incubated without light. Under the Clean Water Act, BOD is listed as a conventional measure of pollution, however a different version of the technique is to be used in determining whether effluent coming out of sewer water treatment facilities meet regulatory standards. The procedure for the bays takes a total of five days to determine the BOD from a water sample. During the 1960s to 1990s, two water samples were taken at each station using paired glass Winkler bottles, one was fixed to prevent changes in DO, and both were immediately put on ice. These samples are collected once per month from each station within the Hempstead Bay estuary. Laboratory testing of these samples began by first performing a Winkler titration on the fixed sample in order to find total dissolved oxygen content. The second sample from each station were placed in an incubator set at 30 degrees Celsius for five days. After the five-day period Winkler titrations were then performed on the second samples to determine the remaining dissolved oxygen. The DO of the incubated sample was subtracted from that of the field sample to determine the BOD, the oxygen utilized to metabolize available organic mater in the water. As electronic DO instruments became available, they replaced the Winkler method for the day-to-day measurement of DO. Field readings taken using YSI oxygen probes were compared to post-incubation measurements done on the one water sample that was returned to the lab.

The average BOD for West, Middle and East Bay sampling stations for three decadal time intervals are depicted on Figure 40 on the following page. Over the years, the average calculated BOD has gradually increased at a slow rate in the upper West Bay and the easternmost part of East Bay. It also appears that sampling stations in the West and Middle Bays generally have had higher BOD readings than East Bay (Fig. 55), likely reflecting increased rates of microorganism activity in those parts of the bay. When working to manage microbial blooms, this information will help target the effort to identify impacts and develop appropriate measures to correct the causes of identified problems.

Near the end of the 1990s, the BOD results were trending towards zero. After an extended period when BOD appeared to show no results or inconsistent results, it was decided that BOD was no longer producing useful information and that BOD should be dropped from the program to allow for the addition of urea and silica. The standard field method, although intended to measure organic mater from pollution sources, is subject to other environmental and technical influences. Differences in the initial dissolved oxygen, the accuracy of the DO measurements, living phytoplankton, and living zooplankton can all influence the result and produce misleading interpretations. Unfortunately, unreliable field measurements for DO during the 1998-2003 period appear to have caused misleading BOD results. Based on the work done during the preparation of this report, we have dropped the DO and BOD data from the 1998-2003 period and are considering reinstatement of the use of BOD and investigating alternative updated and more accurate methods for measuring organic contamination from fixed organic carbon compounds that BOD was intended to measure.

Biological Oxygen Demand *continued*

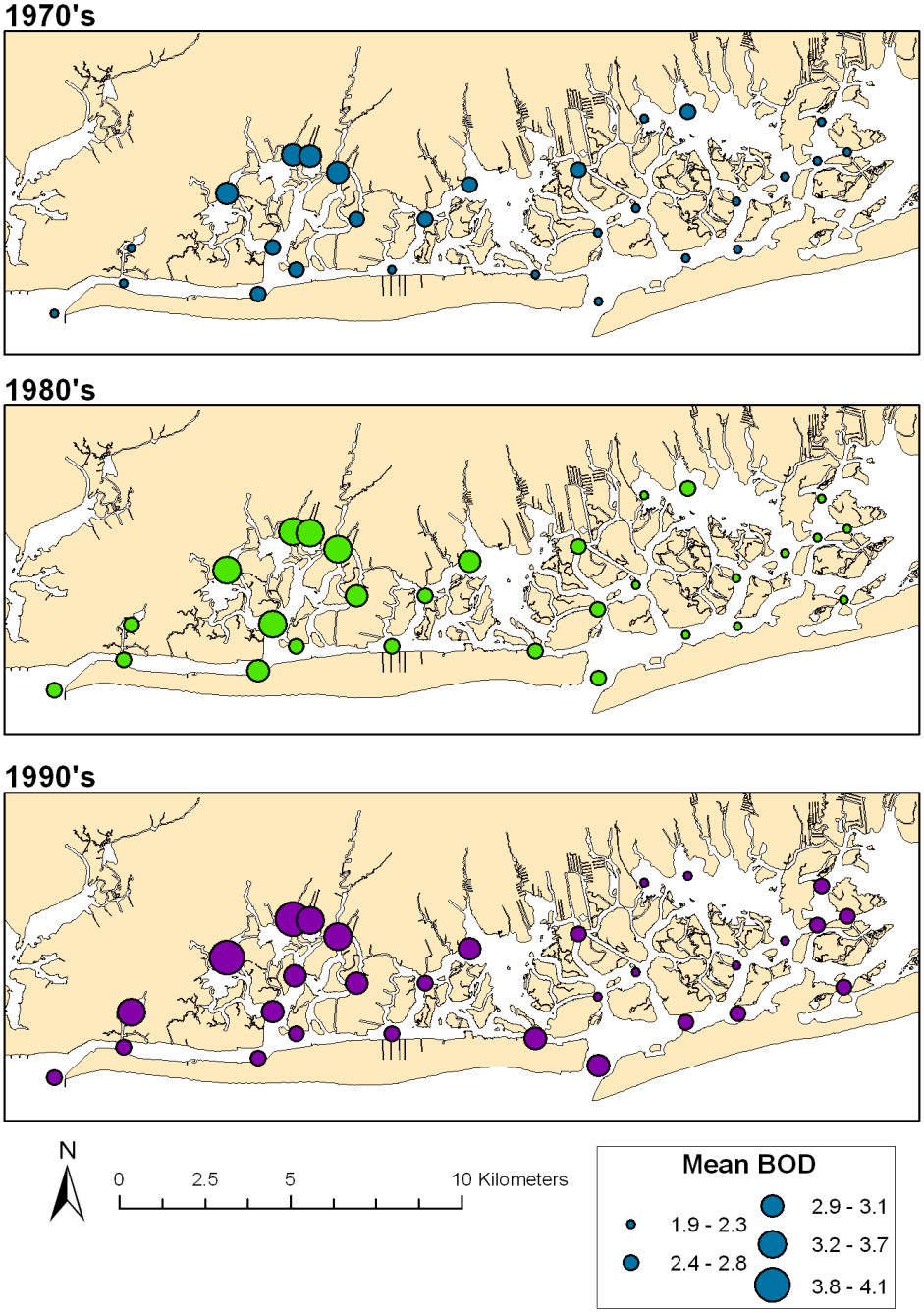


Figure 40. Monthly Biological Oxygen Demand values averaged for East, Middle, and West Bays at each sampling station, Hempstead Bay, 1975-1998.

3. Comparisons between Selected Stations: Overall and Monthly Time Trends

3.1 Station 4

Station 4 is located in Reynolds Channel just off the Bay Park Outfall, and shows several direct influences from the outfall that differ greatly from even nearby stations in the bay. One indication of this influence is the salinity values at Station 4 that were lower than values at other stations in the bay. In particular, the median values were significantly lower than at stations 3 and 11 that are also located in Reynolds Channel. Even stations that are more inland and more influenced by surface fresh water runoff, such as Stations 6, 6A, and 7, have significantly higher salinity(Fig. 41). Water at Station 4 is therefore significantly diluted by the influx of treated sewage, averaging about 5% and occasionally as much as 30% effluent, as indicated by the lower salinity and the different chemical and biological signatures (Fig. 42). The notches in Figure 41 are a visual representation of a statistically significant difference when they fail to overlap. These very local and extreme differences can lead to inaccuracies when incorporating of this station into the interpretation of bay-wide trends.

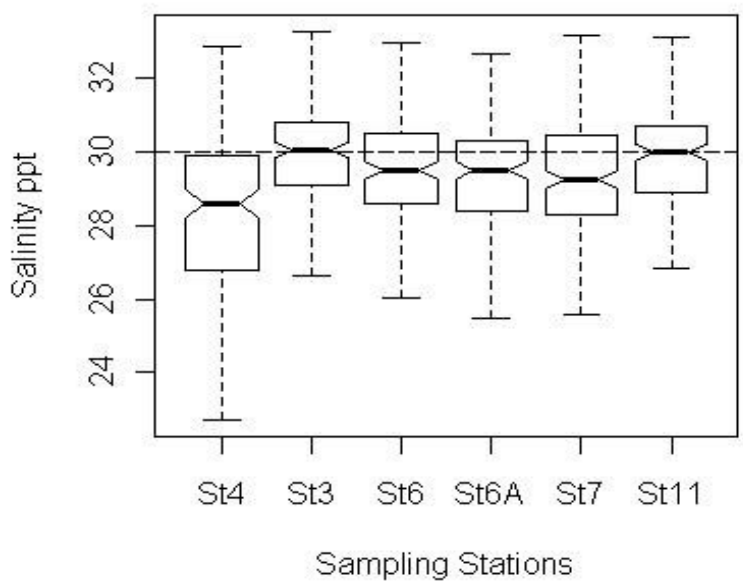


Figure 41. A box plot with notches centered on the median salinity values at Station 4 and other nearby stations from 1975 – 2011, and indicating a significant difference when notches fail to overlap.

Station 4 continued

Station 4 ammonia values were higher than those at the West Bay stations and showed an increasing temporal trend. A similar trend was evident in nitrite values though the disparity between station 4 and the upper West Bay values was most apparent in recent years. Nitrate values at station 4 were the least disparate compared to those at West Bay stations (Fig. 42).

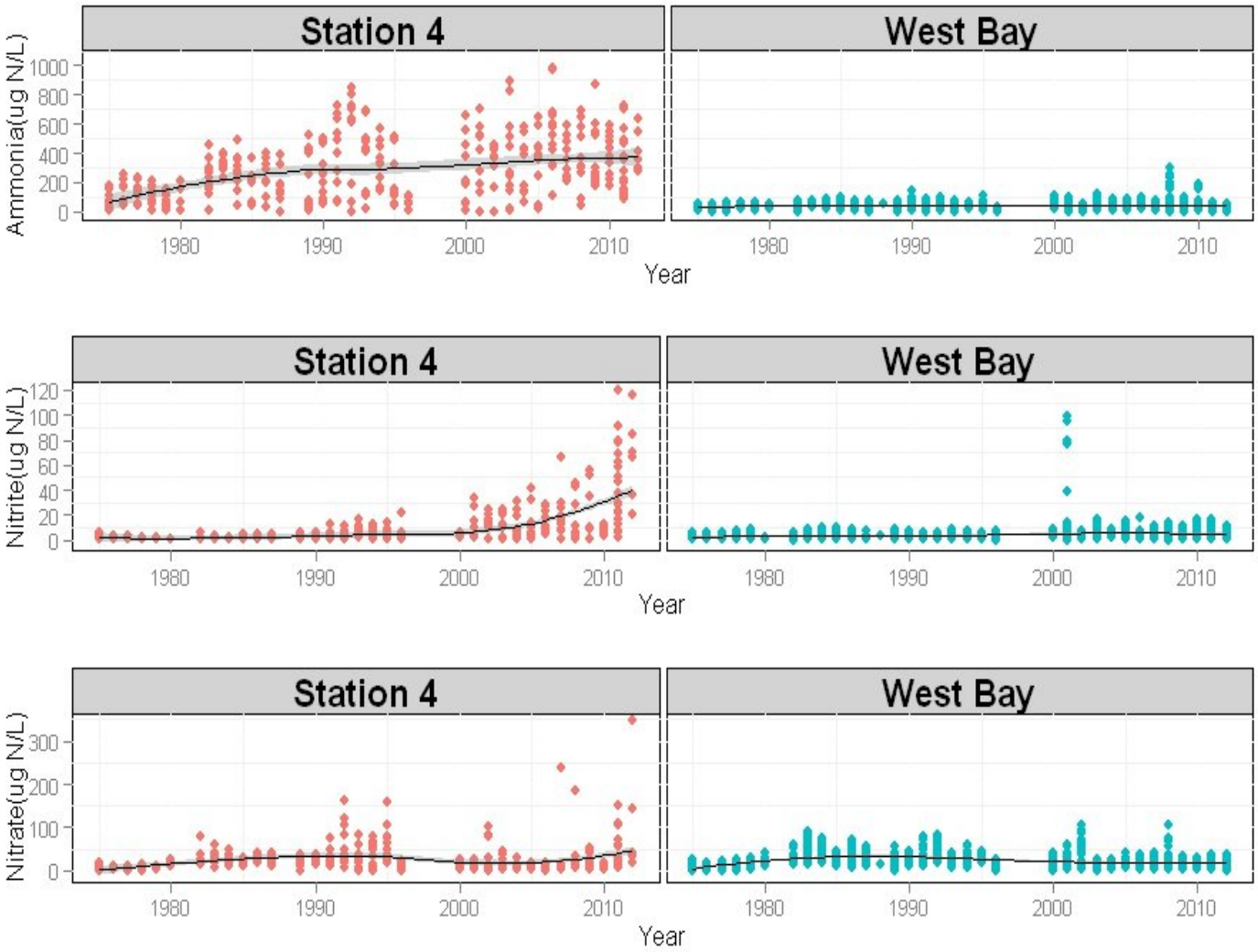


Figure 42. Yearly ammonia, nitrite and nitrate values of Station 4 and West Bay from 1975 - 2011 fit with a loess curves and 95% confidence regions. Data from 1997-1999 were removed.

Another anomaly at Station 4 was the time trend in the bacteriological data. While all other stations, with the exception of Station 34, showed reasonably consistent trends of reduced total coliform and fecal coliform, Station 4 showed increases in these parameters until very recently (Figure 43).

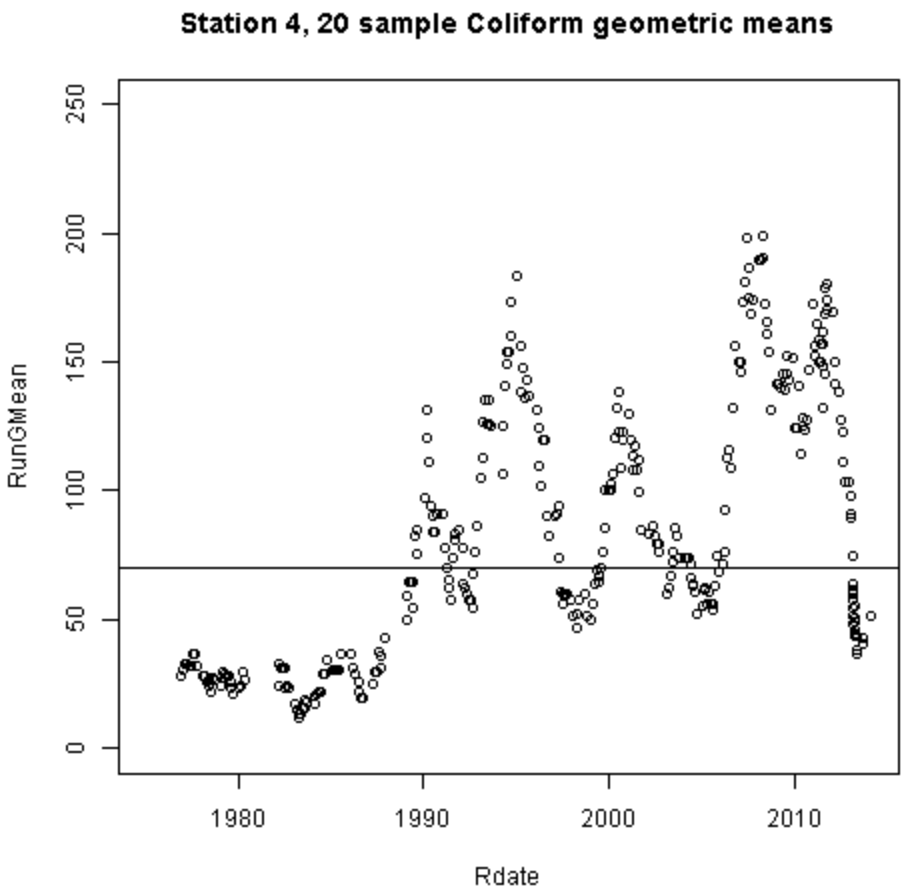


Figure 43. Station 4 running geometric means of 20 total coliform readings.

Station 4 also shows a slow increase in orthophosphates (Fig. 44). There was a trend in salinity (Fig. 47) that shows a decrease through time, possibly indication an increase in efluent flow over the time interval. Some other parameters do not show great change through the study period (Figures 46, and 48 -- 53), including chlorophyll “a” (Figure 45), although the seasonal changes in chlorophyll are very large (Fig 51).

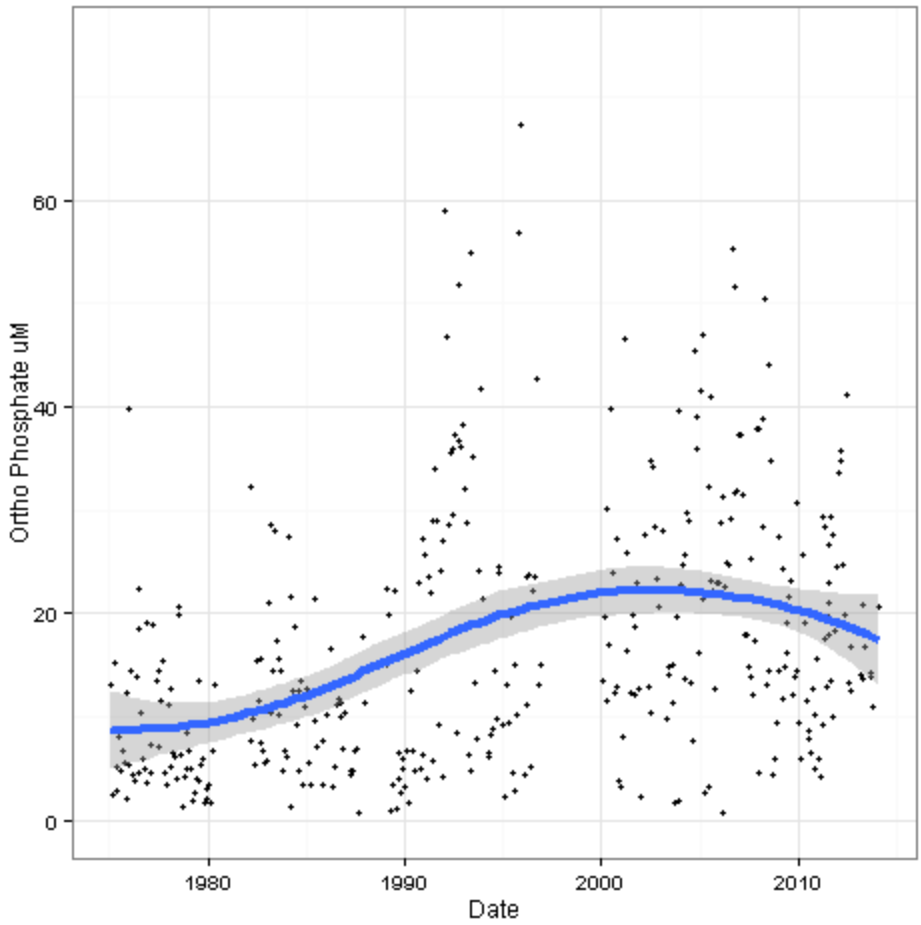


Figure 44. Orthophosphate as µM at station 4 with a loess nonparametric fit and 95% confidence limit.

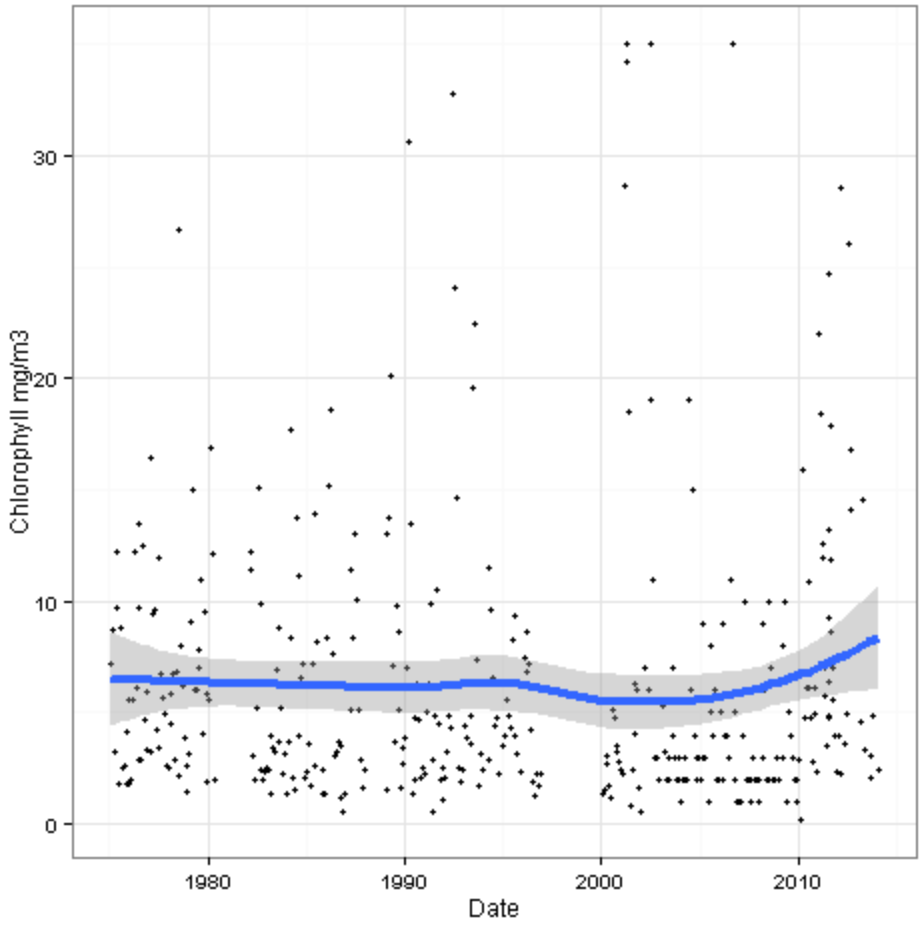


Figure 45. Chlorophyll "a" as mg/L at Station 4 with a loess nonparametric fit and 95% confidence limit.

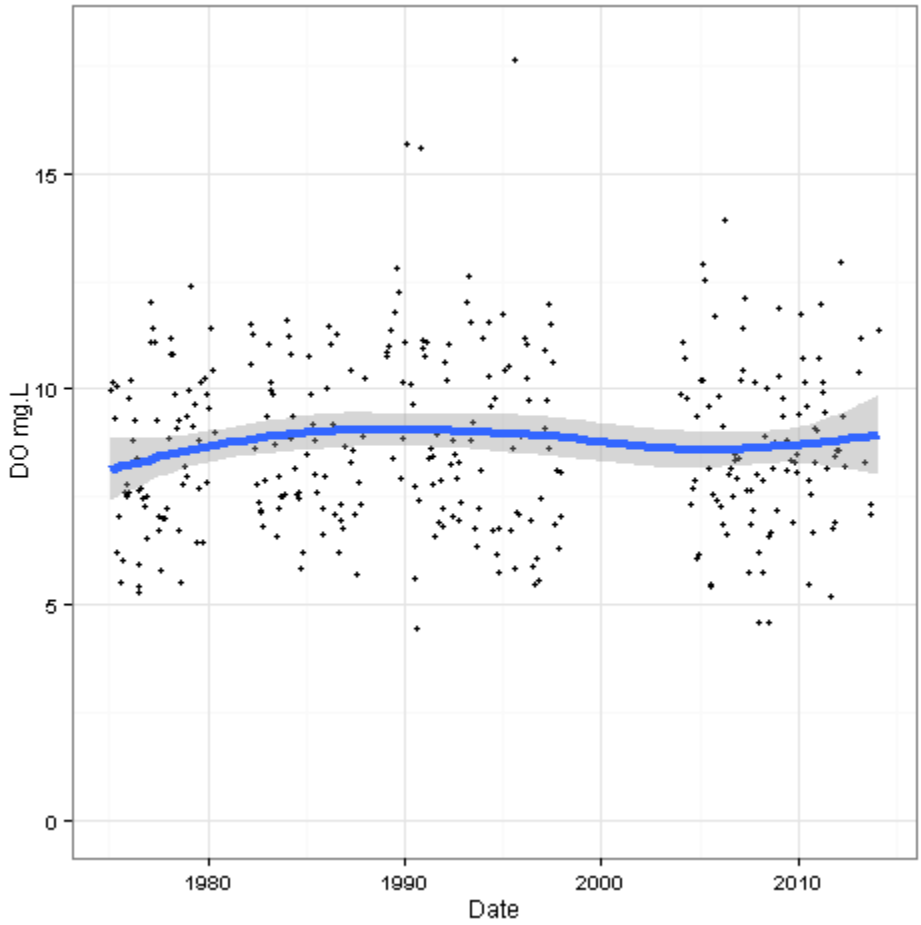


Figure 46. Dissolved Oxygen as mg/L at Station 4 with a loess nonparametric fit and 95% confidence limit.

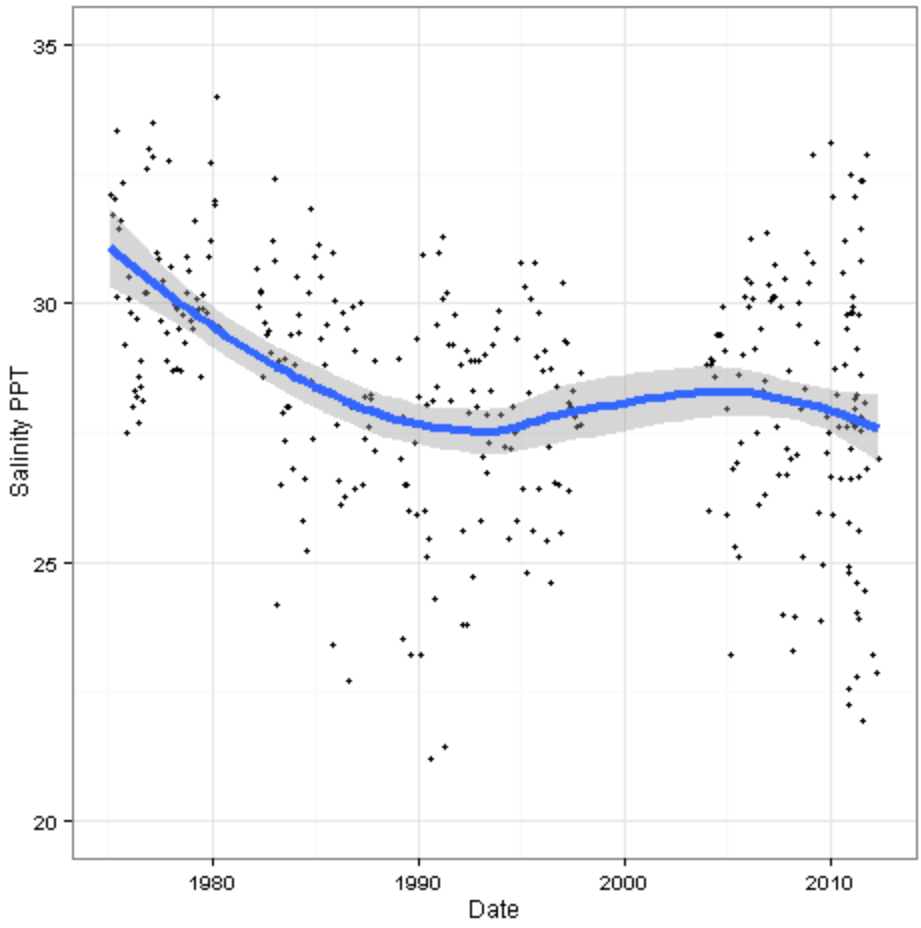


Figure 47. Salinity as PPT at Station 4 with a loess nonparametric fit and 95% confidence limit.

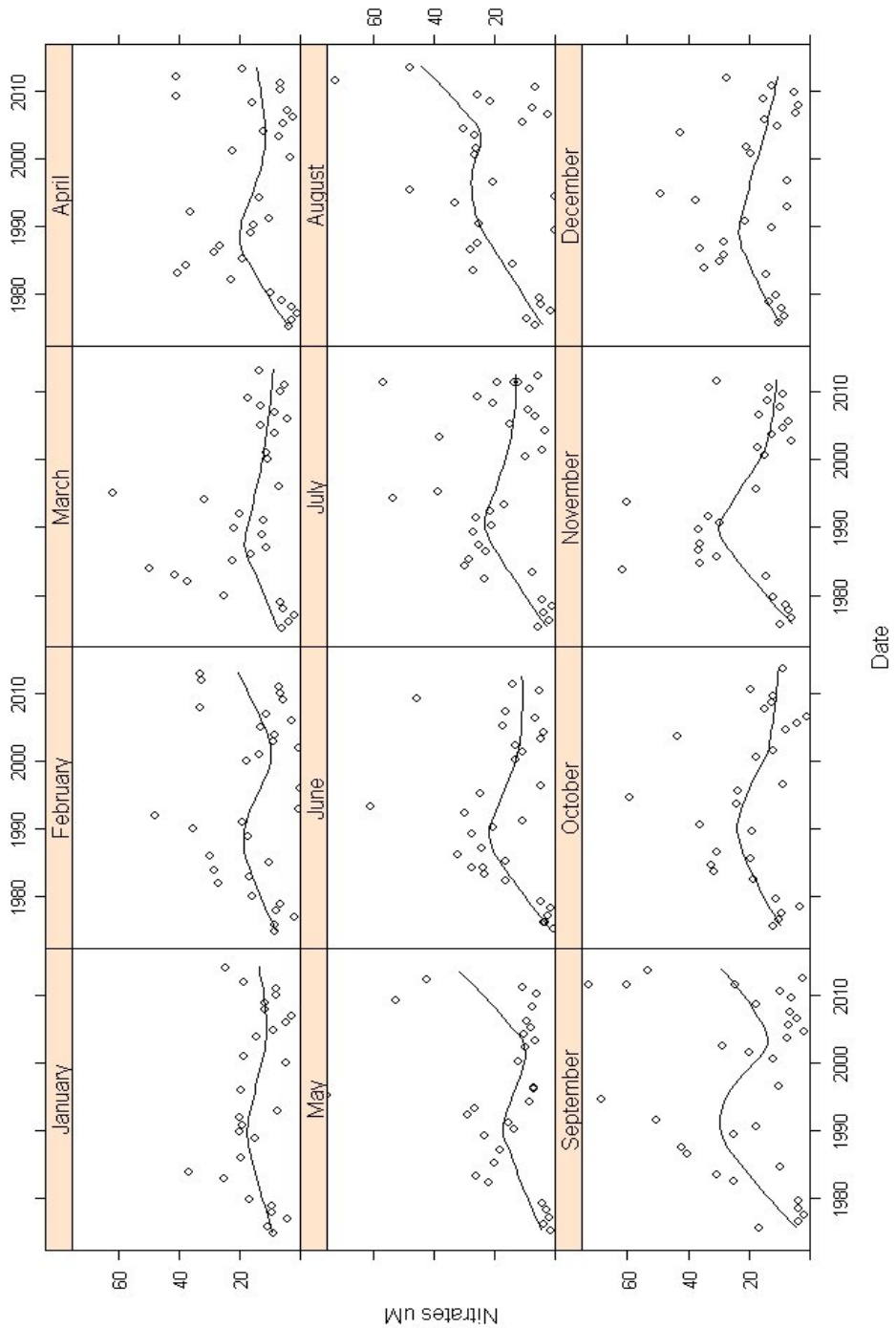


Figure 48. Nitrate as µM at Station 4 with a loess nonparametric fit.

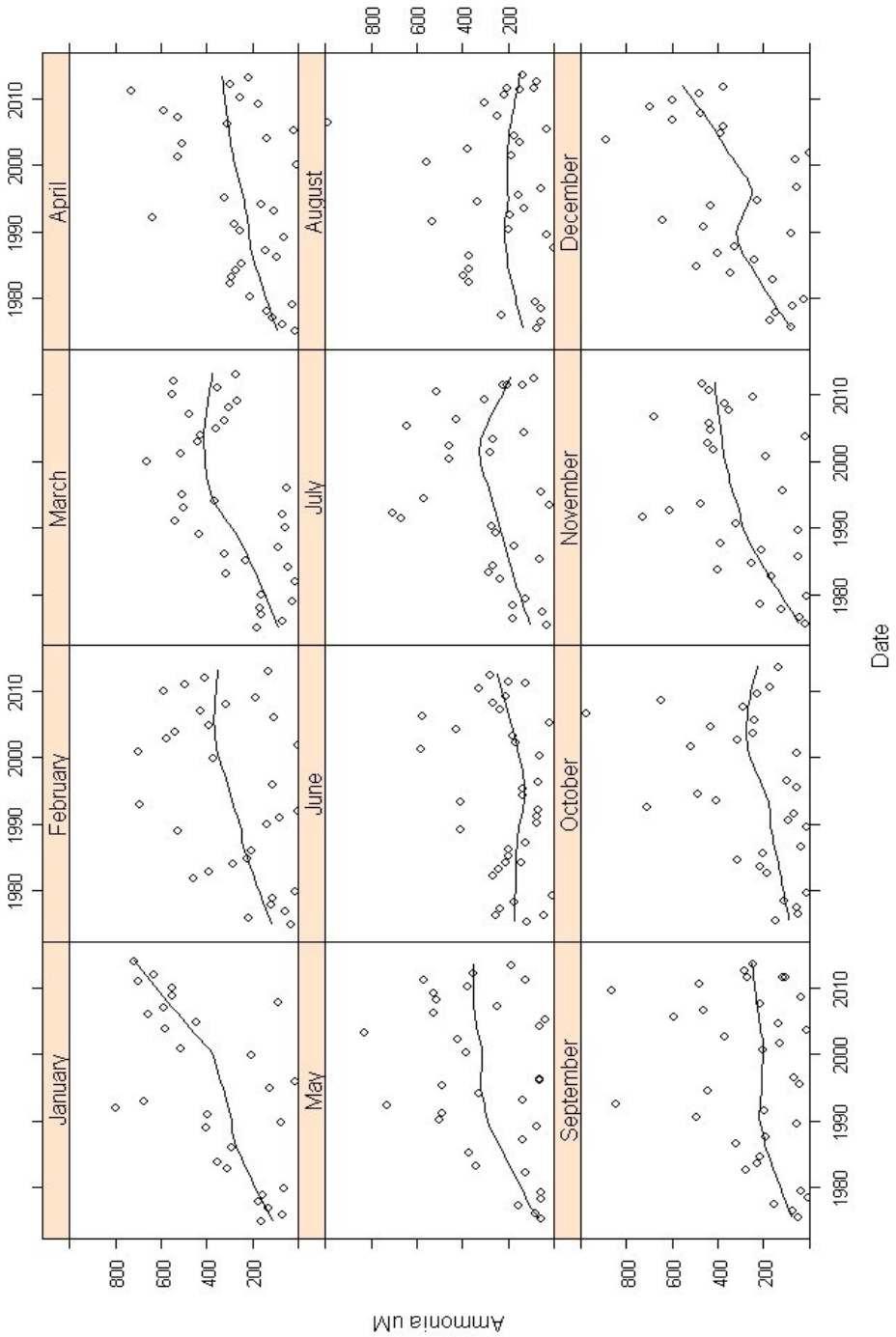


Figure 49. Ammonia as µM at Station 4 with a loess nonparametric fit.

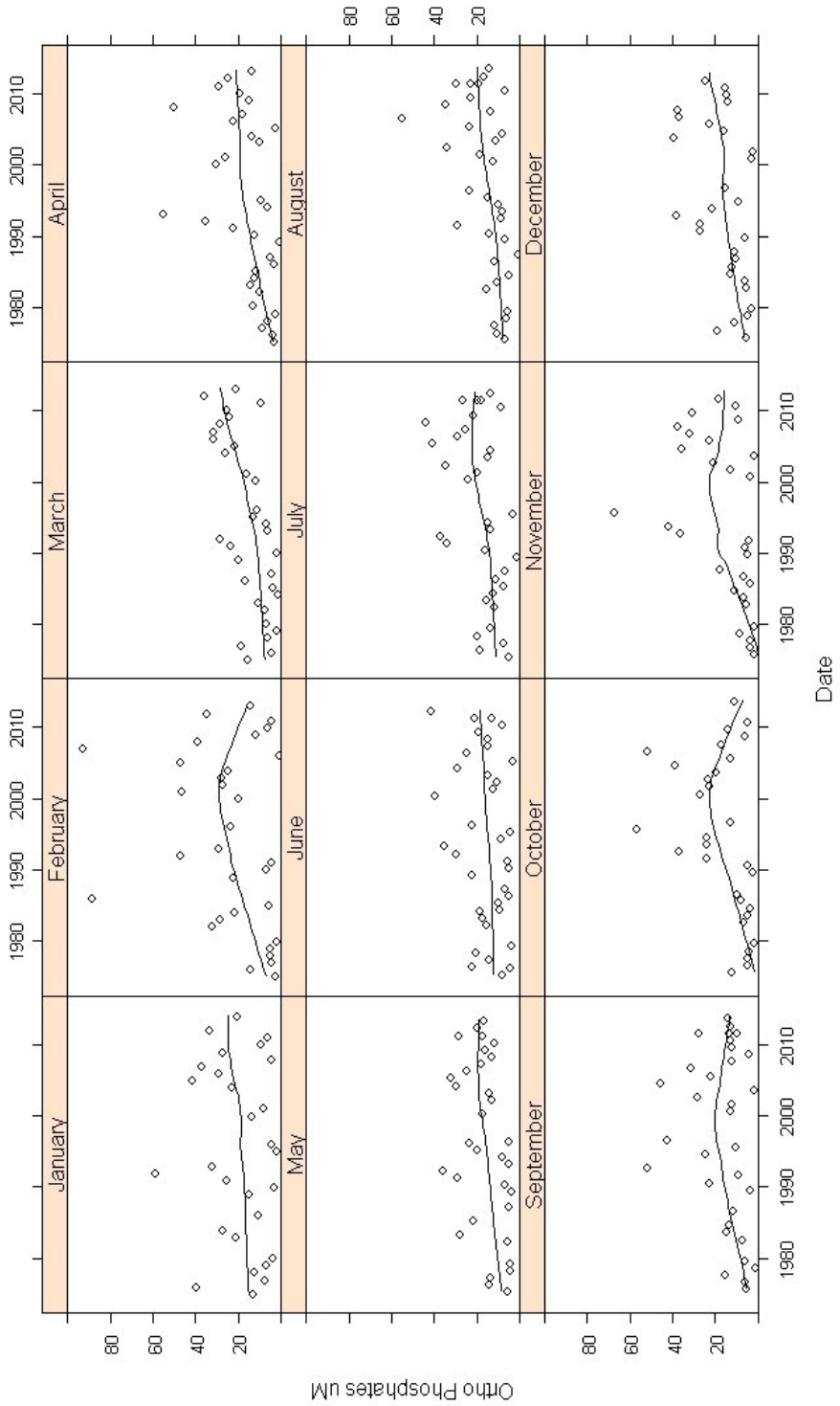


Figure 50. Phosphate as µM at Station 4 with a loess nonparametric fit.

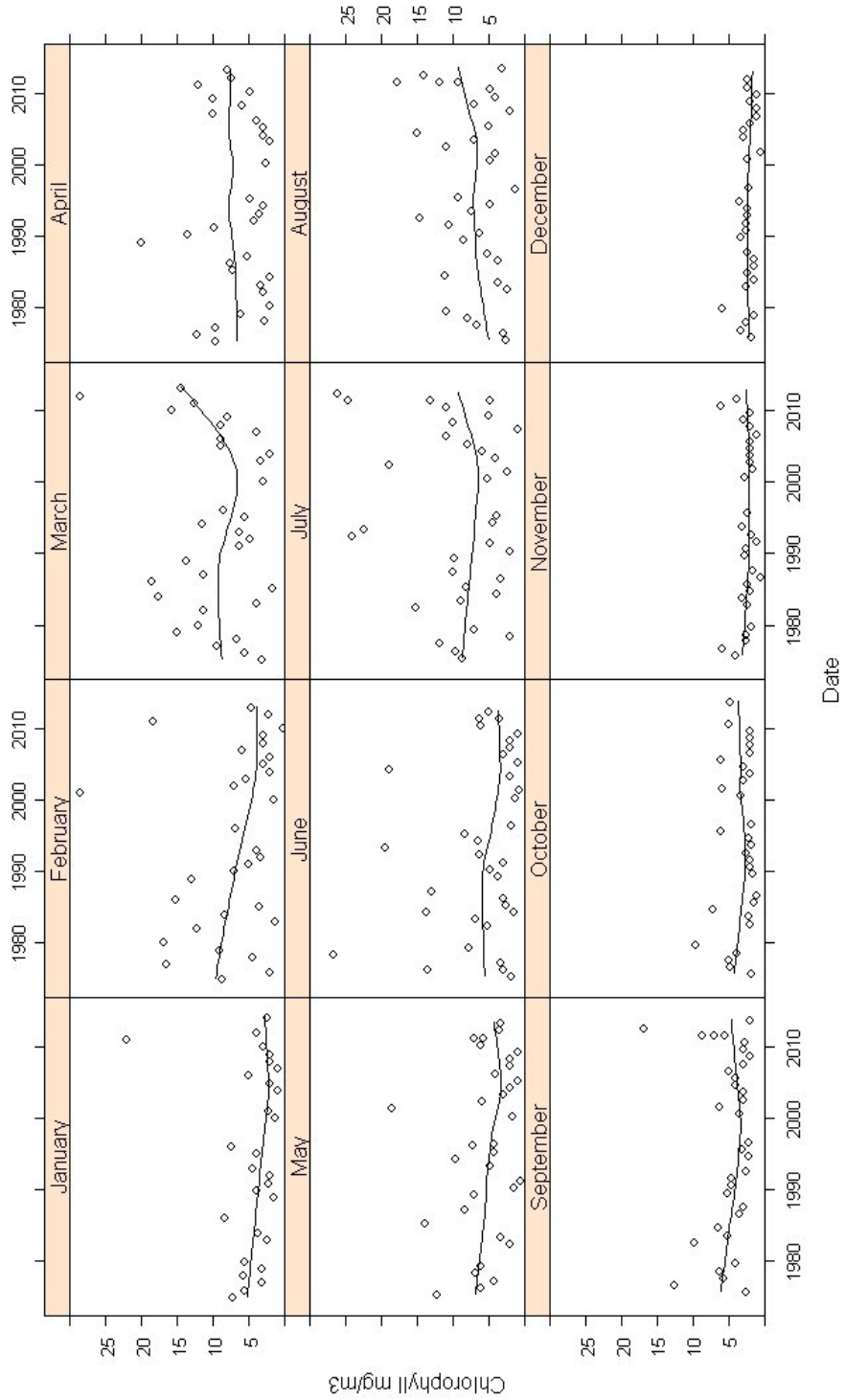


Figure 51. Chlorophyll as mg/l at Station 4 with a loess nonparametric fit.

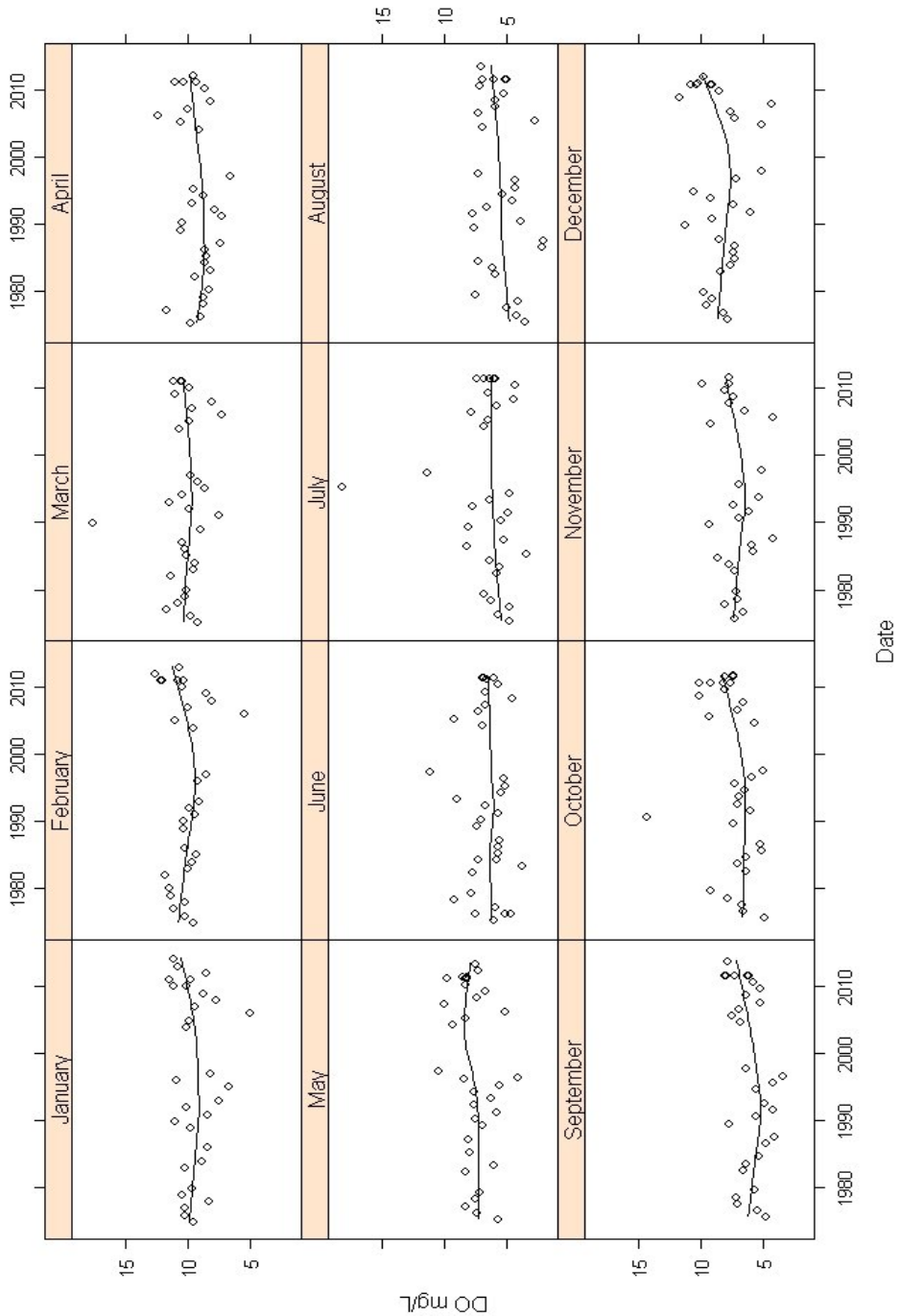


Figure 52. Dissolved Oxygen as mg/l at Station 4 with a loess nonparametric fit.

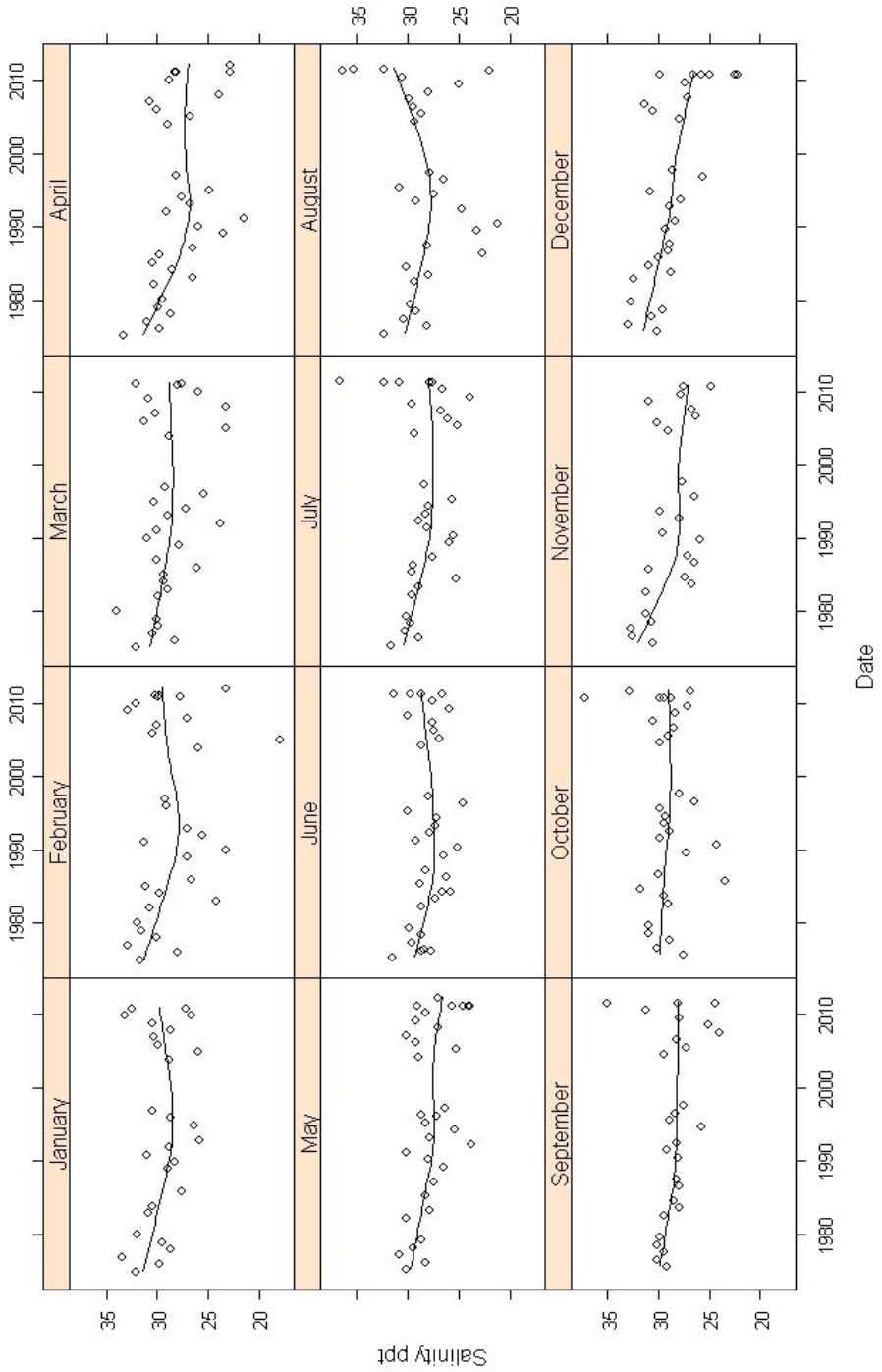
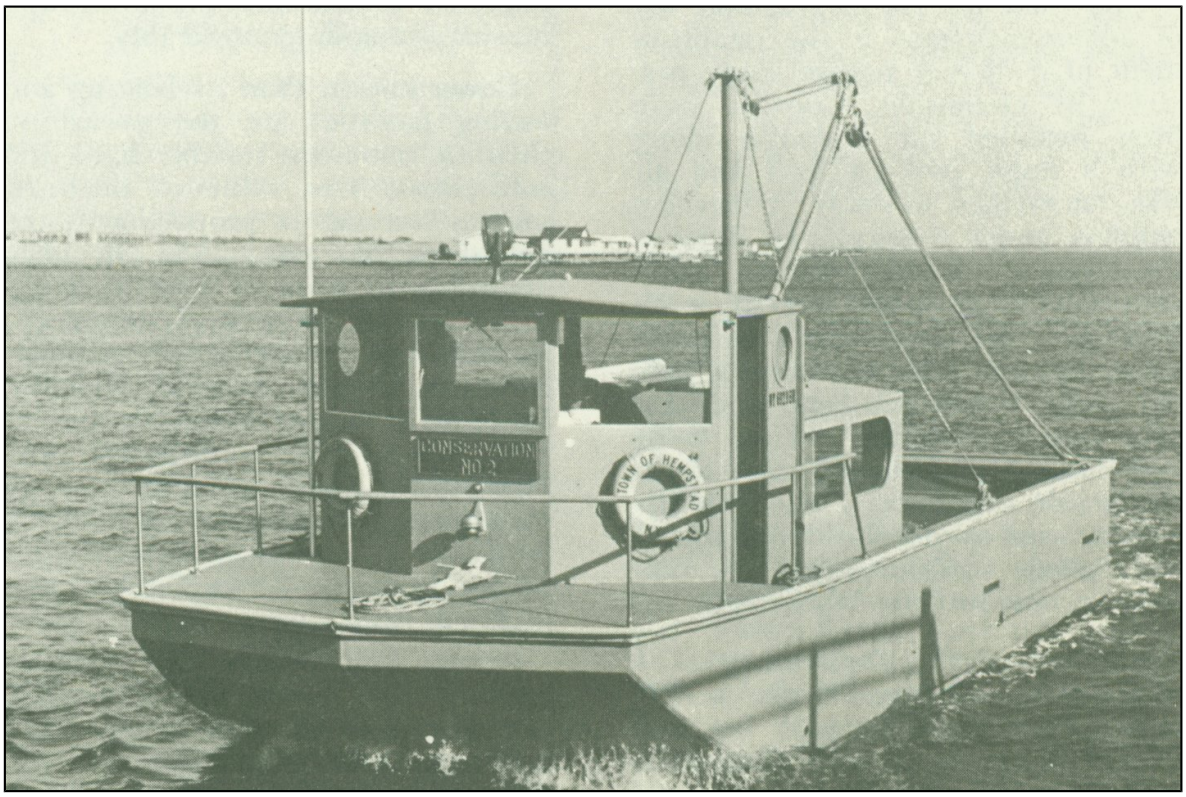


Figure 53. Salinity as PPT at Station 4 with a loess nonparametric fit.

3.2 Inlets, Stations 1 and 18

Stations 1 and 18 (Inlets) are located at inlets and reflect ocean water conditions more than any other stations included in this study. The parameters measured at these stations are strongly influenced by the tide, with incoming tides showing ocean water conditions while outgoing tidal readings integrate bay water qualities.

In general, these two sites reported similar values for the measured parameters and tended to have lower values than the rest of the stations (although the East Bay was often close in value to the Inlets). This is likely caused by dilution of bay water by ocean water during tidal exchange. This hypothesis is supported by the higher salinity values at the Inlets compared to the representative West, Middle, and East Bay stations (Figure 54). While salinity at other stations was lower because of runoff and rainwater, inlet stations likely reflected ocean salinity.



The primary C&W research vessel 1966 – mid 80s

For many parameters, there was little difference between Inlet values and representative stations (e.g. BOD and Dissolved Oxygen; Figure 55, A and B). However, Dissolved Organic Nitrogen (DIN) values showed a strong difference between Inlet and two of the three representative stations (Figure 56). DIN was slightly but significantly higher in the Inlets than East Bay, and both of these values were lower than those from West Bay and Middle Bay. This trend was also seen in the individual components of DIN (i.e. Ammonia, Nitrite, and Nitrate). In addition, East Bay was most similar to the Inlets in Salinity, suggesting that either the ocean has more of an effect on this bay than on West Bay and Middle Bay, or that the East Bay is evolving independently.

In general, monthly cycles and trends of nitrates, ammonia, phosphates, chlorophyll 'a', DO and salinity seem similar between the two inlets and long term changes in the time trends do not seem obvious (Figures 57 – 62).

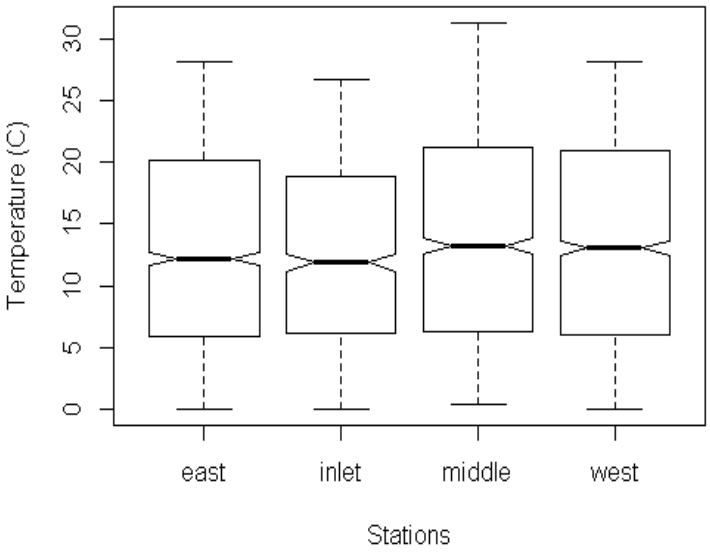
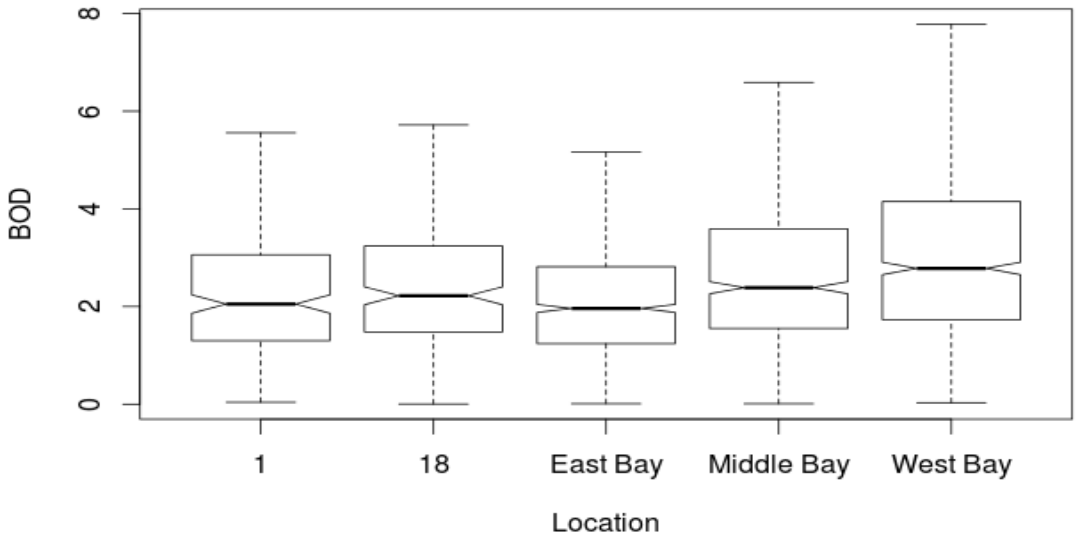


Figure 54. A box plot with notches showing the median temperature readings for the combined inlet Stations 1 and 18 and comparing them to the East, Middle, and West Bay representative stations.

A



B

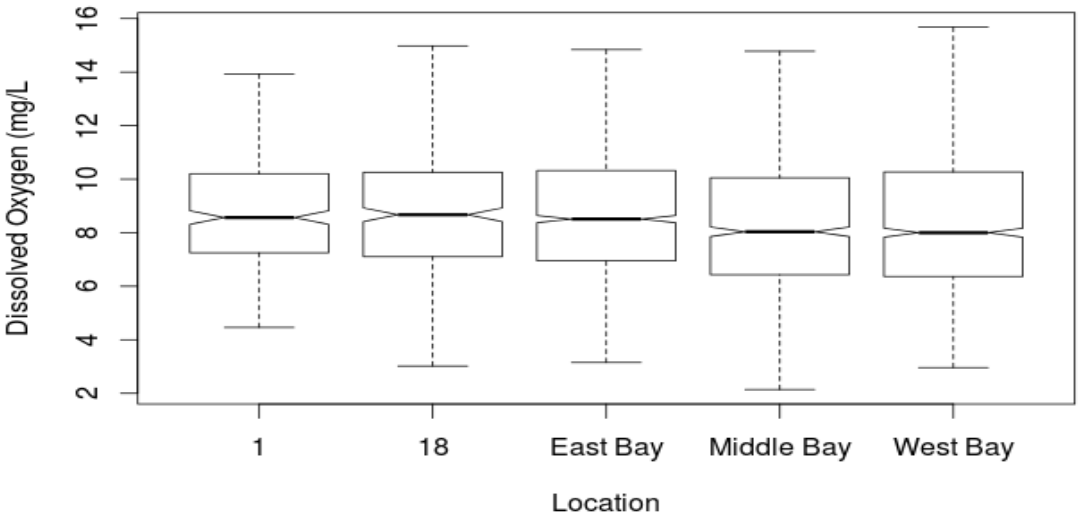


Figure 55. Median Biological Oxygen Demand, and Dissolved Oxygen values for Stations 1 and 18, and the representative stations from East, Middle, and West Bays.

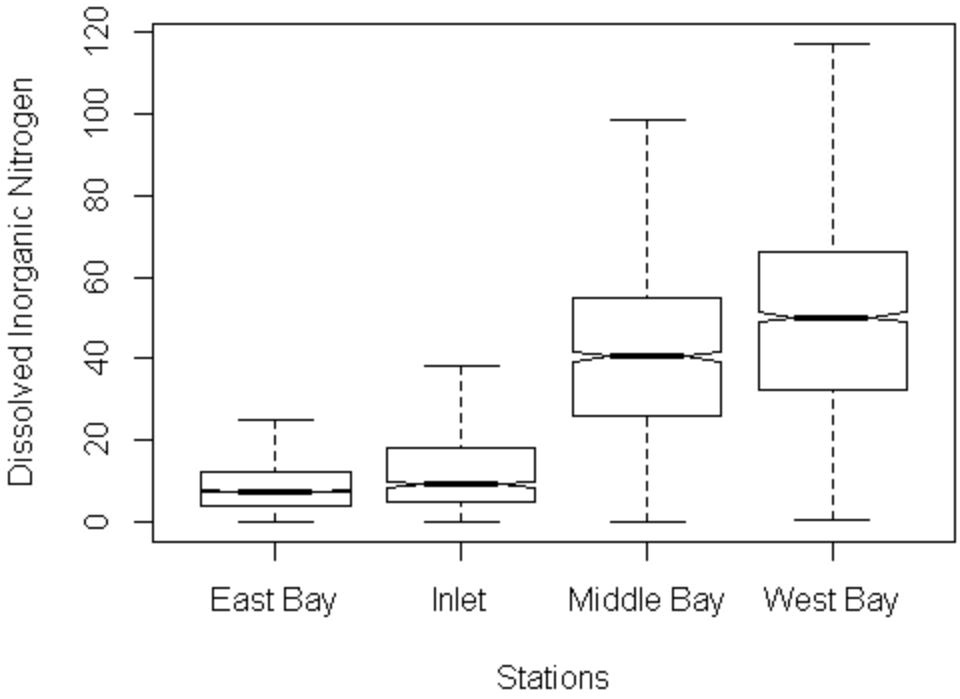
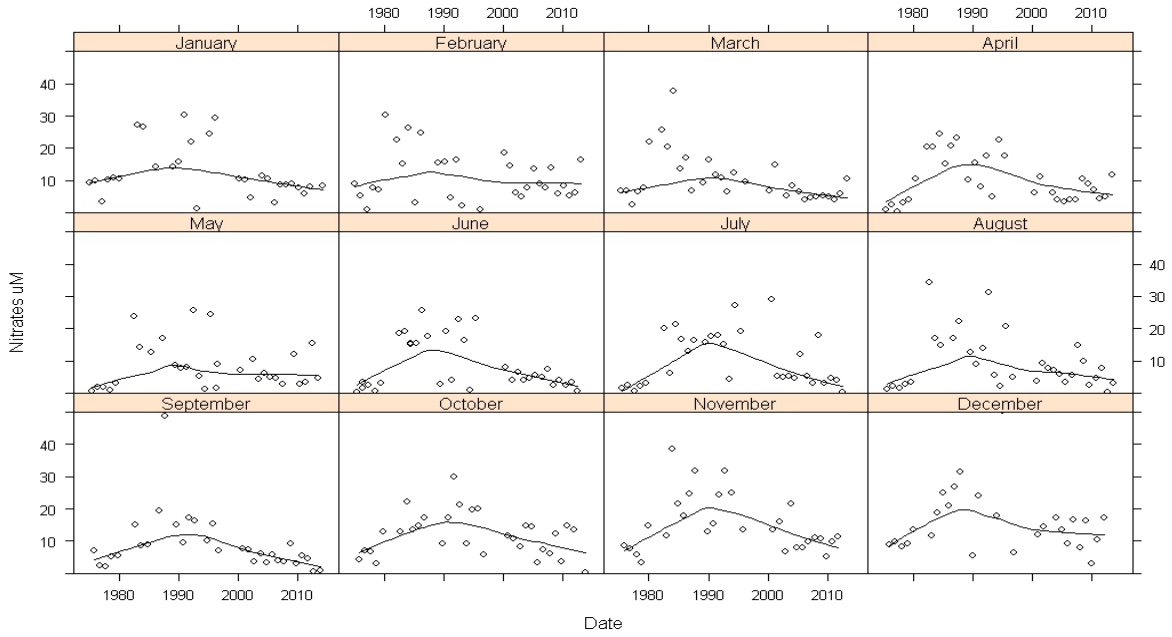


Figure 56. Median combined Dissolved Inorganic Nitrogen values for Stations 1 and 18, and Representative Stations for East, Middle, and West Bays.

A Double crested Cormorant

A



B

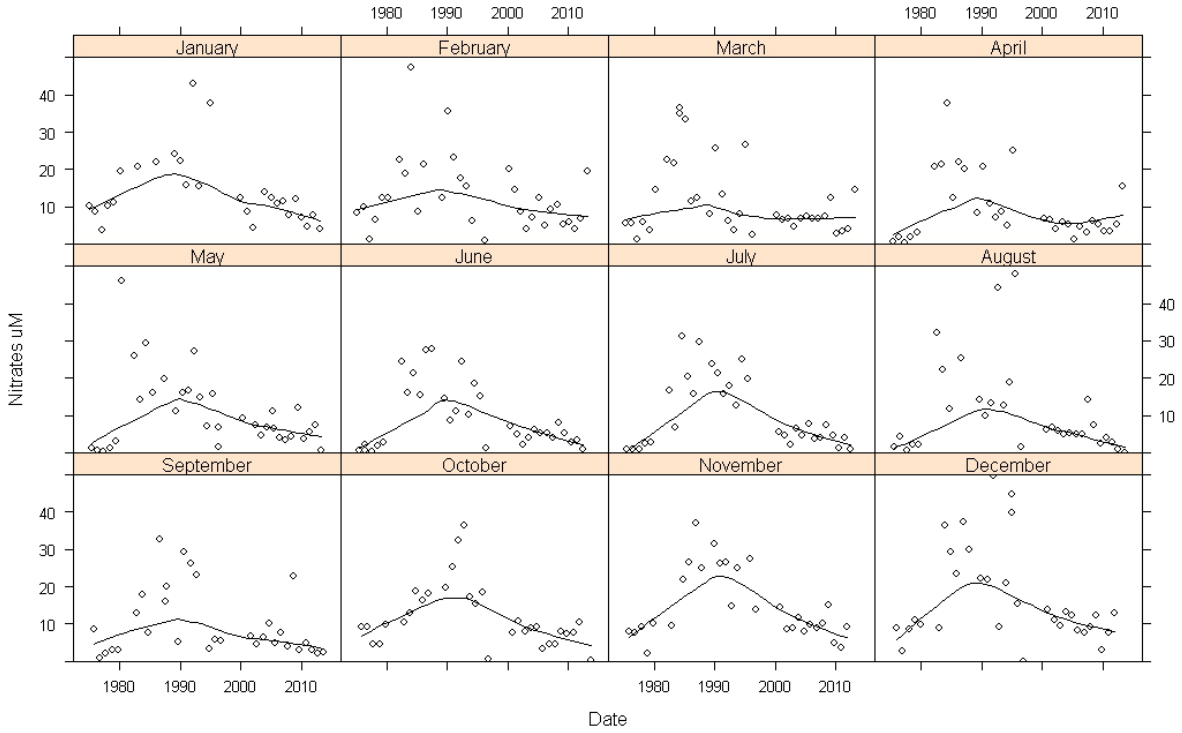
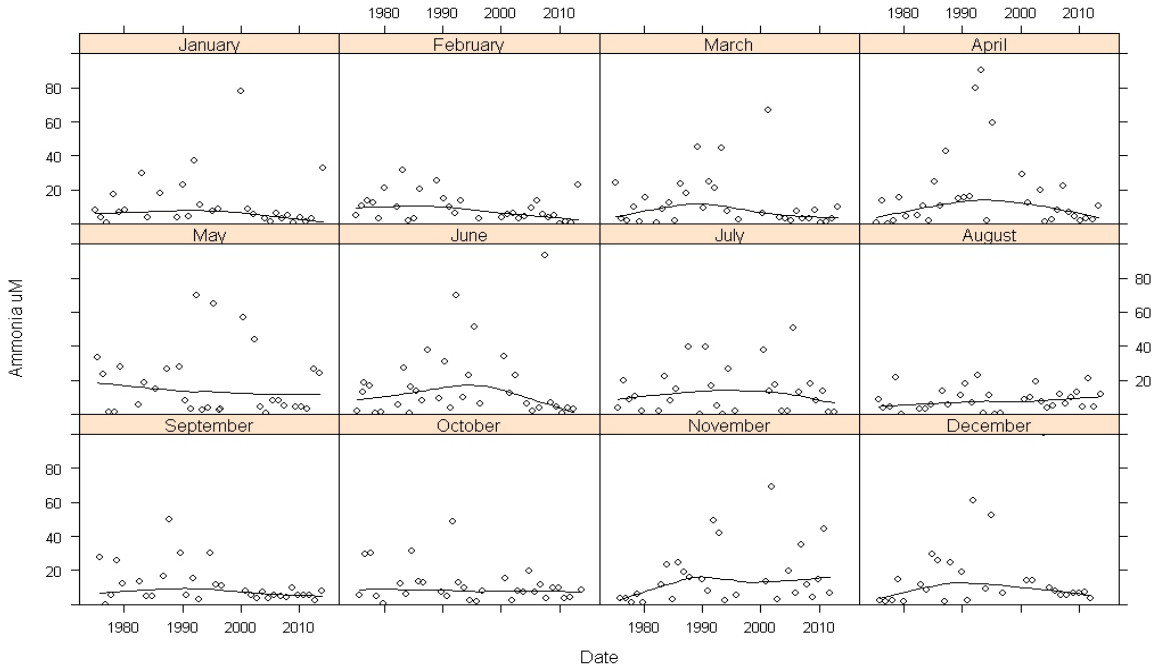


Figure 57. Stations 1 and 18 (A & B respectively) Nitrates µM by month with a nonparametric loess fit.

A



B

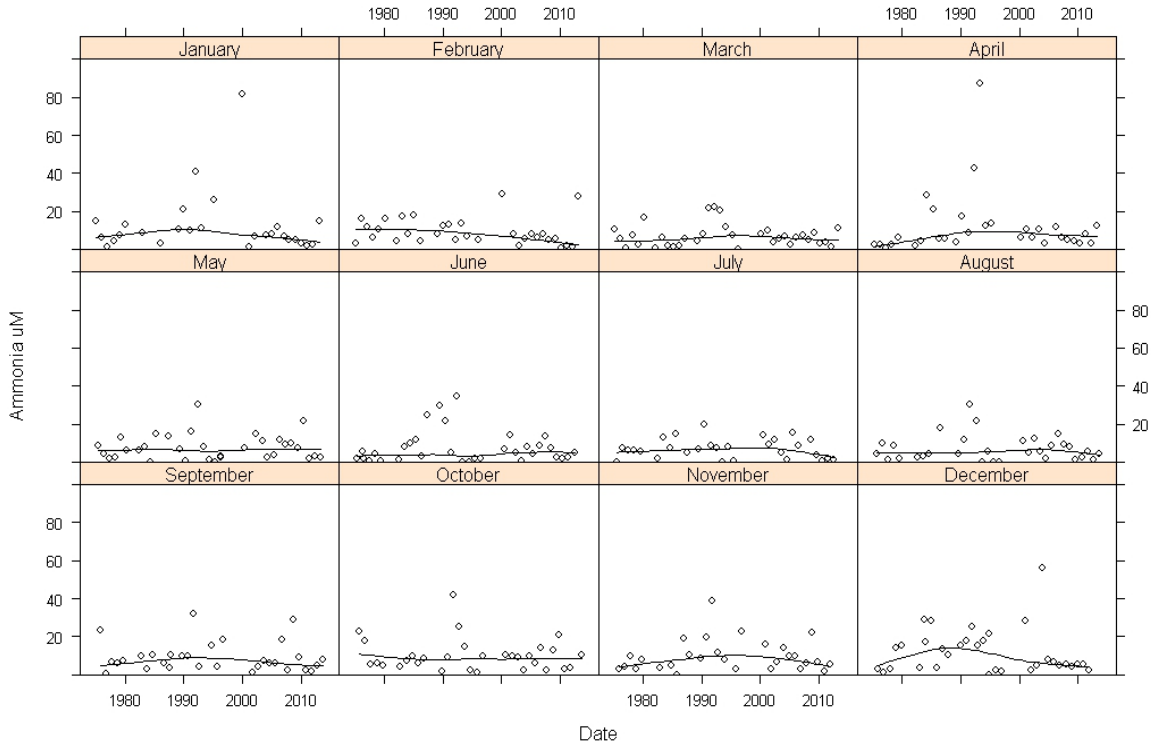
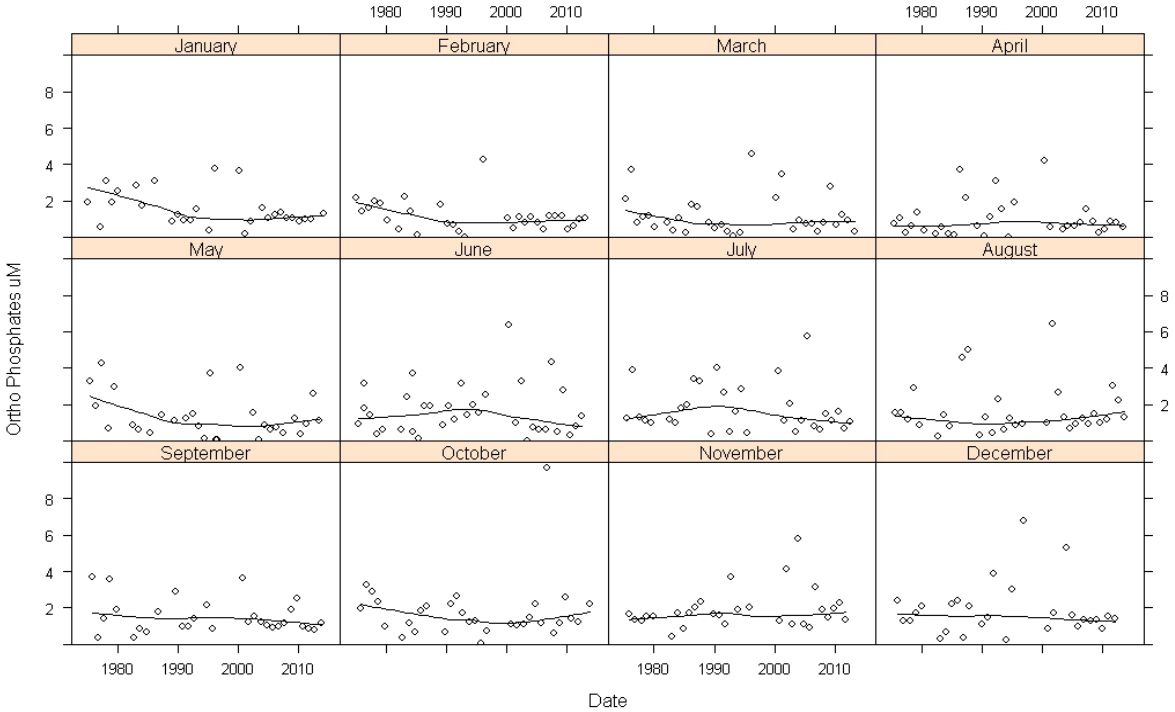


Figure 58. Stations 1 and 18 (A & B respectively) Ammonia µM by month and nonparametric loess fit.

A



B

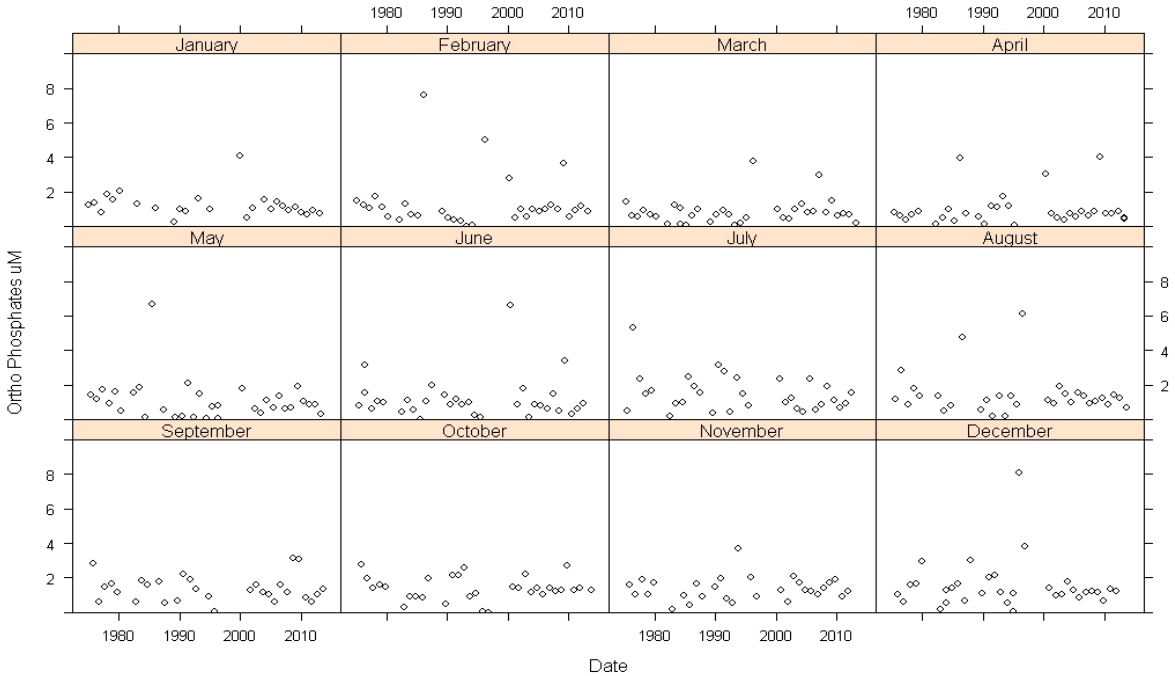
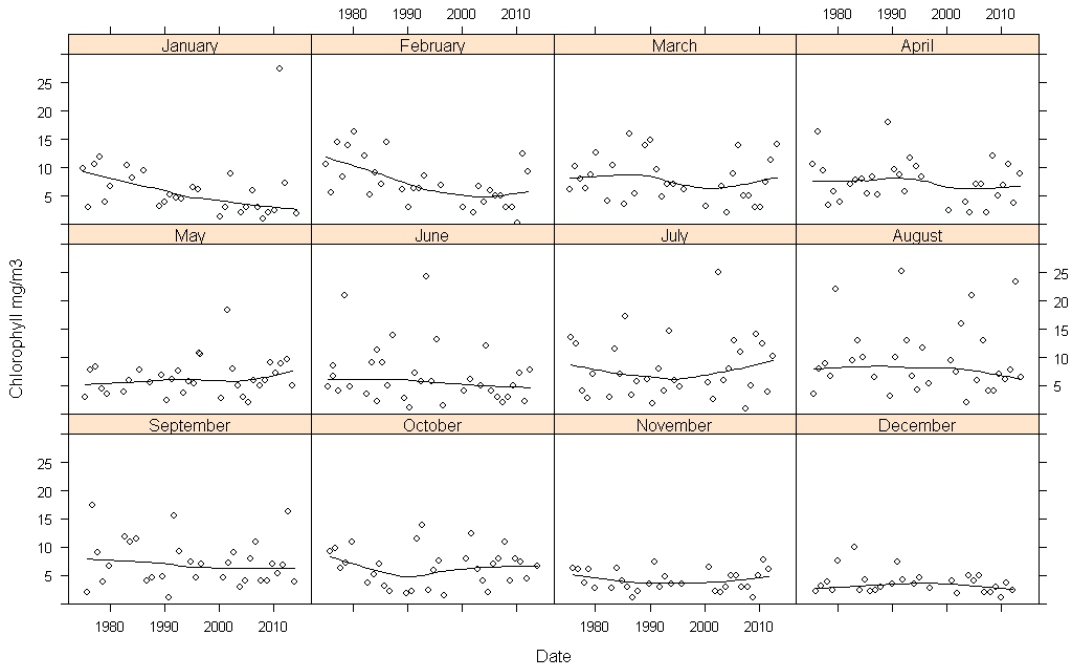


Figure 59. Stations 1 and 18 (A & B respectively) Orthophosphate µM by month.

A



B

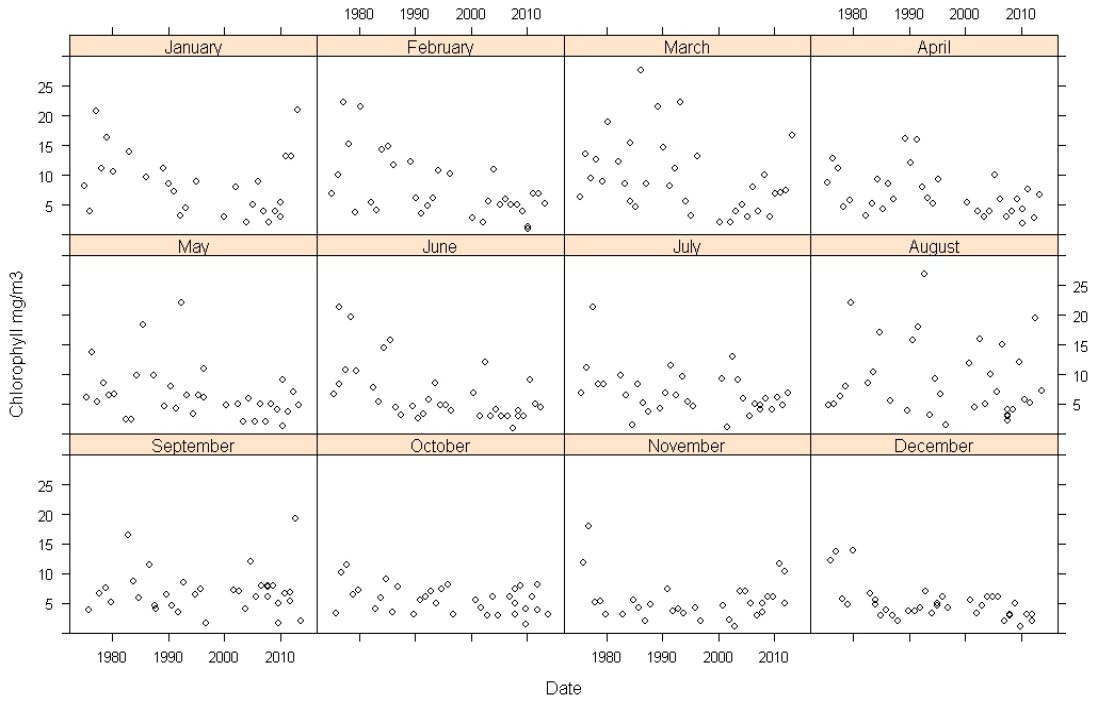
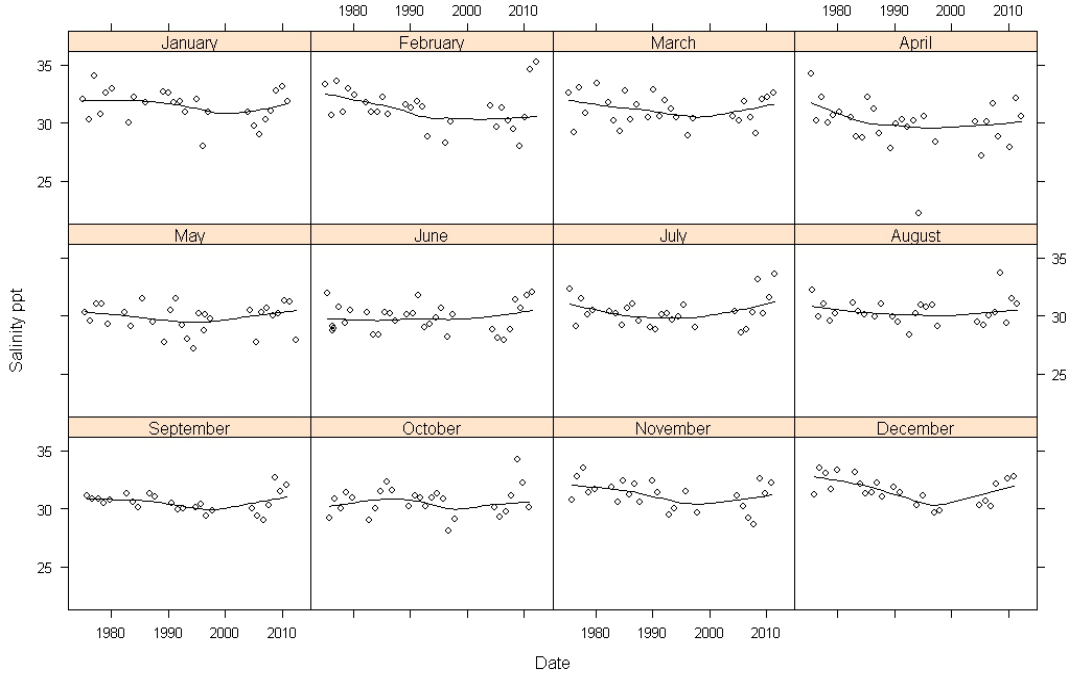


Figure 60. Station 1 and 18 (A & B respectively) Chlorophyll as mg/l by month.

A



B

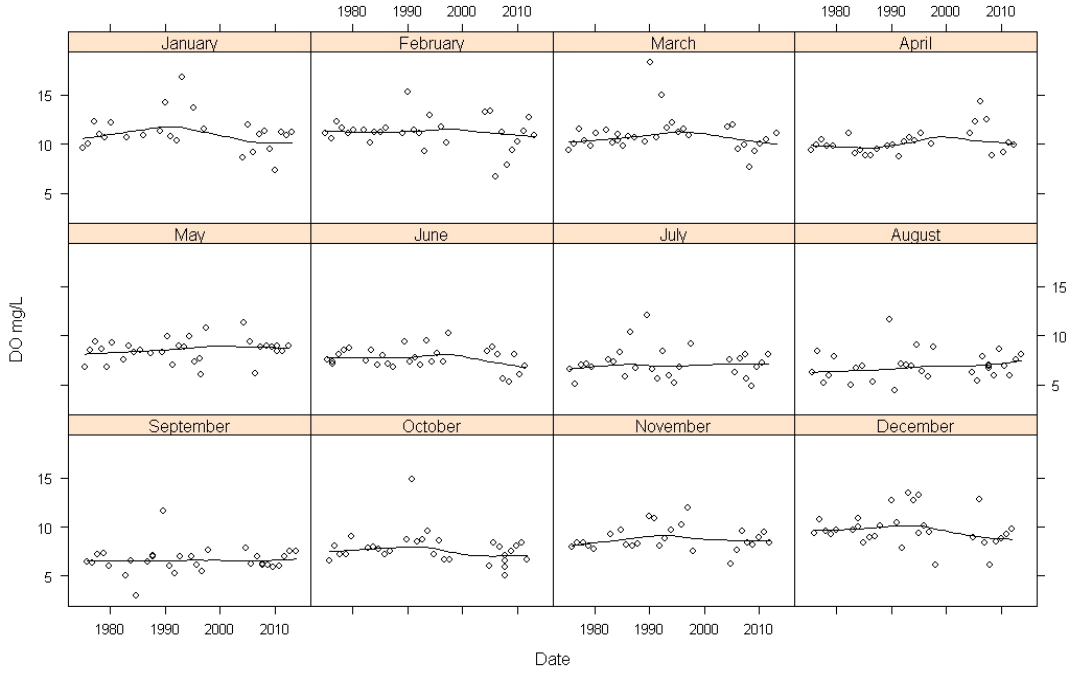
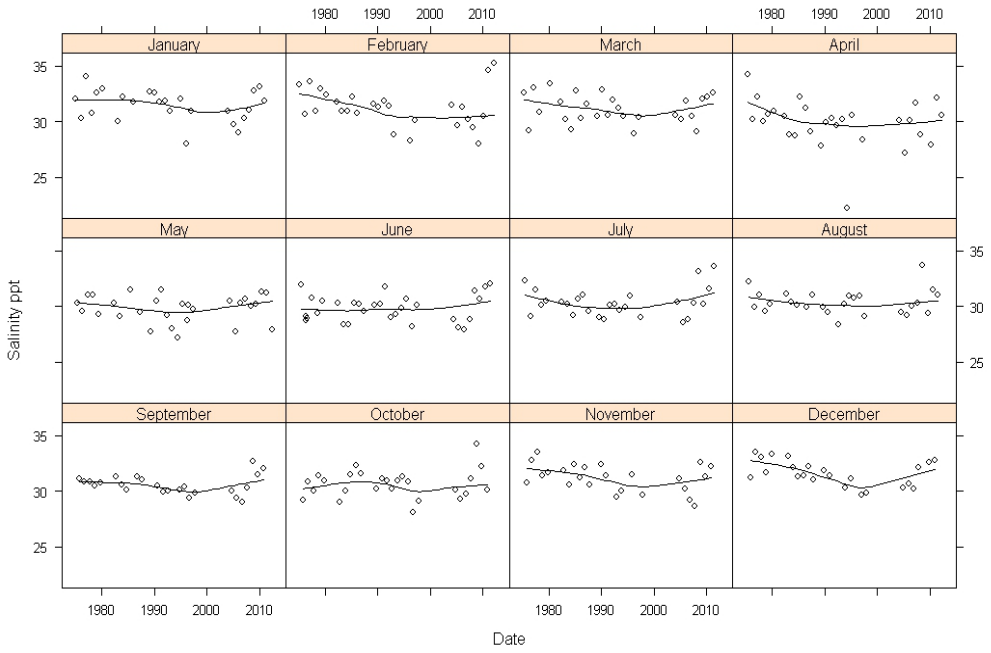


Figure 61. Station 1 and 18 (A & B respectively) DO as mg/l by month.

A



B

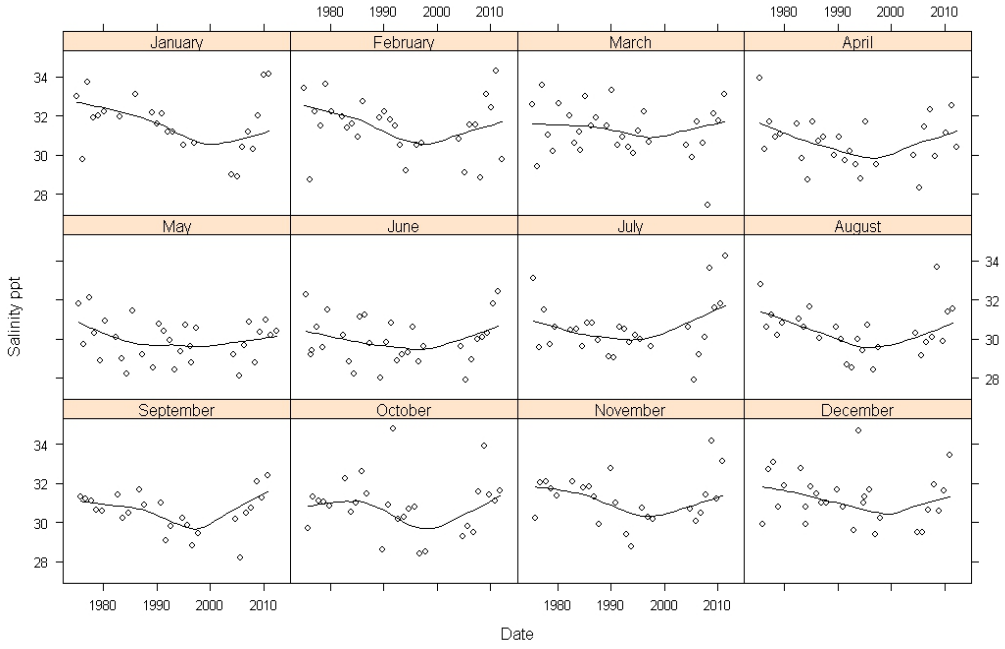


Figure 62. Station 1 and 18 (A & B respectively) Salinity as PPT by month.

3.3 Station 10, mouth of Mill River, West Bay

Station 10 is located in East Rockaway Channel at the mouth of Mill River, a stream system that drains much of the central Town of Hempstead. It is the main natural fresh water surface flow to the West Bay system. Total Coliform at this location declined since the mid 1980s (Figures 63 and 64), but not after 2008 as was seen in East Bay.

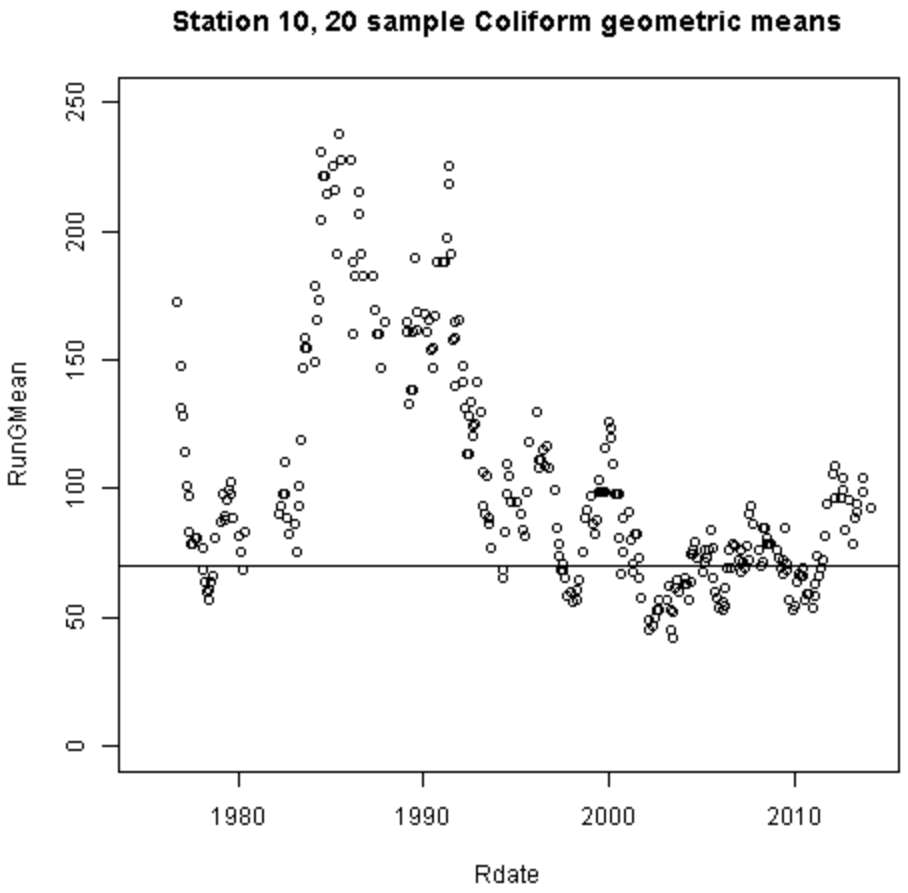


Figure 63. The 20 sample moving geometric means for Station 10.

Nitrates at Station 10 seem to have risen and then declined during the four decade time interval covered in this report (Fig. 65). The Ammonia, Phosphate, Chlorophyll “a,” DO, and Salinity trends do not display obvious changes through time (Figures 66 - 70). The monthly time trends also seem to lack differences through time that differ from the overall trends (Figs. 71 - 76). However, some seasonal variation is seen. Phosphates are low in January through March but high in July (Fig. 73). Chlorophyll varies greatly, with seasonal highs in February, March, June, and July, but much lower values from September through January (Fig. 74). DO also shows the seasonal variation that is driven by the changes in temperature its effect on oxygen solubility (Fig. 75).

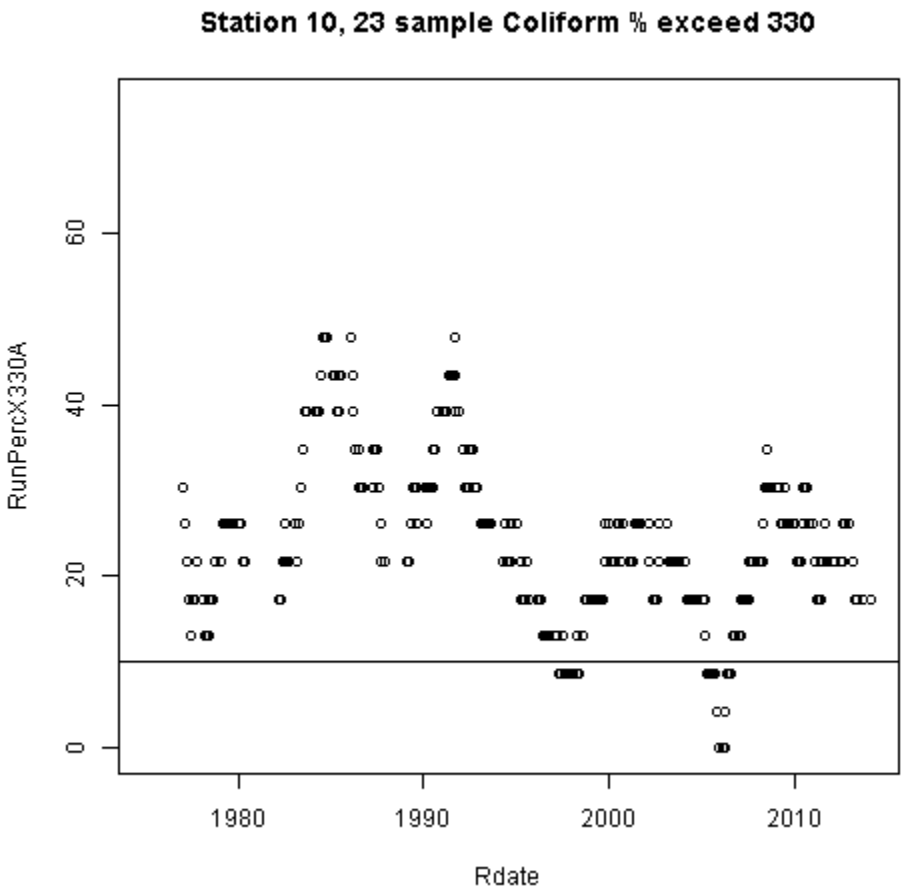


Figure 64. The moving calculation of the percentage of total coliform readings over 330 MPN 100ml at Station 10.

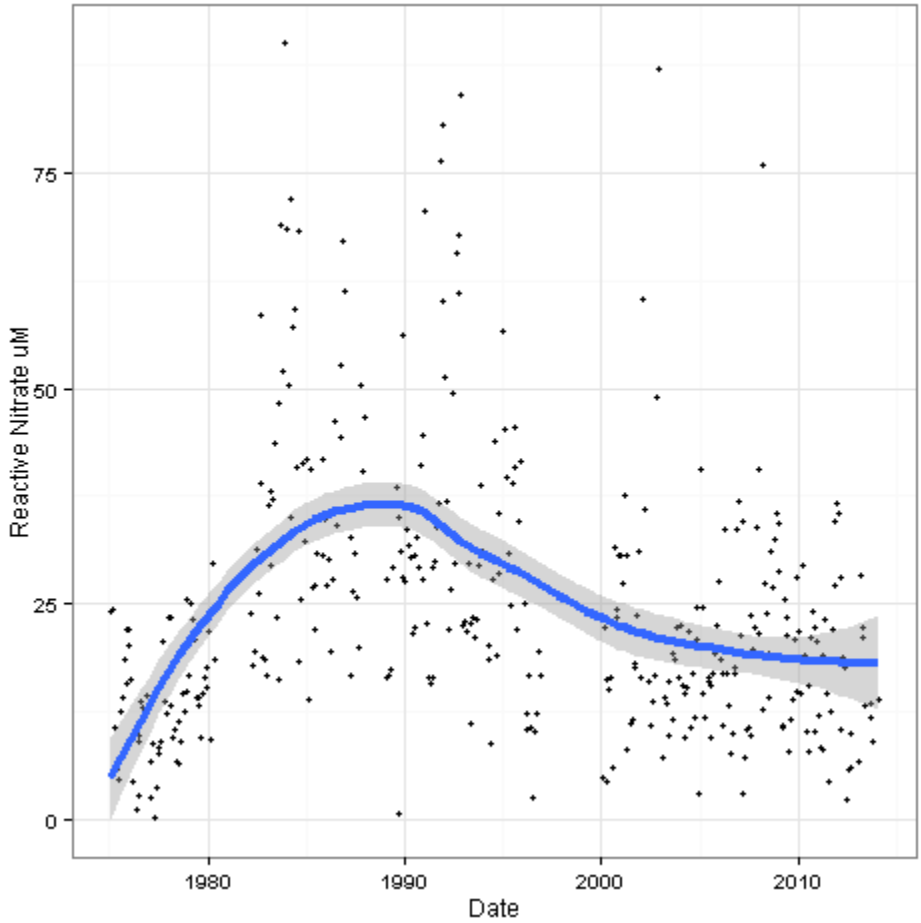


Figure 65. Reactive nitrates as µM at Station 10 with a loess nonparametric fit and 95% confidence limit.

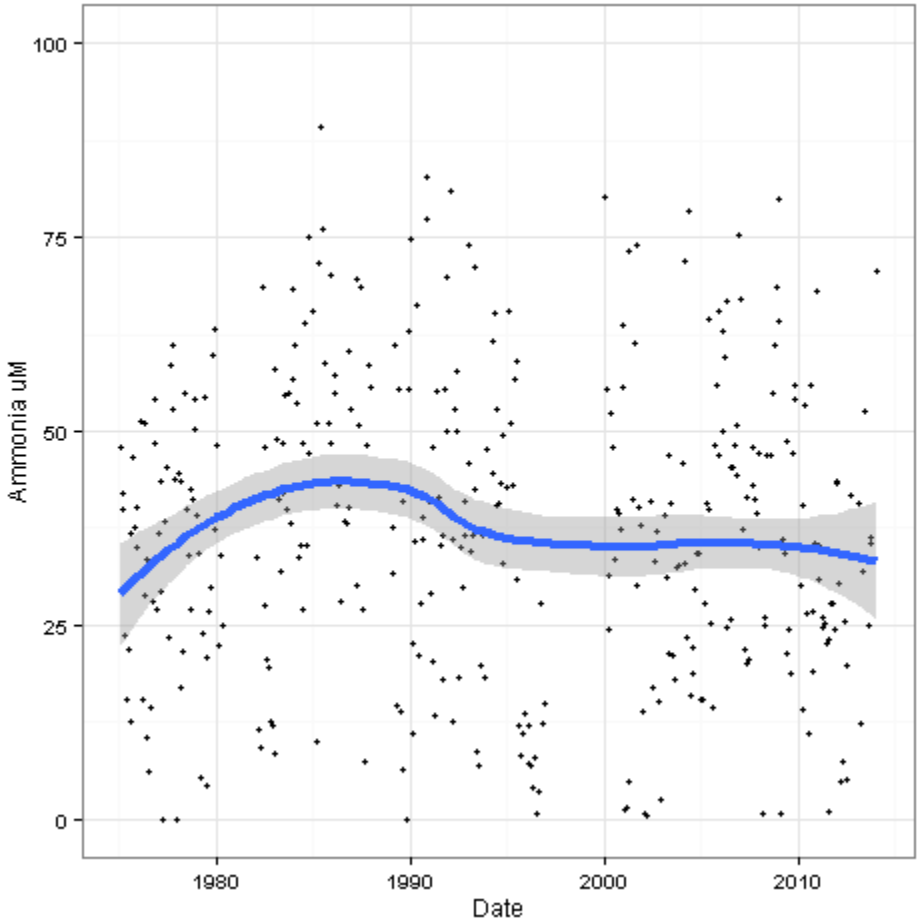


Figure 66. Ammonia as µM at Station 10 with a loess nonparametric fit and 95% confidence limit.

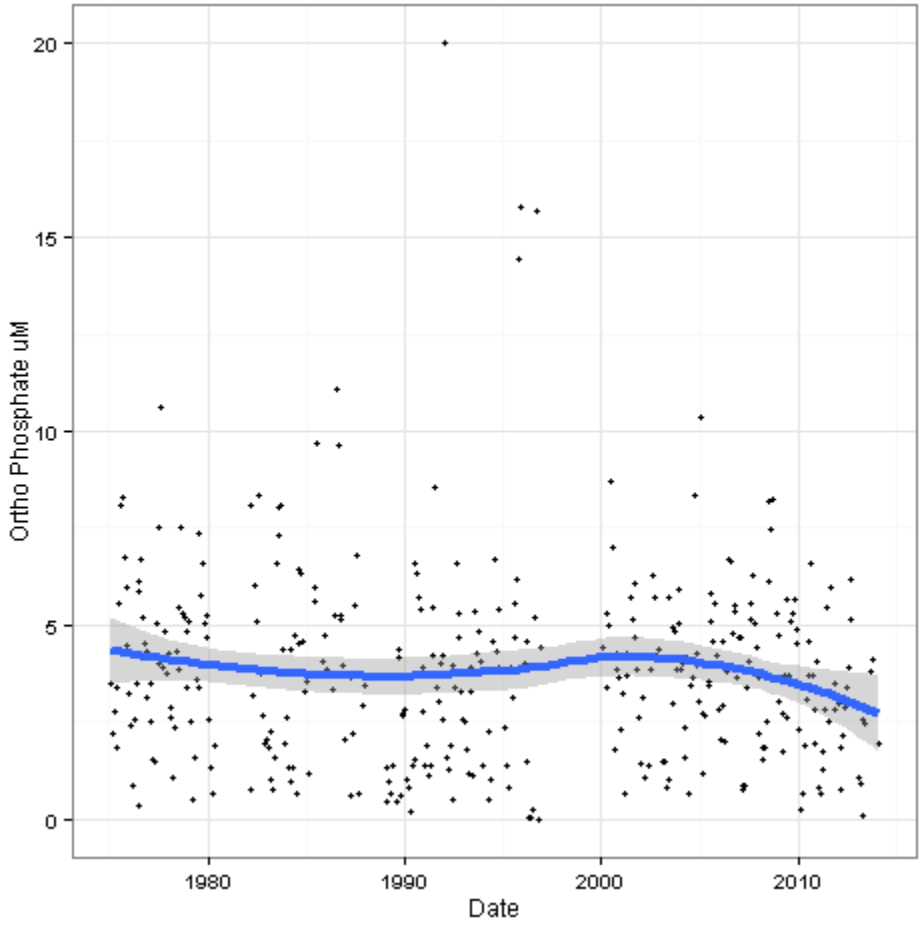


Figure 67. Orthophosphate as µM at Station 10 with a loess nonparametric fit and 95% confidence limit.

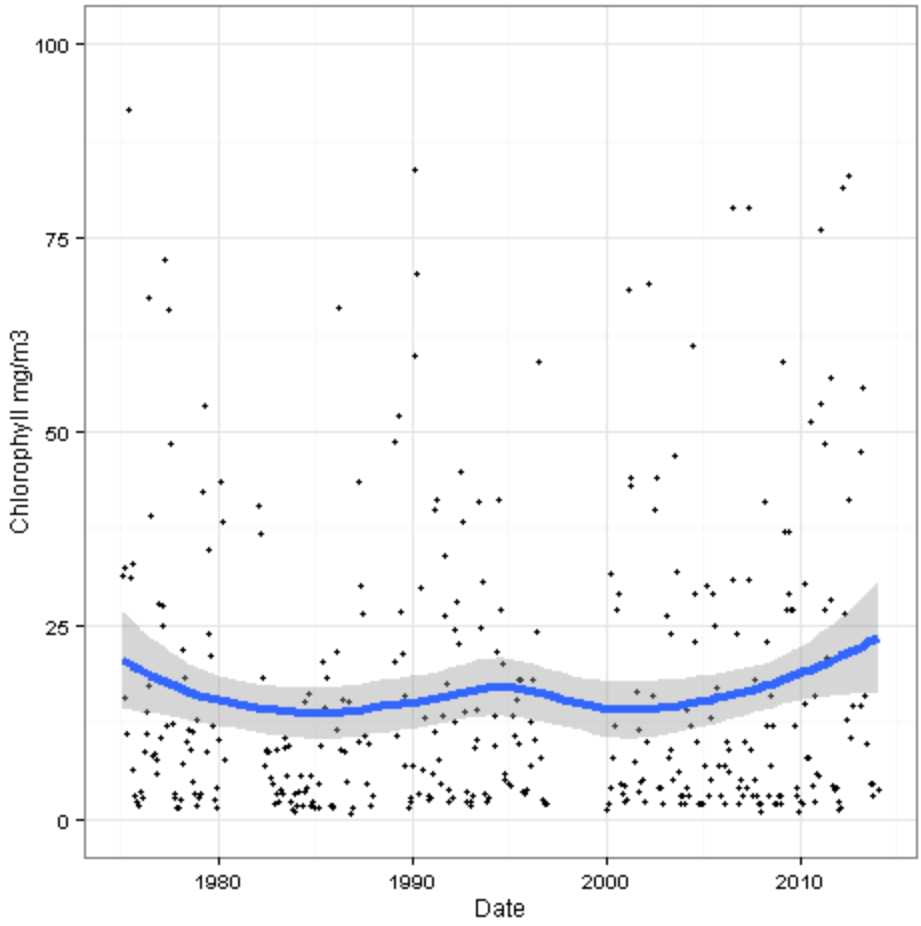


Figure 68. Chlorophyll “a” as mg/L at station 10 with a loess nonparametric fit and 95% confidence limit.

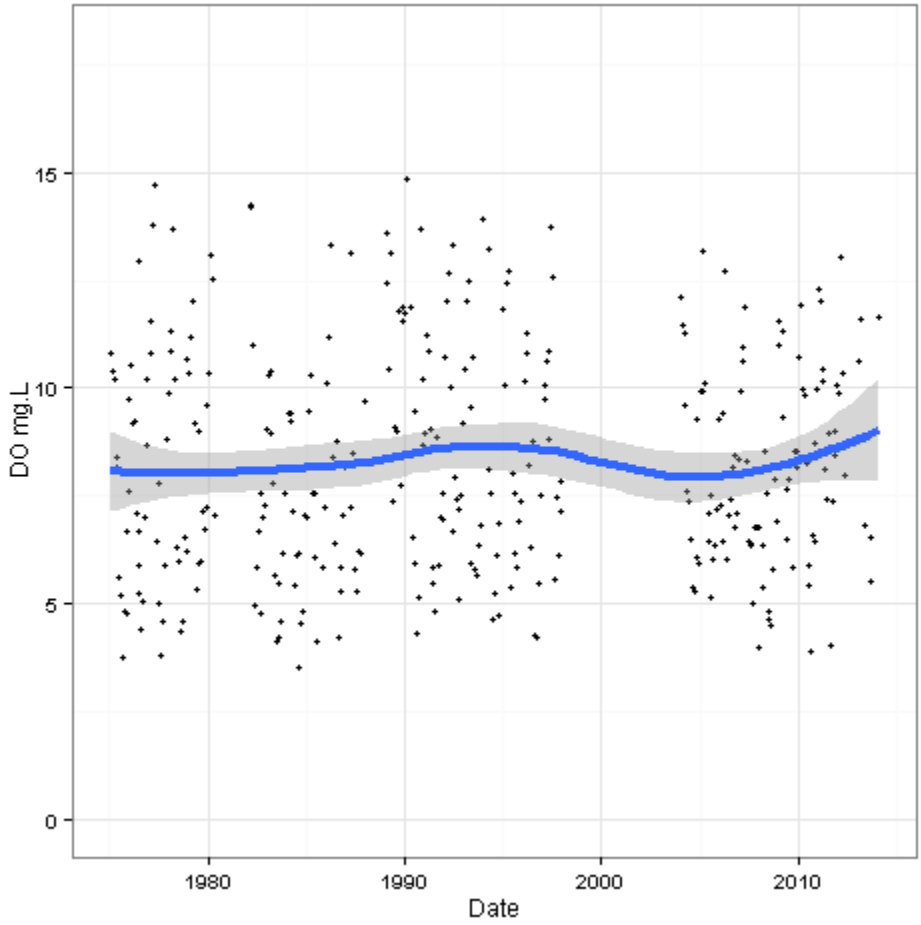


Figure 69. Dissolved Oxygen as mg/L at station 10 with a loess nonparametric fit and 95% confidence limit.

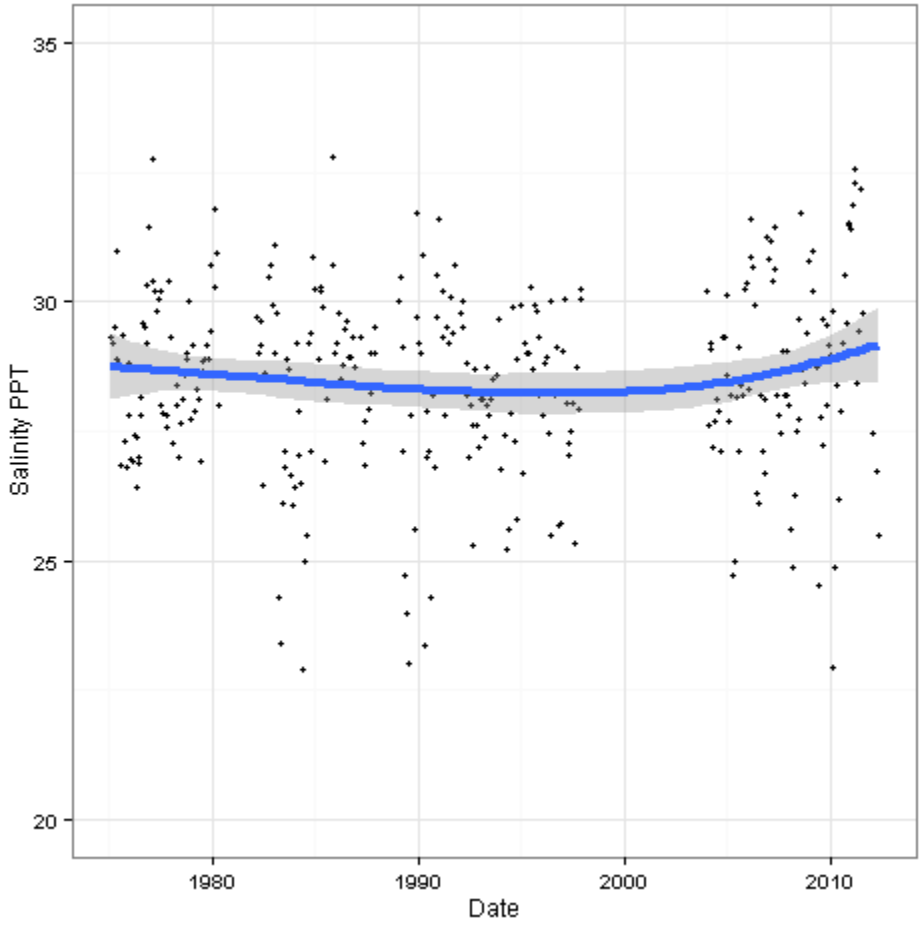


Figure 70. Salinity as PPT at station 10 with a loess nonparametric fit and 95% confidence limit.

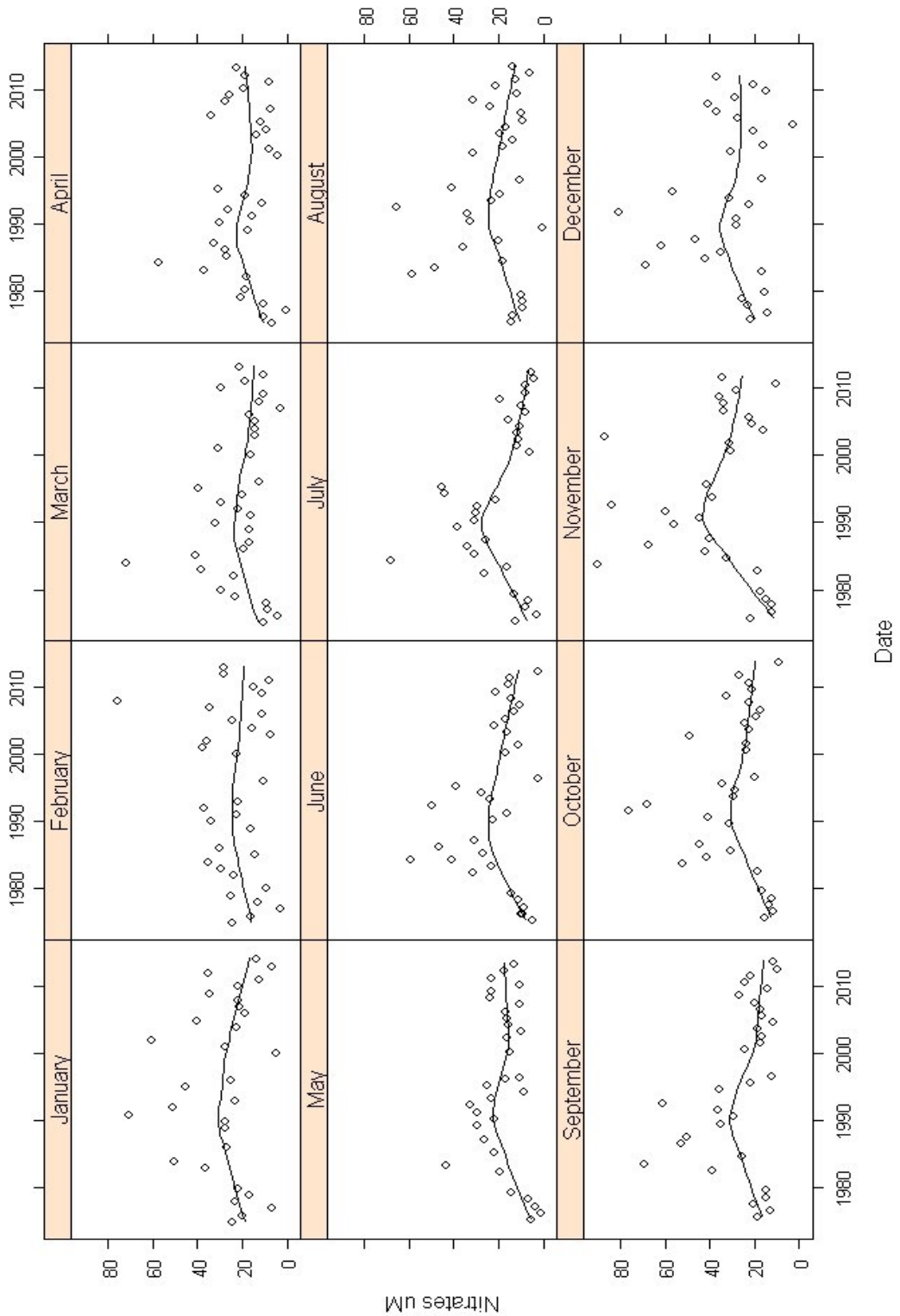


Figure 71. Station 10 Nitrates μM by month with a nonparametric loess fit.

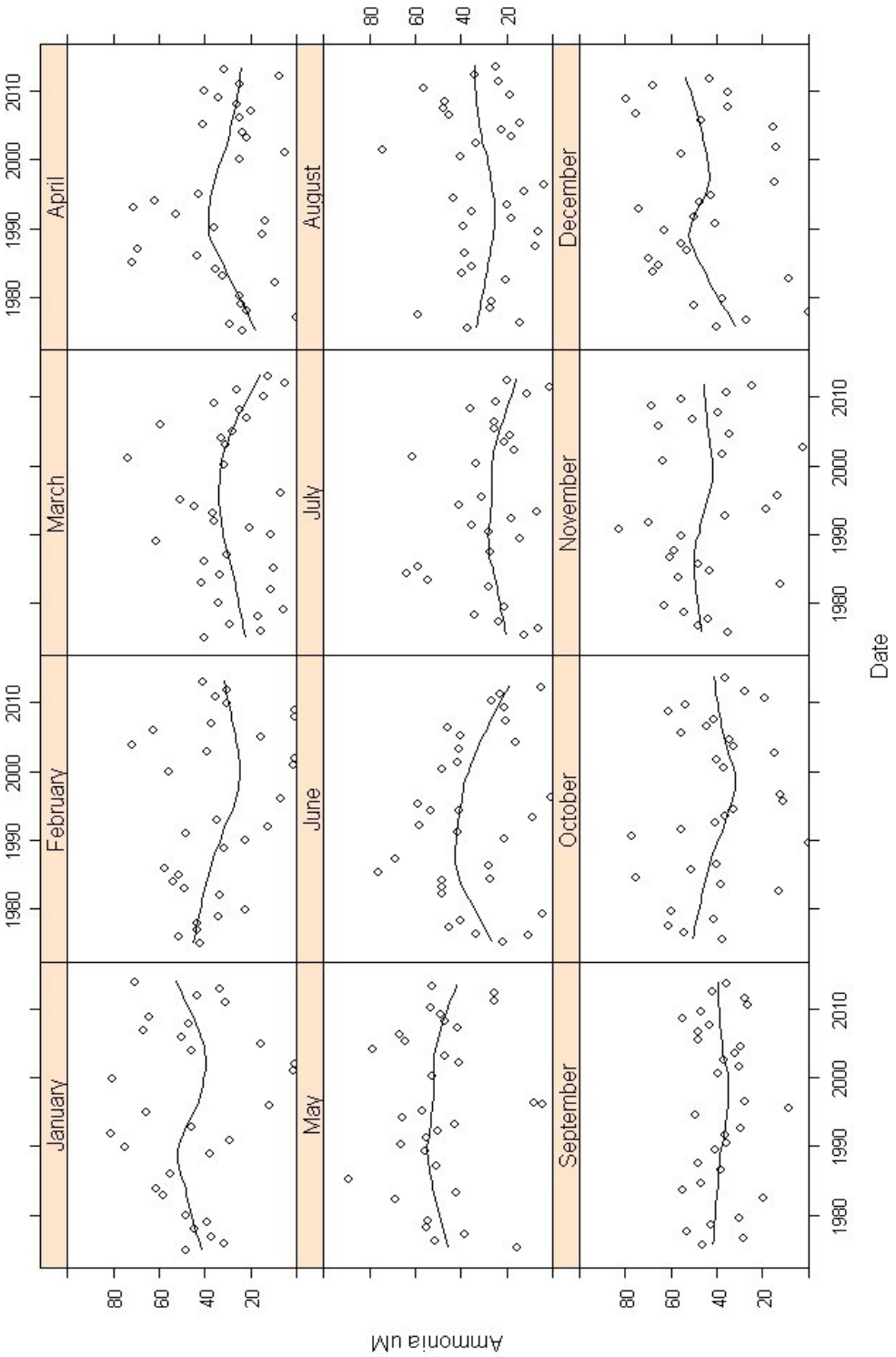


Figure 72. Station 10 Ammonia μM by month with a nonparametric loess fit.

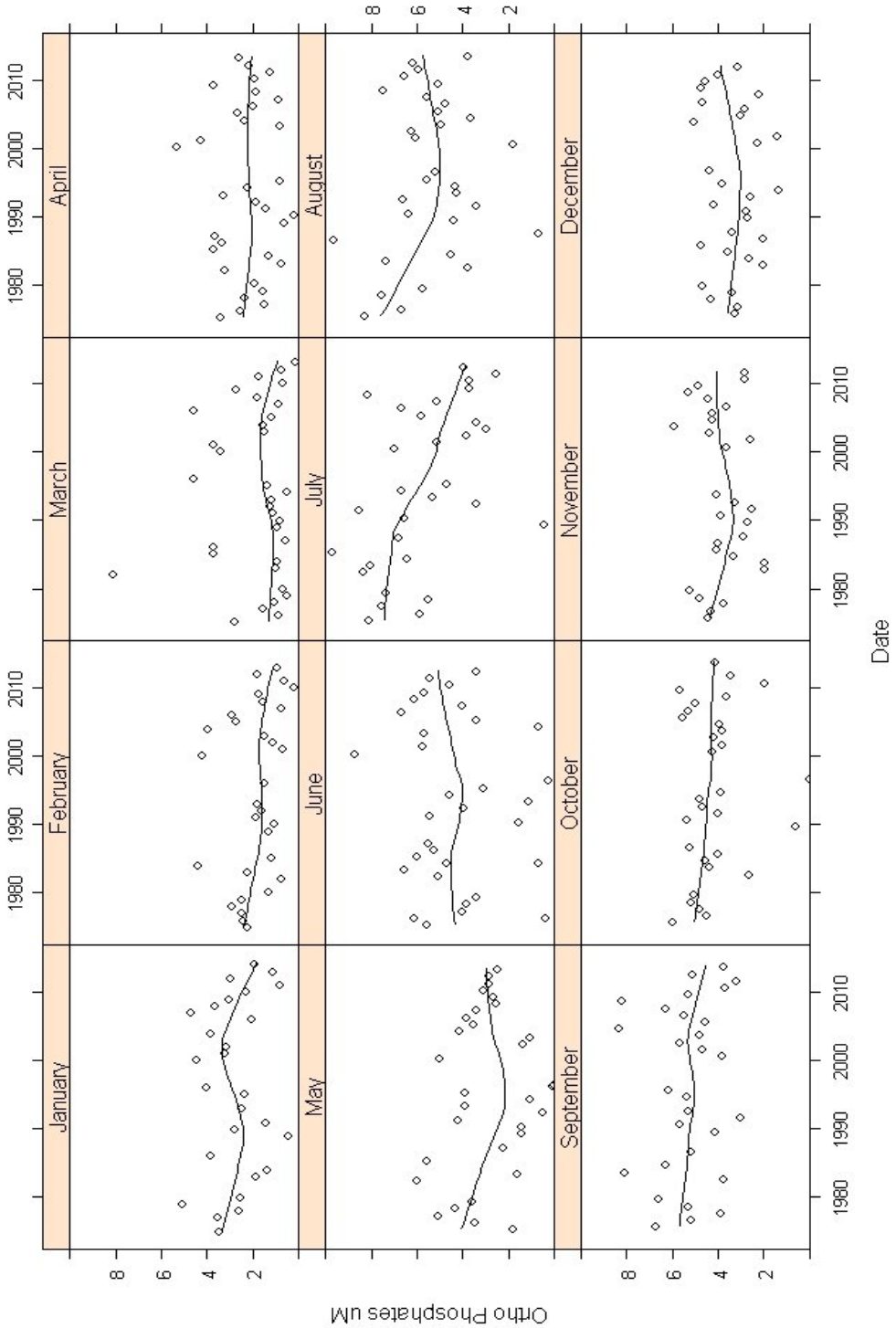


Figure 73. Station 10 Orthophosphate μM by month with a nonparametric loess fit.

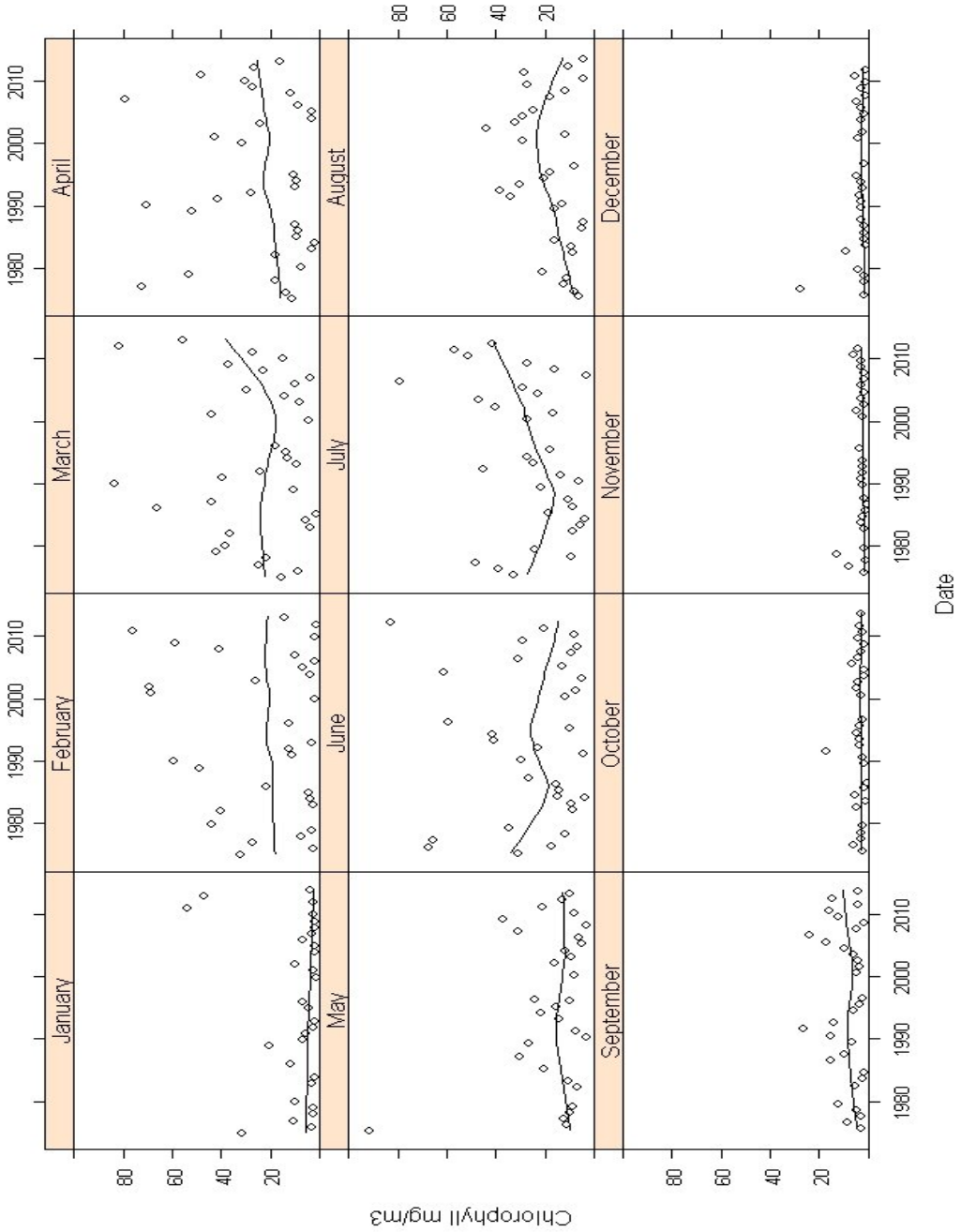


Figure 74. Station 10 Chlorophyll mg/L by month with a nonparametric loess fit.

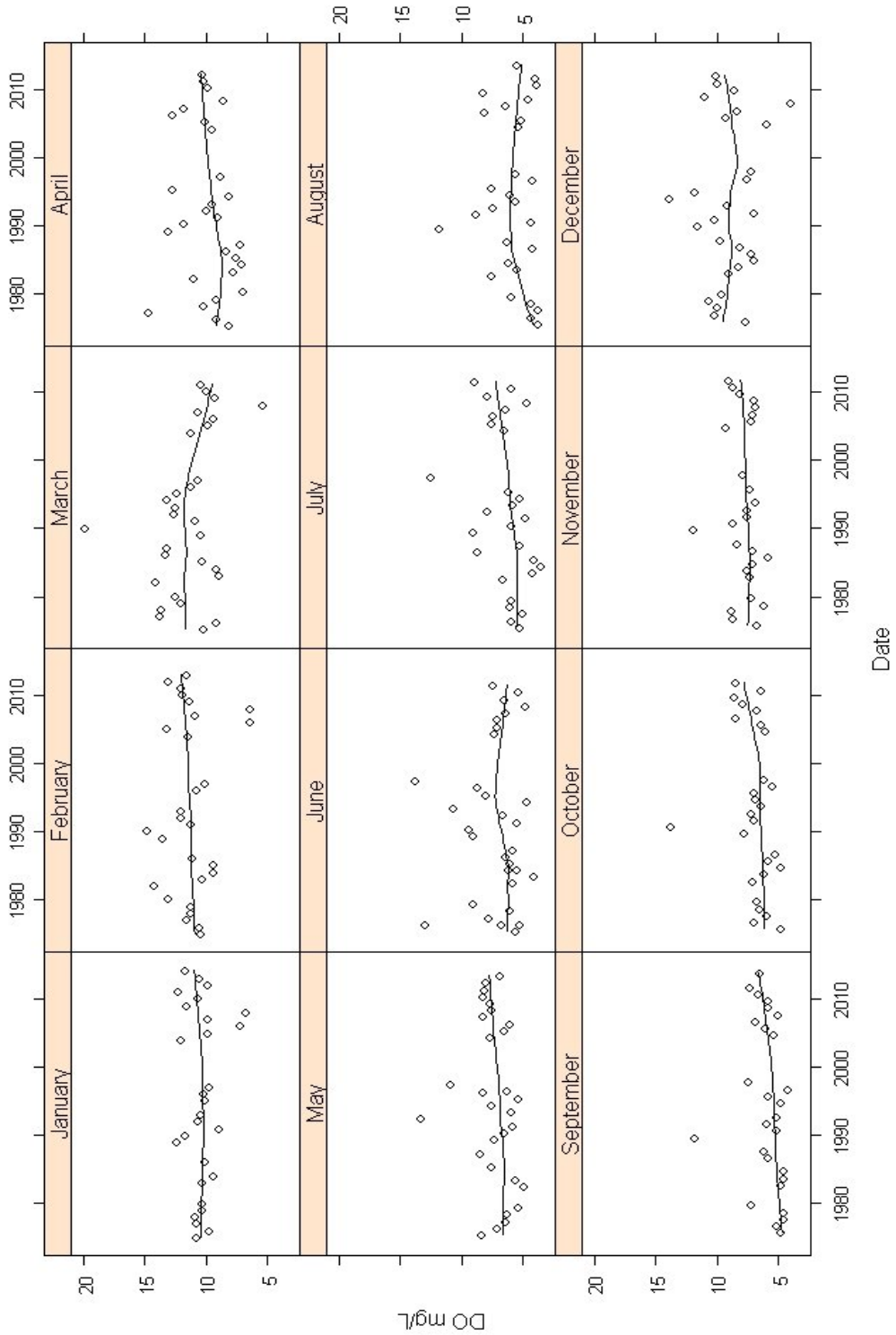


Figure 75. Station 10 Dissolved Oxygen mg/L by month with a nonparametric loess fit.

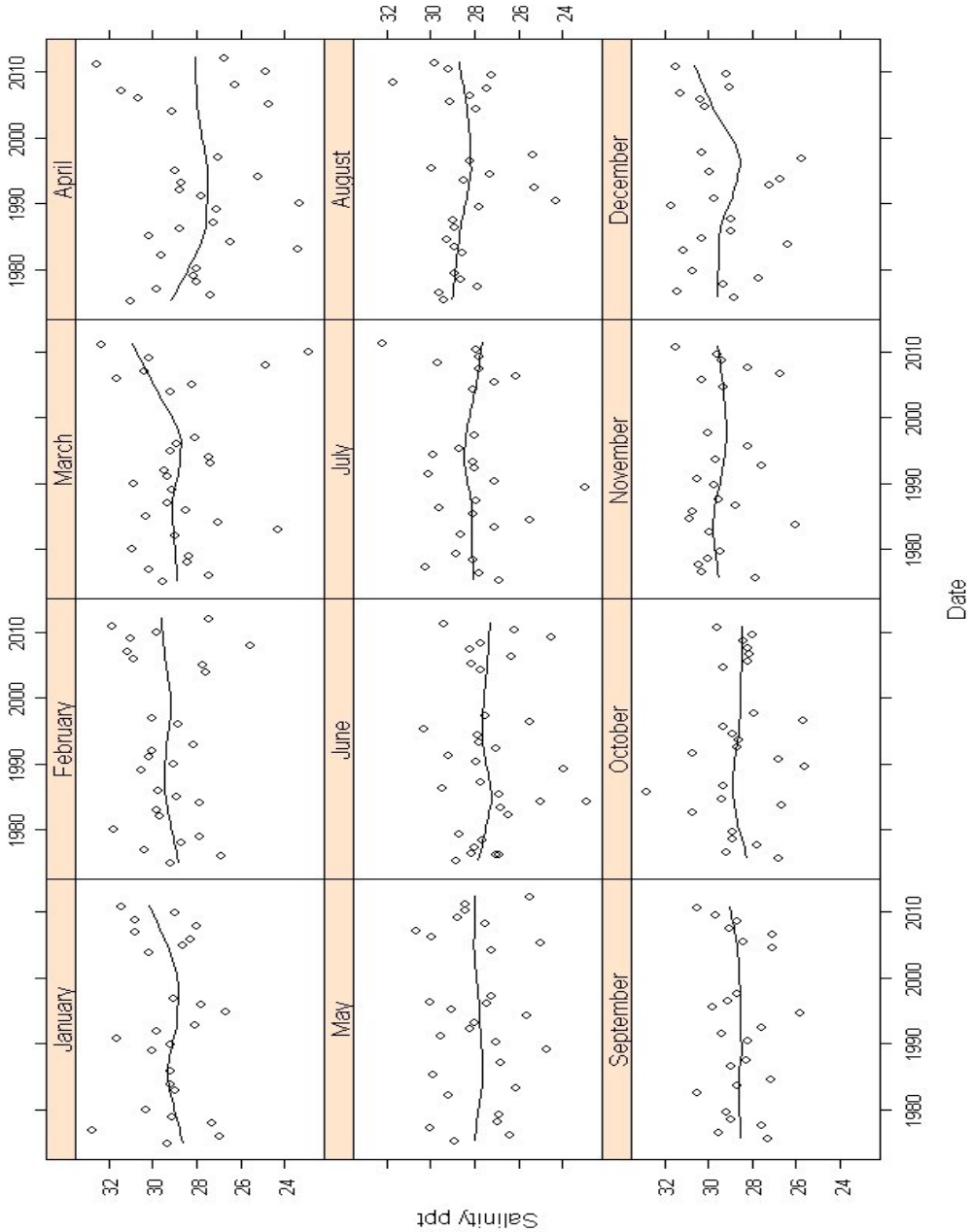


Figure 76. Station 10 Salinity PPT by month with a nonparametric loess fit.

3.5, Station 28, south-east East Bay

Station 28 is at the south-east corner of East Bay in the State Boat Channel just north of Jones Beach and, of all our stations, is the most remote from anthropogenic influences. Station 28 is also one of the original stations, having been monitored since the early 1970s. Total coliforms at this station have remained low throughout the study period (Figures 77 and 78).

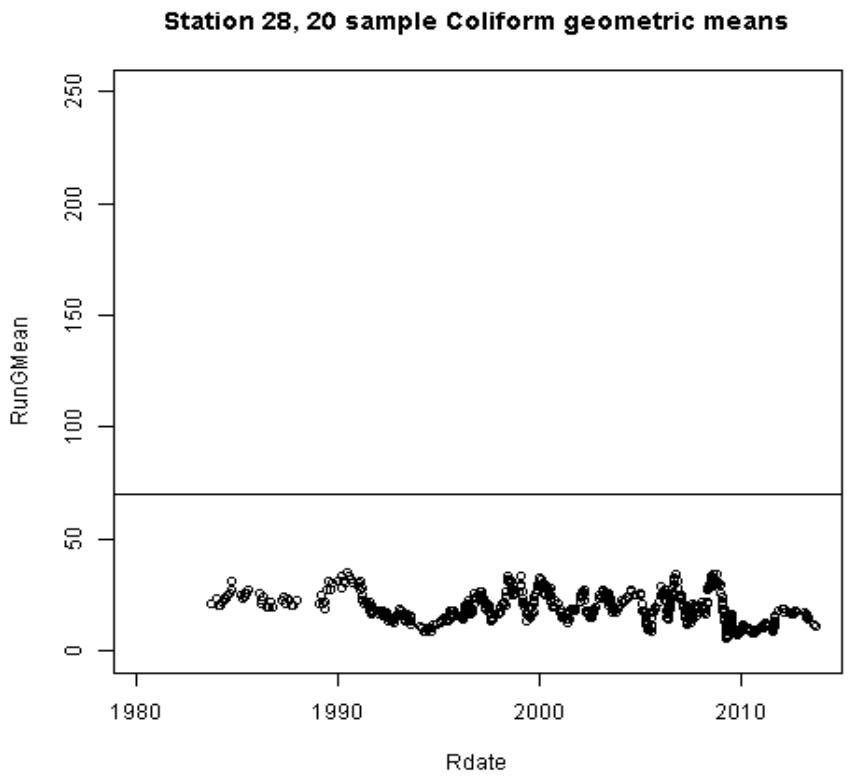


Figure 77. The moving 20 sample geometric means for total coliforms for Station 28.

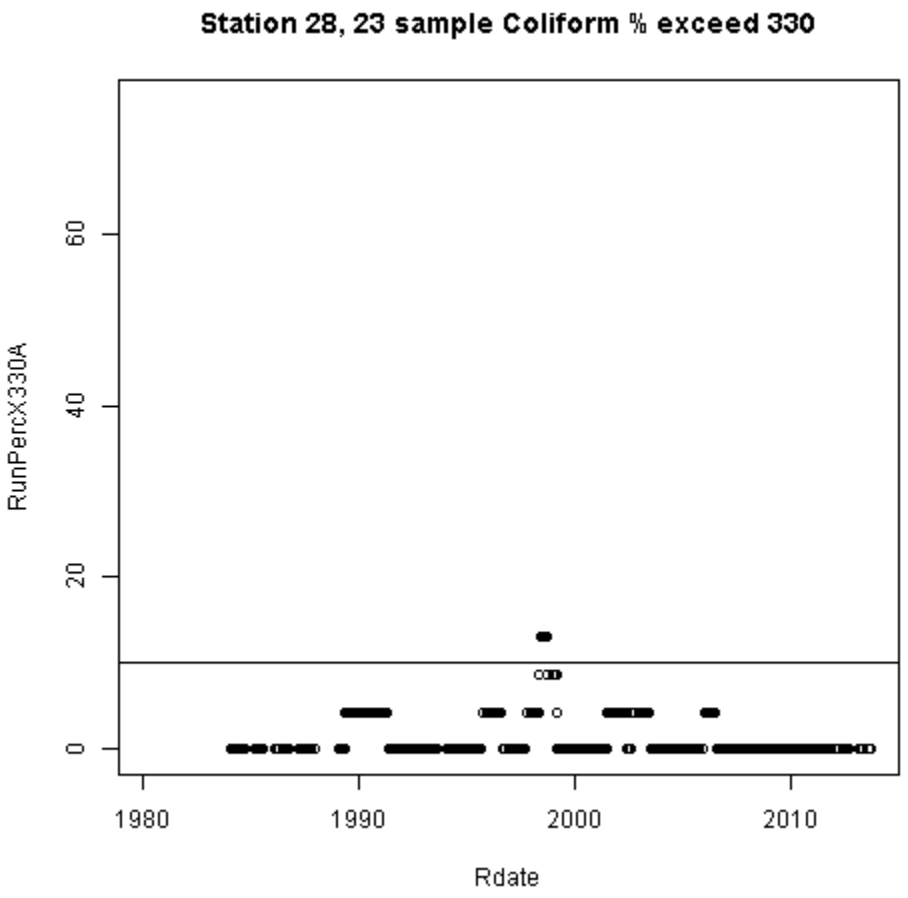


Figure 78. The moving calculation of the percentage of total coliform readings over 330 MPN 100ml at Station 28.

Nitrates show a significant overall decline through the four decade study period when viewed overall (Fig. 79), or idividually foreach month (Fig. 85). No similar change was seen for Ammonia, Phosphate, or Chlorophyll "a" (Figures 80 – 82 and 86 – 88). Neither DO nor salinity showed consistent trends though the time period of the study (Figures 83, 84, 89 and 90).

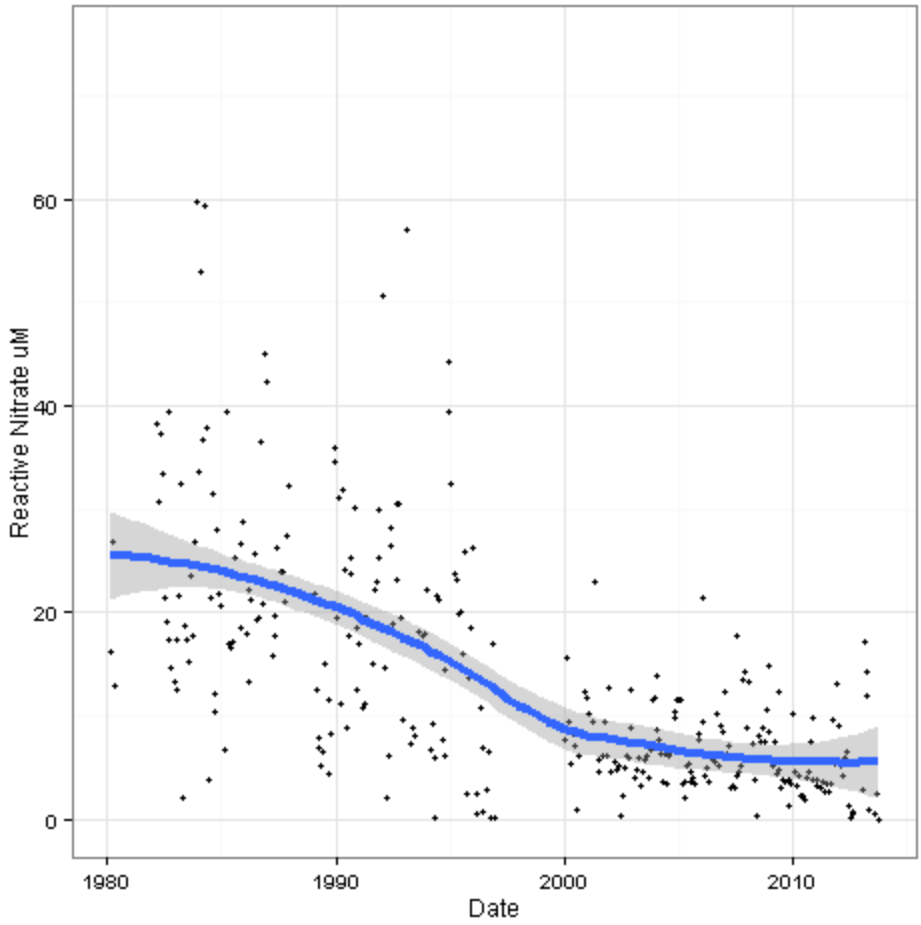


Figure 79. Reactive Nitrates as µM at Station 28 with a loess nonparametric fit and 95% confidence limit.

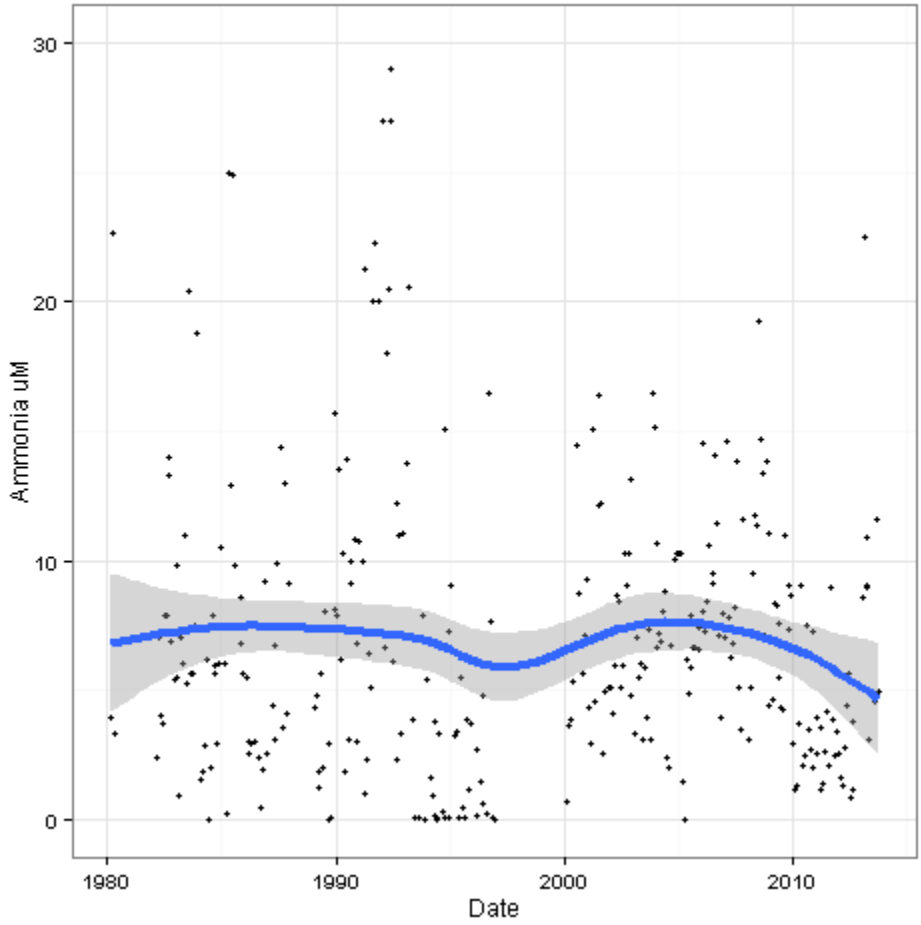


Figure 80. Ammonia as µM at Station 28 with a loess nonparametric fit and 95% confidence limit.

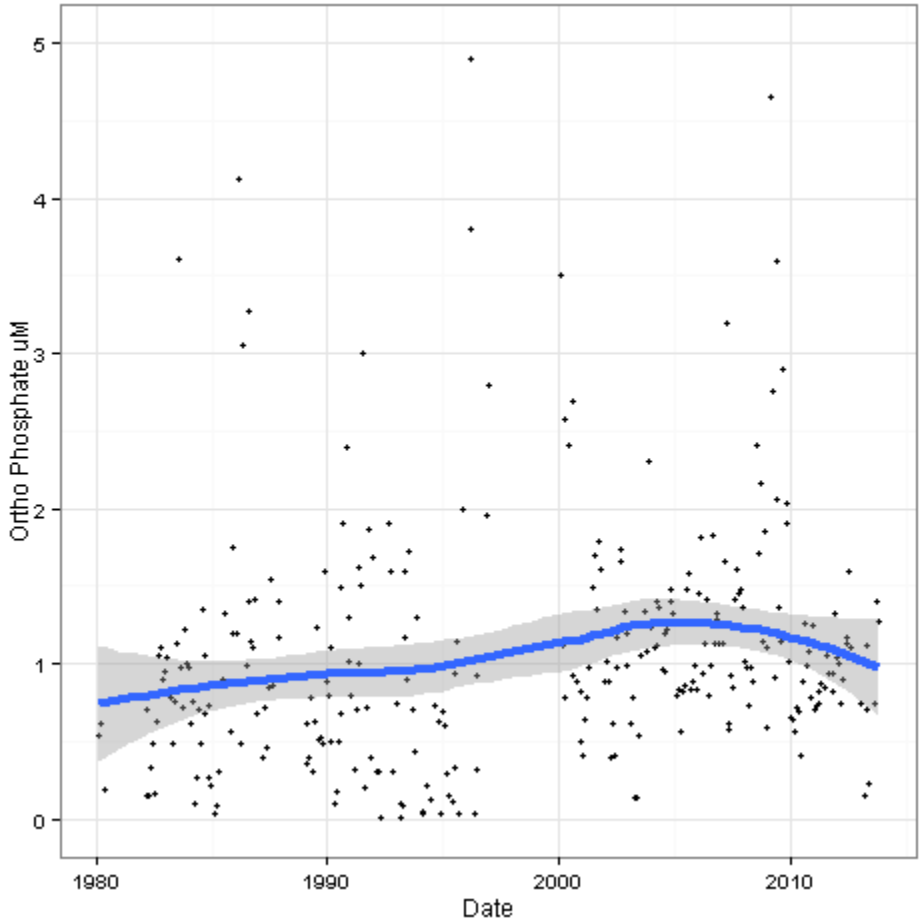


Figure 81. Orthophosphates as µM at Station 28 with a loess nonparametric fit and 95% confidence limit.

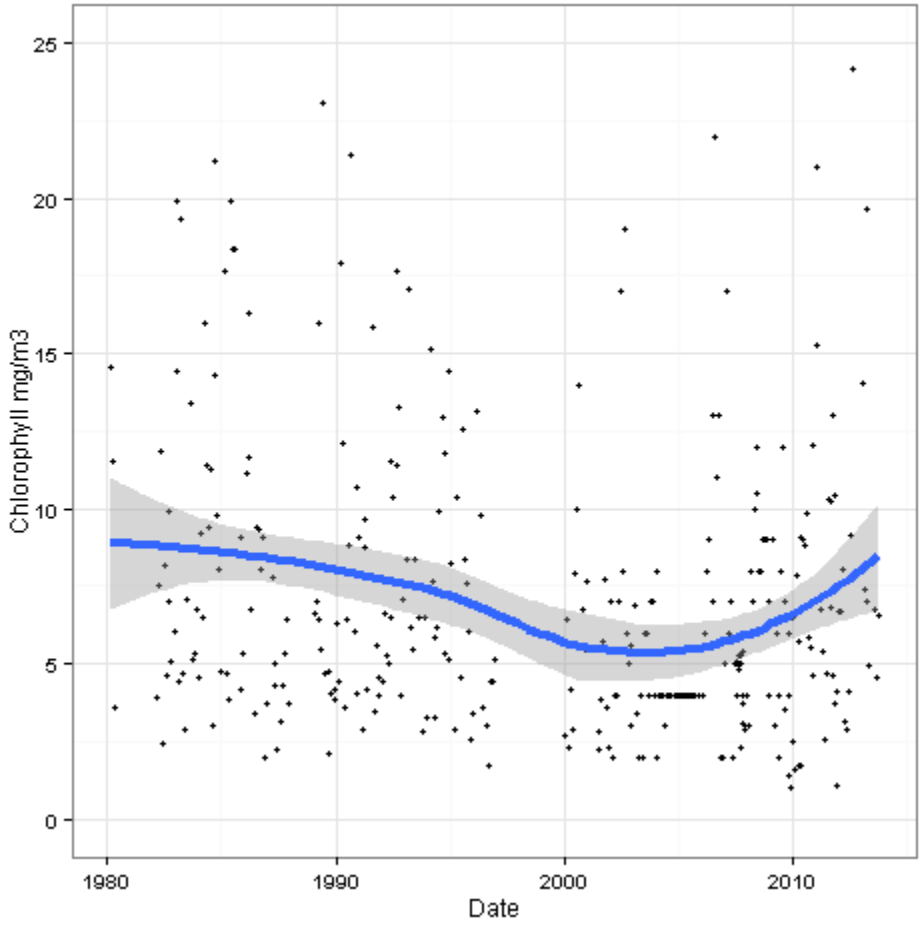


Figure 82. Chlorophyll as mg/L at Station 28 with a loess nonparametric fit and 95% confidence limit.

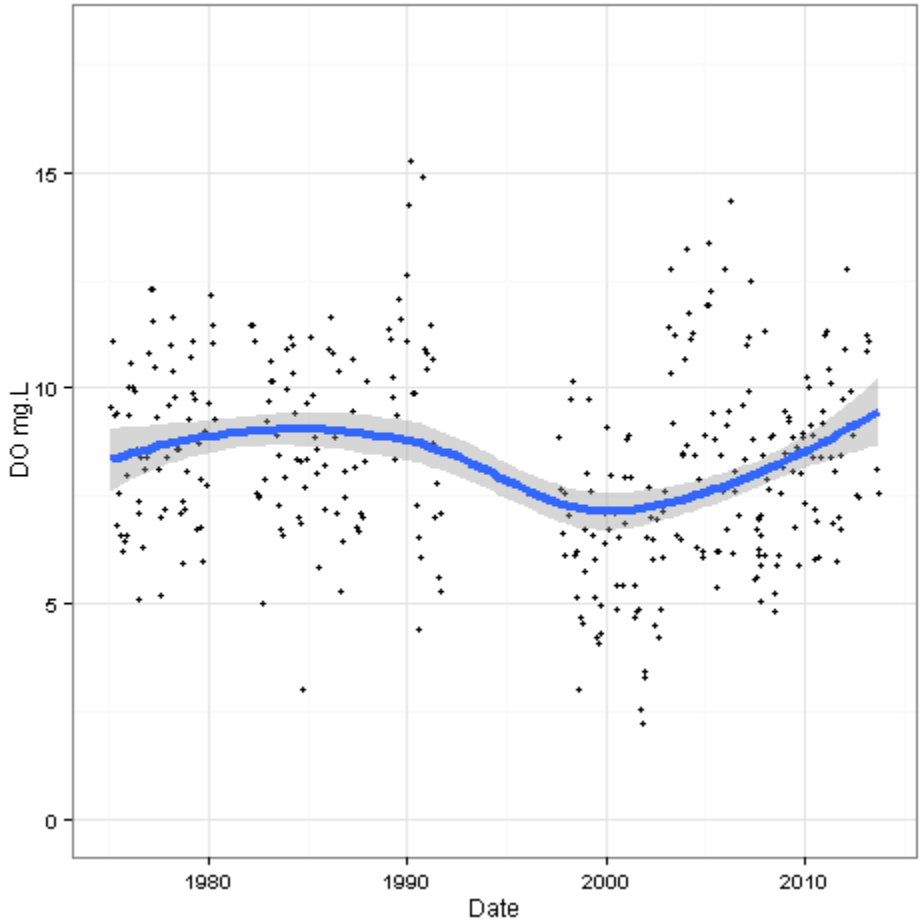


Figure 83. Dissolved Oxygen as mg/L at Station 28 with a loess nonparametric fit and 95% confidence limit.

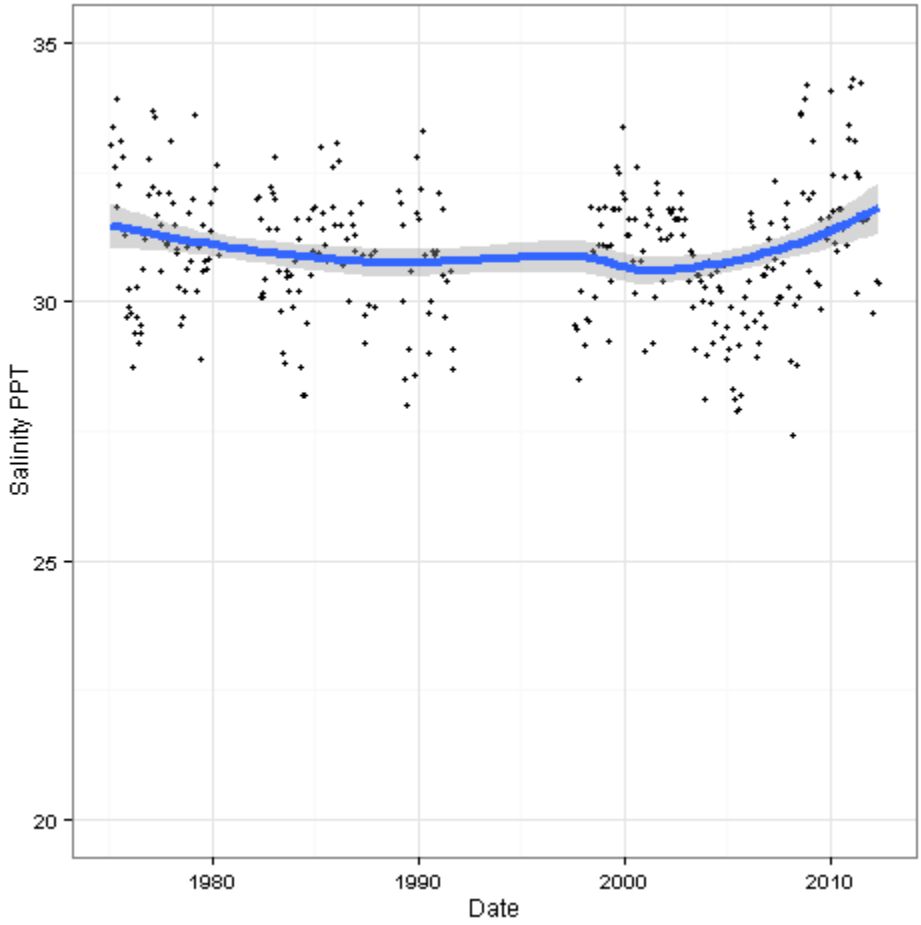


Figure 84. Salinity as PPT at Station 28 with a loess nonparametric fit and 95% confidence limit.

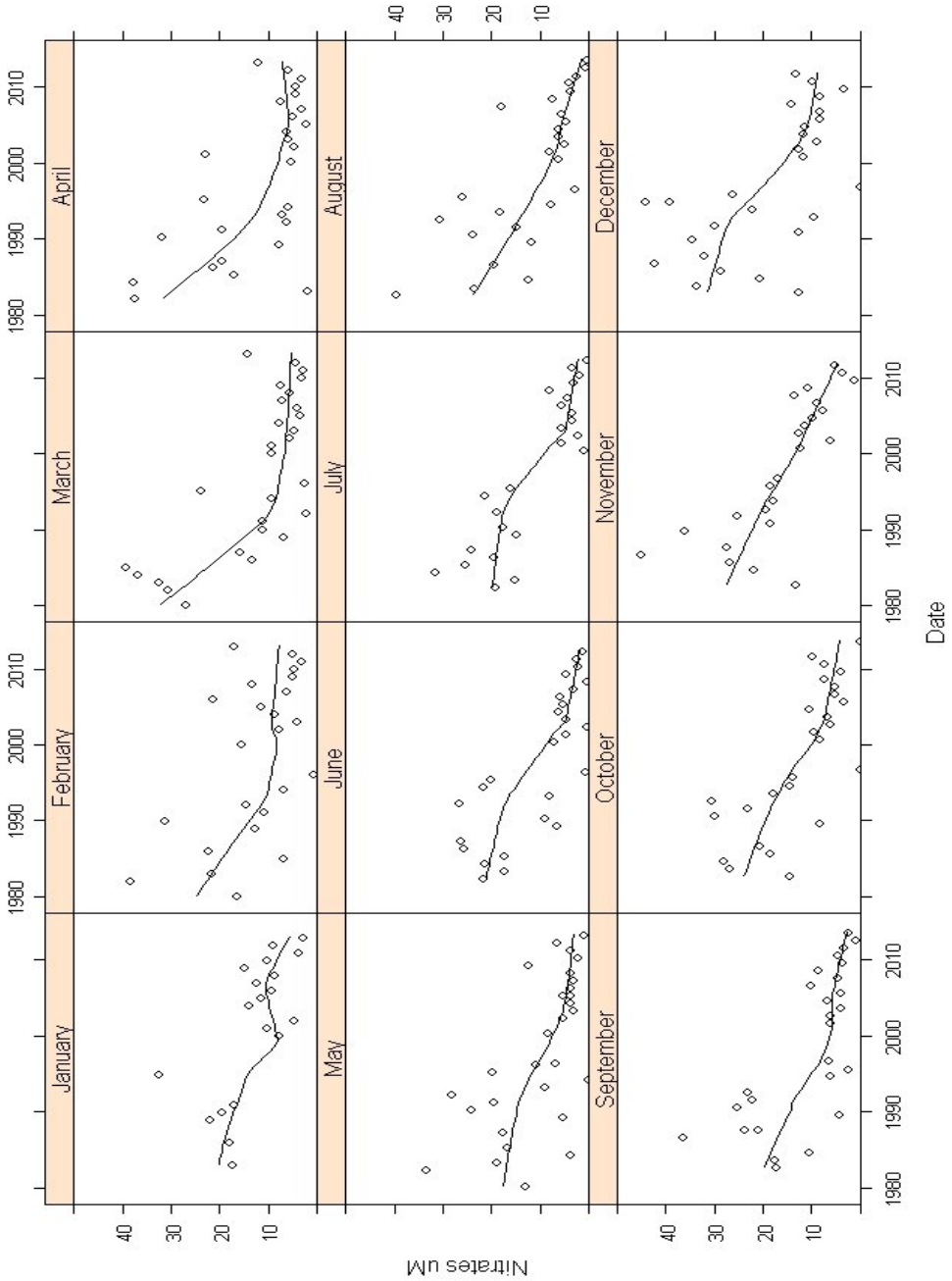


Figure 85. Station 28 Nitrate μM by month with a nonparametric loess fit.

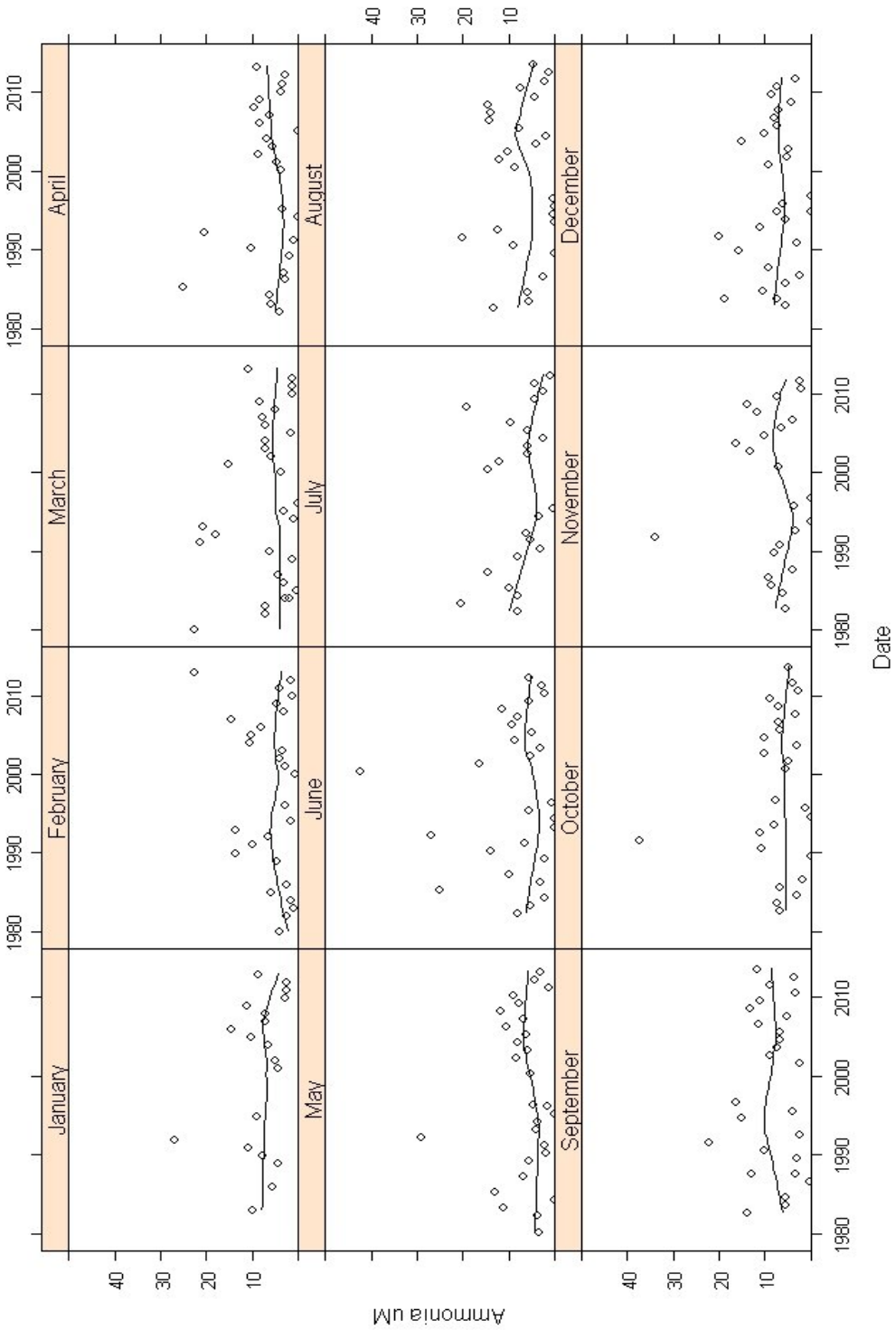


Figure 86. Station 28 Ammonia μM by month with a nonparametric loess fit.

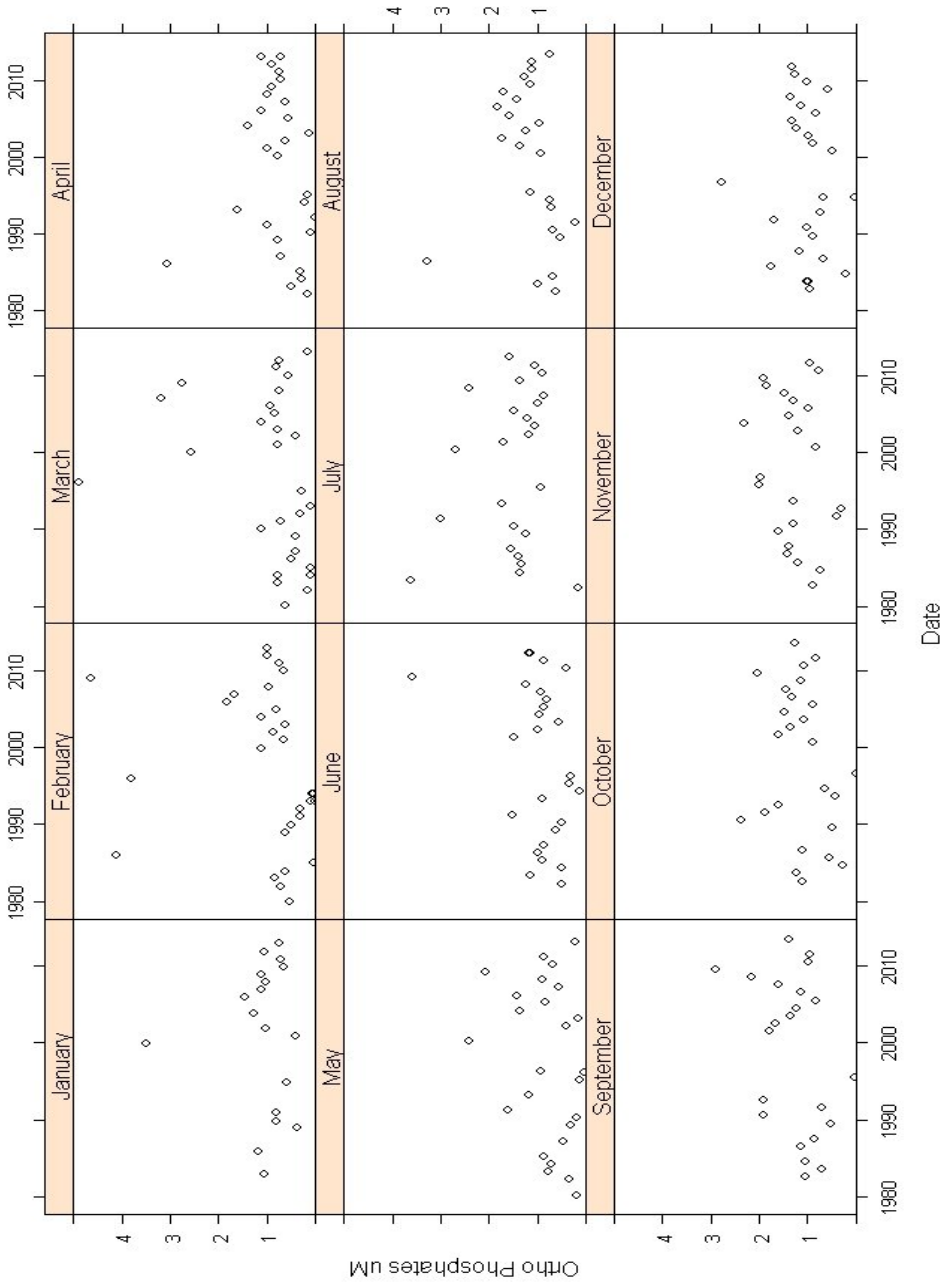


Figure 87. Station 28 Orthophosphate μM by month with a nonparametric loess fit.

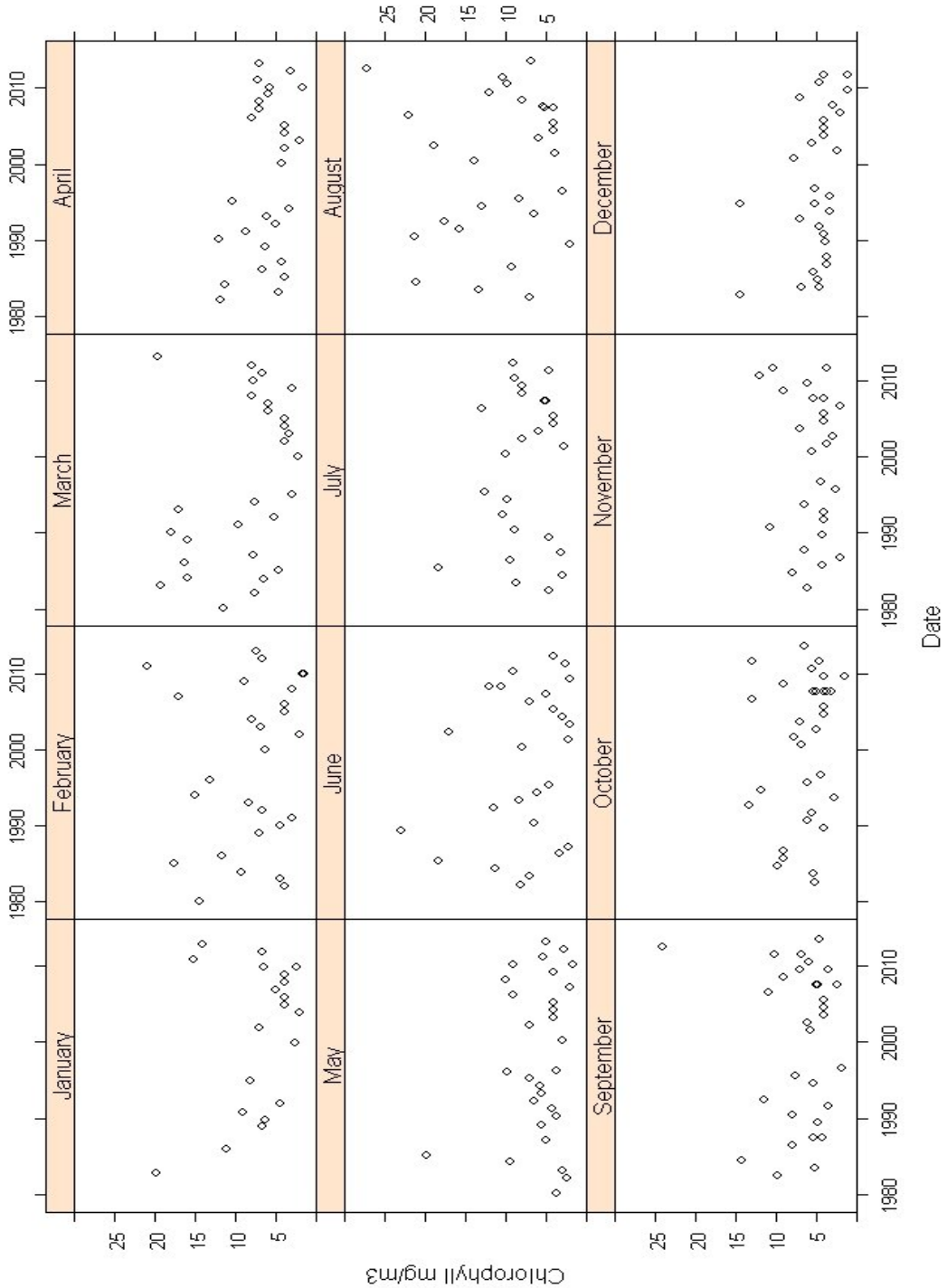


Figure 88. Station 28 Chlorophyll mg/L by month with a nonparametric loess fit.

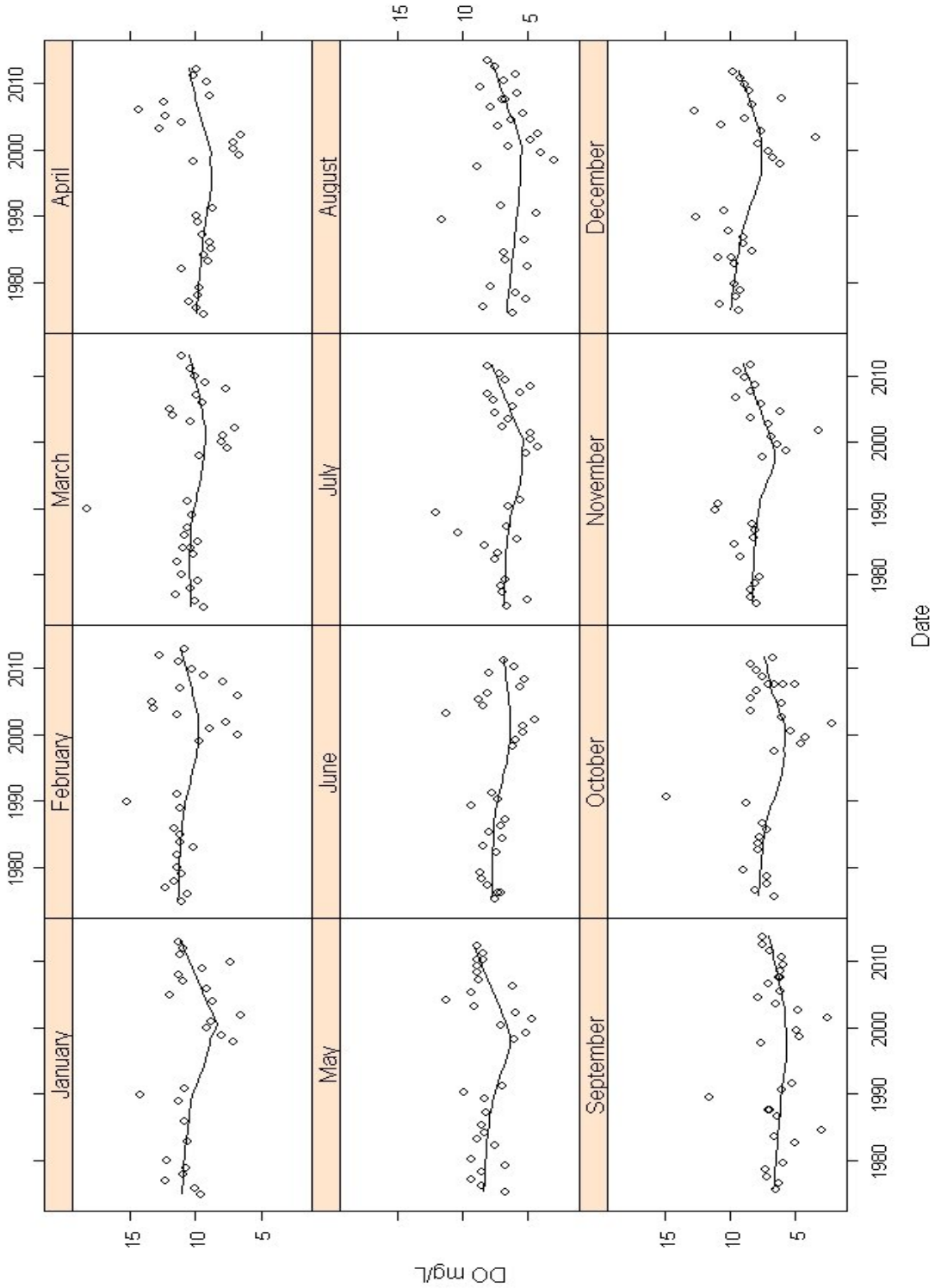


Figure 89. Station 28 Dissolved Oxygen mg/L by month with a nonparametric loess fit.

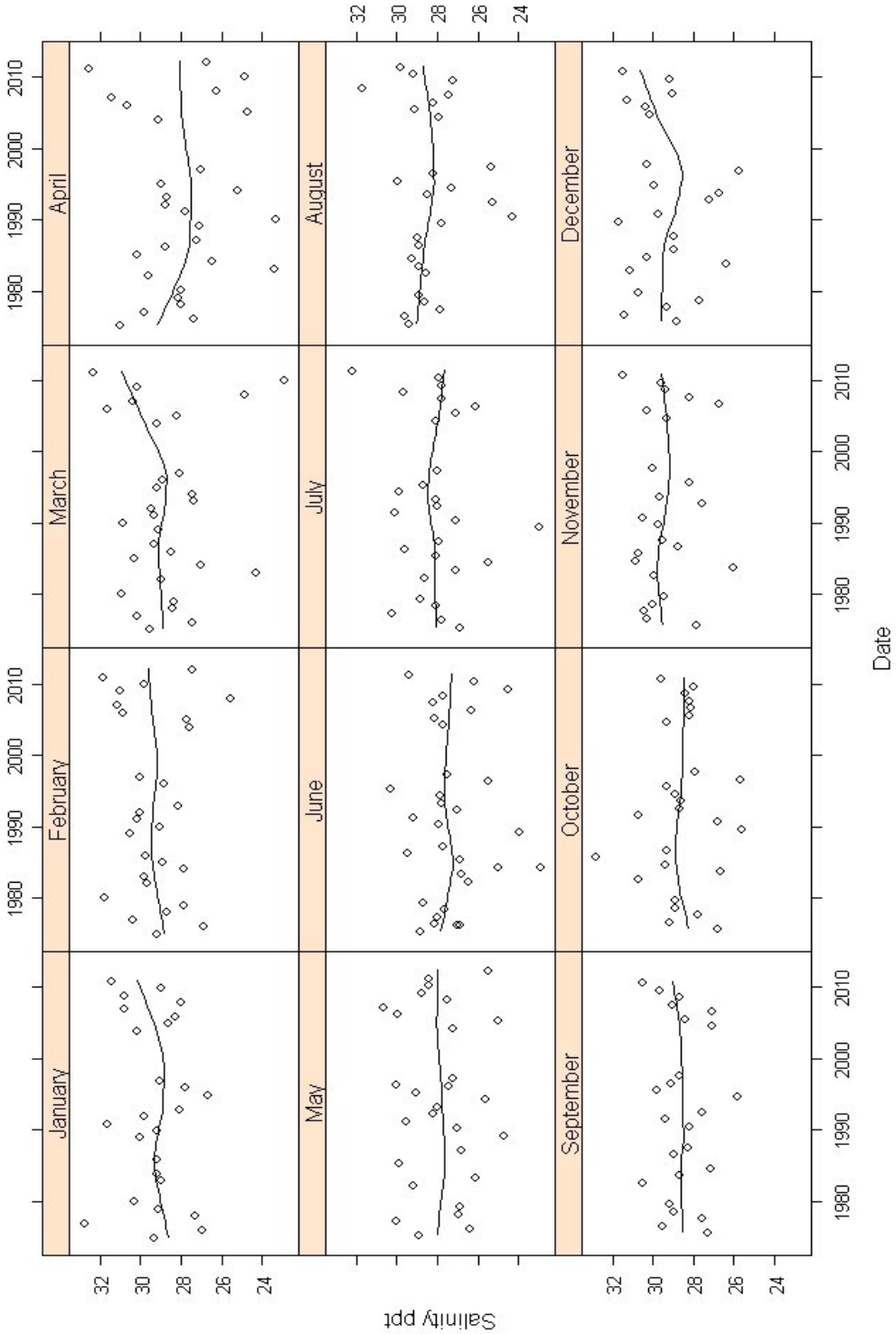


Figure 90. Station 28 Salinity PPT by month with a nonparametric loess fit.

3.6 Comparison with 1968 Report

The 1968 Water Quality Study examined the Water Temperature, Salinity, Nitrate, Coliform, Chlorophyll "a", and Orthophosphate readings at 26 bay sampling stations and 3 ocean stations (Figure 91). To understand how these parameters have changed since 1968, we examined spatial figures and compared 1968 and 1975 data. Although the locations and numbering of the sampling stations used in the 1968 study differ from those used in this report, we compared parameter values at similarly located stations (1968 Stations: 19, 4, 5, 8, 14, 10, 3 and 1975: 3, 11, 6, 14, 17, 23, 12 respectively).

Salinity values in 1968 were similar to those reported from 1975-2011 (Figure 3, page 9) with lower values in northern sections of the bay where water was diluted with runoff.

Nitrates were significantly higher in 1968 than in 1975 (41.2 and 8.28. μM average, respectively; $p<0.01$; Fig. 92). Spatially, 1968 data indicates higher values in the western and middle sections of the bay, similar to the pattern seen in recent decades (Fig. 18, page 23). Coliform values were also higher in 1968 than in 1975 with averages of 830.3 and 442.4 MPN/100 ml, respectively (Fig. 93). Chlorophyll "a" values were similar in 1968 and 1975 with averages of 8.7 and 9.4 mg/m^3, respectively (Fig. 94).

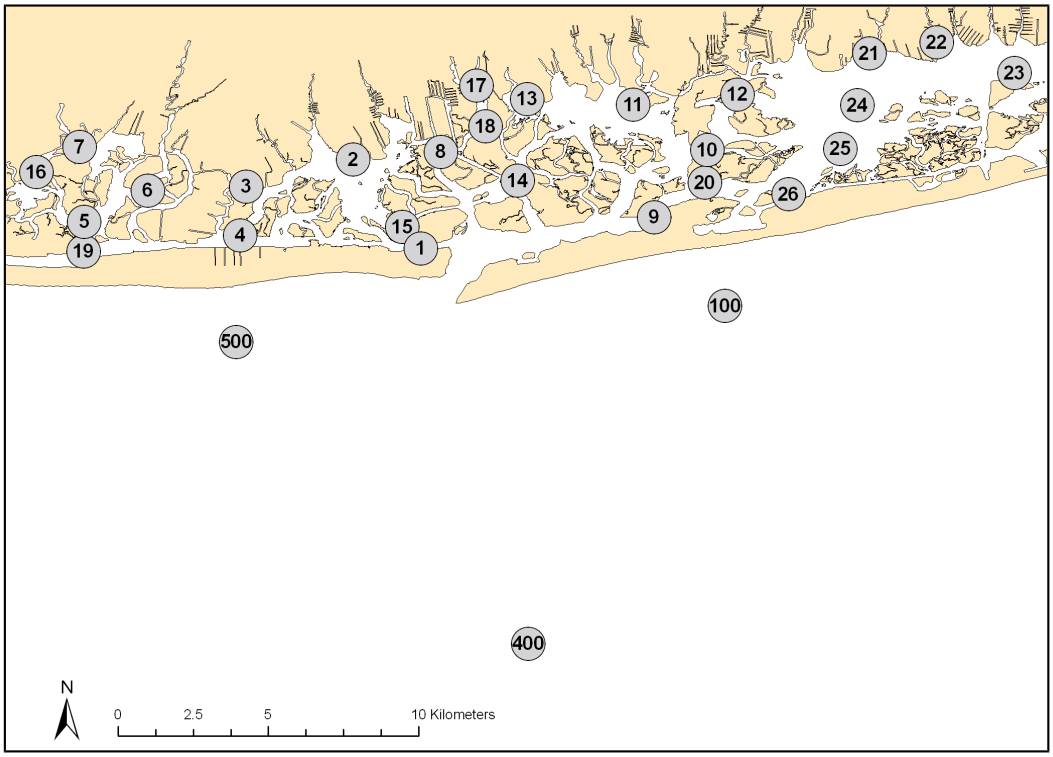


Figure 91. Location of stations used to collect water quality data during the 1968 report.

Comparison with 1968 Report *continued*

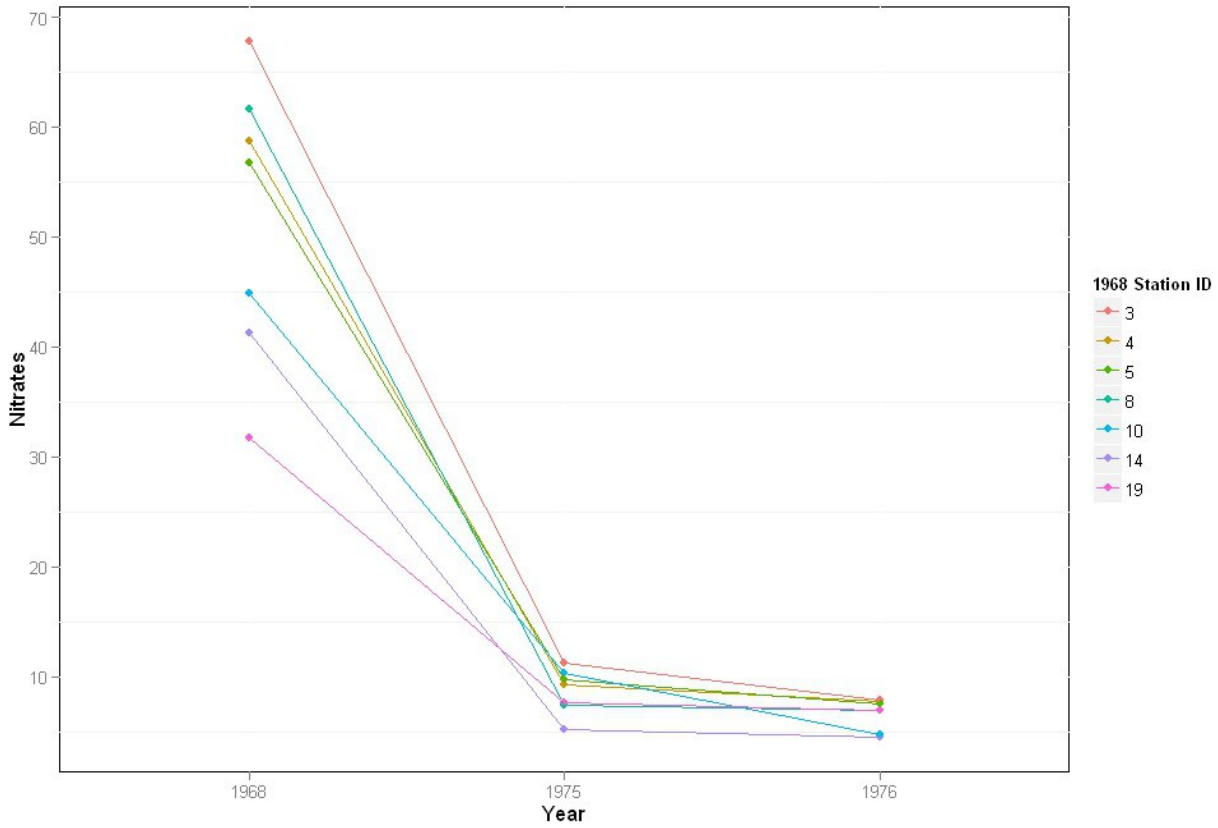


Figure 92. Nitrate (µM) values at similarly located sampling stations in 1968, 1975 and 1976. Paired stations are identified by the 1968 ID.

Salicornia

Comparison with 1968 Report *continued*

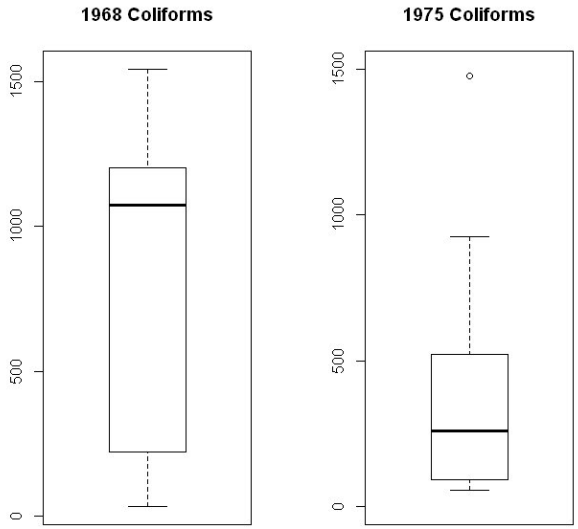


Figure 93. Median Coliform values at sampling stations in 1968 and 1975.

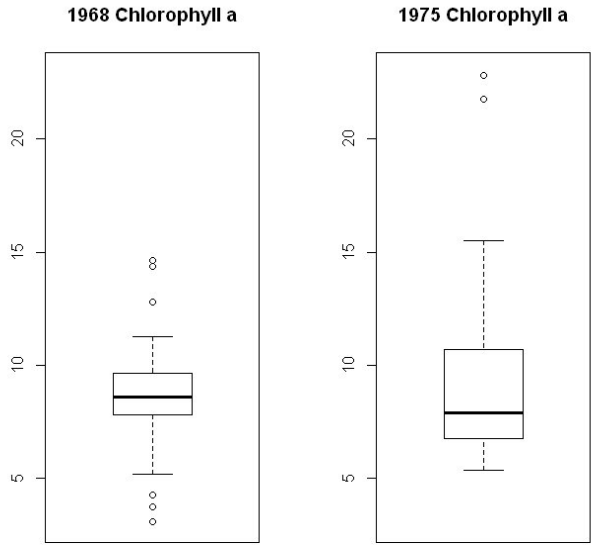


Figure 94. Median Chlorophyll "a" values at sampling stations in 1968 and 1975.

4.1 Discussion and Conclusion

This study examined the water quality of Hempstead Bay by dividing the region into three areas: West, Middle and East Bays. One of the most evident striking differences between the three bays was the high nitrogen level in West Bay, especially around the Station 4 outfall (Fig 18, page 23). The high levels of nitrogen found in this area likely caused the other disparities found between the three bays such as differences in Chlorophyll “a”, silica, and Secchi transparency. The nutrient loading occurring in West Bay also likely accounts for the heightened parameter values for nitrate and ammonia found in Middle Bay.

We divided the eastern section of the bay into eastern-Middle Bay and western-East Bay to test for differences between these two areas. Several parameters were found to be significantly ($p<0.05$) different, with eastern-Middle Bay reporting lower values for urea, total coliform and fecal coliform, whole others were significantly higher in the eastern-Middle Bay: Chlorophyll 'a', Secchi transparency, ammonia, nitrite and nitrate. One potential explanation for these higher values in eastern-Middle Bay is the possible movement of nutrients from West Bay sources. Additional evidence of this water movement was found when comparing Stations 2 and 2A in lower West Bay to upper West Bay and Middle Bay. The lower West Bay stations reported lower nitrogen and chlorophyll levels while Secchi readings were higher. These sites may be more impacted by ocean water, as reflected in the higher salinity values, than the nutrient loading affecting the rest of West Bay.

The differences between the 1968 and 1975 water testing results, especially nitrate values, may have been influenced by regulations that were established between the samplings including wetland protection efforts. The neighborhoods serviced by the Bay Park plant were only sewered the previous decade, so residual nutrients from septic system contaminats in ground water may have temporarily overlapped with and added to nutrients from the treatment plant. The Freeport Sewage Treatment Plant had emptied into Freeport Creek, but was closed during this time period and redirected to the Cedar Creek plant.

The Department of Conservation and Waterways is conducting numerous other studies to examine the water quality and bay ecosystems of this area. These include clam and oyster studies, vertical water profiling, outfall monitoring and tributary water testing.

Appendix 1. Glossary of Terms

Barrier island - a long narrow island lying parallel and close to the mainland, protecting the mainland from erosion and storms

Box plot with notch – A form of graph that shows the median and the first and second quartiles, the notch is scaled with the variance such that if the notches of two boxes fail to overlap the medians are assumed significantly different.

Coliform - belonging to a group of rod-shaped bacteria typified by *E. coli*

Cordgrass - a coarse wiry coastal grass (Genus *Spartina*, family *Gramineae*) that is sometimes used to stabilize mudflats

Dowitcher - a wading bird of the sandpiper (Genus *Limnodromus*, family *Scolopacidae*), with a long straight bill, breeding in arctic and subarctic North America and eastern Asia

Dredge - clean out the bed of (a harbor, river, or other area of water) by scooping out mud, weeds, and rubbish . with a dredge

Effluent - liquid waste or sewage discharged into a river or the sea

Estuary - the tidal mouth of a large river, where the tide meets the stream

Flats - an area of low level ground, especially near water

Herring - a silvery fish (Genus *Clupea* and other genera, family *Clupeidae*) that is most abundant in coastal waters and is of great commercial importance as a food fish in many parts of the world

Hypoxic - oxygen deficiency in a biotic environment

Interpolate – insert (an intermediate value or term) into a series by estimating or calculating it from surrounding known values

Killifish - a small carplike fish (Families *Fundulidae* and *Cyprinodontidae*), which include numerous genera of egg-laying killifishes of fresh, brackish, or salt water, typically brightly colored

Loess curve[1] - locally weighted polynomial regression in which at each point in the data set a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated.

Moving geometric means - for each date the geometric mean of the previous dates is calculated for a given prior period that is determined as needed.

MPN – Most probable number, the standard way of reporting total and fecal coliform results from wate quality laboratory analysis for sea water.

Nutrient load[2] - the mass of nutrients carried by water into surrounding waterways, over a period of time. Because of the use of fertilizers and manure, water that passes through agricultural soils often carries a high 'nutrient load' into local creeks. An overabundance of nutrients in water causes algae to grow, use up oxygen, and reduce the availability of oxygen to other organisms such as fish.

Outfall - the place where a river, drain, or sewer empties into the sea, a river, or a lake

Oxic - designating a process or environment in which oxygen is involved or present

Parameters - a numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation

Plover - a short-billed gregarious wading bird (Family *Charadriidae*), typically found by water but sometimes frequenting grassland, tundra, and mountains.

Rookery - a breeding colony of seabirds

Running Mean - In statistics, a moving average (rolling average or running average) is a calculation to analyze data points by creating a series of averages of different subsets of the full data set.

Salt marsh - an area of coastal grassland that is regularly flooded by seawater

Sandpiper - a wading bird (Family *Scolopacidae*) with a long bill and typically long legs, nesting on the ground near water and frequenting coastal areas on migration.

Spartina - see cordgrass

Scaup - a Eurasian, North American, and New Zealand diving duck (Genus *Aythya*, Family *Anatidae*), the male

of which has a black head with a green or purple gloss

Spline[1] - a sufficiently smooth polynomial function that is piecewise-defined, and possesses a high degree of smoothness at the places where the polynomial pieces connect

South Shore Estuary Reserve - Long Island's South Shore bays and the adjacent upland areas draining to them

Tidal flushing[4] - systematic replacement of water in a bay or estuary as a result of tidal flow. The ocean is assumed to be a sink for water discharged during the ebb and a source of new water carried in by the flood.

Wading bird - a waterbird, especially one with long legs, that habitually wades

Waterbird - a bird that frequents water, especially one that habitually wades or swims in fresh water

Waterfowl - ducks, geese, or other large aquatic birds, especially when regarded as game

Watershed - an area or region drained by a river, river system, or other body of water

YSI 6600 SONDE[5] - comprehensive water quality monitoring equipment available with simultaneous measurement of conductivity (salinity), temperature, depth or level, pH/ORP, etc.

References:

[1]http://en.wikipedia.org/wiki/Loess_curve

[2]http://www.hamiltonnature.org/habitats/glossary.htm

[3]http://www.dos.ny.gov/communitieswaterfronts/pdfs/SSERCMP.pdf

[4]http://www.springerreference.com

[5]http://www.ysi.com

All other definitions from http://oxforddictionaries.com/us/