Chapter 2
New York/New Jersey Nearshore Waters—A Case Study in NY/NJ

Abstract The study area is the New York/New Jersey estuarine and nearshore waters. These waters are enriched by increased nutrient loading from point, non-point sources such as agricultural and urban run-off causing eutrophication and pollution. Eutrophication disrupts the pre-existing natural balance of the system, resulting in phytoplankton blooms of both increased frequency and intensity in response to the over-enrichment. Dense and accelerated phytoplankton blooms ultimately increase oxygen demand on the system leading to episodes of hypoxia. To improve the quality of water and control the problem of excessive fertilization, regular monitoring of water quality is required.

Keywords Airborne Visible Infrared Imaging Spectrometer (AVIRIS) · Hudson/Raritan Estuary · Marine geology · Ecology · Hypoxia · Harmful algal blooms · Bioindicator · Nanoplankton · Netplankton · Chlorophyta · Diatoms · Cyanobacteria · Brown tides · Marine geology · Estuarine waters · Polychaetes · Phytoplankton · Zooplankton · Eutrophication

2.1 Environmental Setting of NY/NJ Nearshore Waters

Hudson/Raritan Estuary of NewYork/New Jersey is a complex estuarine system where tidal and wind-driven currents are modified by freshwater discharges from the Hudson, Raritan, Hackensack, and Passaic rivers. These waters are enriched by increased nutrient loading from point and non-point sources such as agricultural and urban run-offs (e.g. agricultural herbicides, toxic discharges, suspended sediments and nutrients), causing pollution. Development along the shoreline has caused much pollution to build up in the estuary over time, particularly from the large cities around the estuary, including New York City and Newark, New Jersey. Sources of pollutants include municipal treatment plants, industrial discharges, combined sewer overflows, storm water tributaries, landfill leachate, navigable vessels, and atmospheric deposition. The estuary is used for many recreational activities including swimming, boating and sport fishing, which are now one of the biggest industries of the area.

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2.1.1 Physical Characteristics

The study area is the Hudson/Raritan Estuary south of the Verrazano Narrows, and bordered by western Long Island, Staten Island and New Jersey (Fig. 2.1).

The partially mixed drowned river estuary is relatively shallow (<8 m) (Oey et al. 1985). It is connected to the Atlantic Ocean through the Sandy Hook Rockaway Point transect and to Long Island Sound through the East River. The Estuary constitutes an extremely complex system involving the interaction of tidal and wind-driven currents modified by the freshwater discharges from Hudson, Raritan, Hackensack, and Passaic rivers.

The freshwater discharge from the Hudson River contributes a monthly average discharge ranging from about 100 m^3/s in dry seasons to about 1800 m^3/s in spring, while the combined monthly average discharges of the Raritan, Passaic and Hackensack rivers ranges from 10 to 100 m^3/s. The number of wastewater inputs include 26 major waste treatment plants, about 100 point sources of industrial and municipal origin and in excess of 700 combined storm drains and sewer outflows. There are four major sewage sources; two with a combined mean discharge of 11 m^3/s are located near the mouth of the Passaic River and near the mouth of Kill Van Kull which opens to the Upper Bay. A third in the East River has a mean discharge of 42 m^3/s, and the fourth sewage source is Jamaica Bay with a mean discharge of 14 m^3/s (Oey et al. 1985).

The volume discharged into the system from Staten Island, New Jersey and the Raritan River is small compared to these sources. Conditions in the Raritan-Lower Bay part of the estuary can be quite variable due to its shallowness and the speed with which it can change in response to factors such as tide, rain and wind. However, the net movement of water within the estuary is counter-clockwise. The following two factors influence the circulation patterns in the estuary: (1) the geometry of the estuary with open boundaries (Sandy Hook connection with the Atlantic Ocean and East

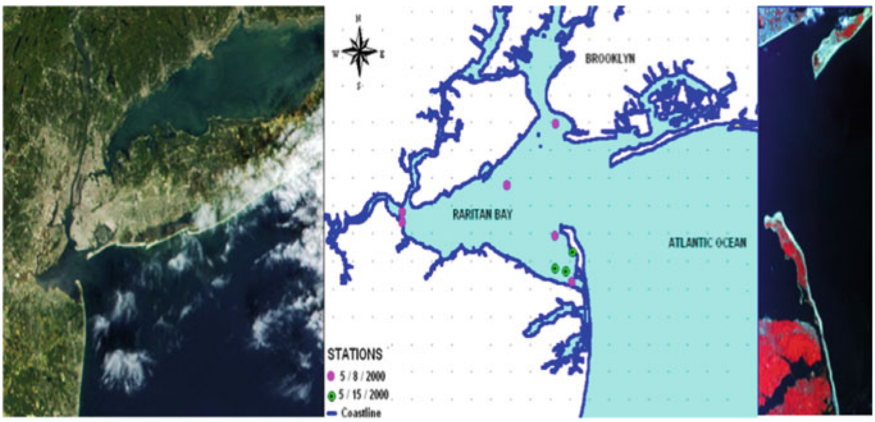

Fig. 2.1 Map of the study area with the locations of sample points

River Strait connection with Long Island Sound) and, (2) surface wind stress which is considered part of the surface boundary conditions. The estimated flushing time of the estuary, 16–21 days or 32–42 tidal cycles (Jeffries 1962), tends to retain pollutants entering the system and delay dilution with receiving waters.

2.1.2 Marine Geology/Ecology

The geologic characteristics of the Hudson/Raritan estuarine floor, are comprised of four major sedimentary regions: the Sandy Hook Bay Muds, the West Raritan Bay Muds, the Keansburg Sands, and the Lower Bay Sands (Nagle 1967). Accumulation of fine-grained sediments is usually indicative of lower energy conditions and protected environment. In contrast, the presence of sand often characterizes high energy conditions and an environment exposed to vigorous waves or strong tidal currents. The principal area of mud accumulation extends from west–Raritan Bay into east–Sandy Hook Bay. The sediment generally becomes finer westward towards the mouth of the Raritan River (Coch 1986) and sandy along the New Jersey coast south of the mud deposit. This sand, derived from the erosion of the Cretaceous beds of sand at the New Jersey shore, persist due to prevailing north-westerly winter winds that raise waves of sufficient energy to prevent the deposition of fine-grained sediment near this coast (Mutler et al. 1984). Extensive sand banks are located to the north of the muds of Raritan Bay and Sandy Hook Bay (Coch 1986; Kastens et al. 1978; Jones et al. 1979). These sediments are primarily relic glacial sands and they cover almost the entire floor of the Lower Bay. Strong tidal currents at the mouth of the Lower Bay have reworked these deposits into large shoals and the penetration of the ocean waves into the Lower Bay prevent the retention of the fine-grained sediment except at a few small but significant sites (Mutler et al. 1984). These sites are borrow pits that were produced by sand mining operations. Within the pits, mud accumulates at rapid rates, even though conditions prevent its deposition on the surrounding sand banks (Olsen et al. 1984).

The Hudson/Raritan Estuary is a complex ecosystem and it is considered “the most intensively developed and industrialized estuary on the U.S. east coast” (Pearce 1988). Many diverse organisms continue to use the estuary for part or all of their lives. These organisms include commercially valuable shellfish and finfish, and lower organisms such as polychaetes, phytoplankton and zooplankton that are basic to the estuarine food web. Many fish depend on the estuary as a nursery and critical stages of their life cycle occur in these waters, while others use it as a key migration route between fresh and sea water. At one time both shell- and fin-fish fisheries thrived in the estuary. Some, such as oyster, hard clam and soft clam shellfisheries collapsed or were reduced because of bacterial contamination. The commercial fin-fishery was relocated offshore due to legislation preventing fishing in the estuary. Today, outside of a few pound nets in the Raritan Bay part of the estuary, most fin-fishing has been reduced to sport activity, although some clams are harvested for depuration or transfer to cleaner waters (MacKenzie 1990).

However the estuary is used for many recreational purposes including swimming, boating and sport fishing, which is now one of the biggest industries.

Over the last century the quality of the estuarine water has degraded in part due to eutrophication. Eutrophication disrupts the pre-existing natural balance of the system, resulting in algal blooms of both increased frequency and intensity in response to the over-enrichment. Blooms are population booms of phytoplankton, tiny organisms that live in water, photosynthesize and form the base of the ocean food chain (Table 2.1). They're like the plants of the deeper ocean, except that unlike plants, some species are able to swim.

Some species also eat other organisms in addition to getting energy from photosynthesis.

There are several causes that can contribute to an algal bloom. These blooms can occur seasonally, after an upwelling of nutrient-rich water, or due to pollution such as agricultural/urban runoff. In both cases, the water becomes saturated with nutrients, creating an ideal environment for phytoplankton productivity. Even natural causes can trigger an algal bloom, such as a rainstorm followed by warm, sunny weather (EPA 2000). While phytoplankton are an important aspect of a healthy body of water and help to provide oxygen and food for aquatic organisms, an imbalance of phytoplankton levels can cause major problems. Noxious phytoplankton blooms are among the potential negative impacts, as are shifts to less desirable species of phytoplankton, diminished aesthetics, and changes in phytoplankton cell size. Dense and accelerated phytoplankton blooms ultimately increase oxygen demand on the system leading to episodes of hypoxia (Bagheri et al. 2005). Hudson/Raritan Estuary together with majority of the world's coastal zones are subject to recurrent outbreaks

Table 2.1 Phytoplankton in Hudson/Raritan Estuary

Divisions/classes	Species	References
Diatom	*Rhizosoplenia delicatula*, *Asterionella glacialis*, *Skeletonema costatum*, *Thalassiosira* sp.	Schuster et al. (2000)
	Asterionella glacialis, *Leptocylindrus danicus*, *Skeletonema costatum*, *Rhizosoplenia delicatula*, *Nitzschia pungerns*	Marshall et al. (1987)
Dinoflagellate	*Prorocentrum* sp., *Katodinium* sp.	Schuster et al. (2000)
	Ceratium fusus, *C. lineatum*, *C. longipes*, *C. tripos*, *Prorocentrum*, *P. minimum*, *P. balticum*	Marshall et al. (1987)
Chrysophyceae	*Calycomonas gracillis*, *Calycomonas ovalis*, *Dictyocha fibula*, *Distephanus speculum*	Marshall et al. (1987)
Cyptophytes		Marshall et al. (1987)
Euglenophyceans		Marshall et al. (1987)
Haptophyceae	*Emiliania huxleyi*	Marshall et al. 1987

Source https://palebluedotreview.wordpress.com/a-closer%C2%A0look/what-are-phytoplankton/

of toxic phytoplankton or harmful algal blooms (HABs) triggered by the combined effect of particular meteorological forcing and nutrient fields. The harmful algal blooms (HABs), which have been observed in every coastal state of the US (Boesch 1997), are formed through dispersal of HAB organisms, nutrient enrichment, and introduction and transport of cysts via ballast water transfers (Hallegraeff 1993). Algal blooms have been recorded over the last 40 years (Olsen 1989). As early as 1960s, red tides were documented to be caused by several species of phytoflagellates, such as *Olishthodiscus leteus*, *Katodinium rotundatum*, and Prorocentrum spp. (Mahoney and McLaughlin 1977). The major phytoflagellate red tides were confined primarily to the Hudson/Raritan Estuary (Olsen 1989). In 1985, the brown tide caused by *Aureococcus anophagefferens* was first observed in the Long Island Sound (Sieburth et al. 1988). In New Jersey, brown tides were first confirmed in lower Barnegat Bay and adjacent Little Egg Harbor Bay in 1995 (Nuzzi et al. 1996). Negative impacts of these exceptional blooms as opposed to the annual spring blooms are associated with the presence of toxins secreted by various species of dinoflagellates, diatoms and cyanobacteria and are documented as a byproduct of shellfish bed closures, public health reports as noxious aerosols and aquatic mortality events and environmental conditions. HABs pose a serious threat to ecosystems and public health, as well as to the economy, as they are responsible for fish kills, shellfish poisoning, and human illness (Table 2.2).

While reports of toxic outbreaks are escalating worldwide, early detection remains elusive, impeding progress towards understanding the forces responsible for bloom initiation, development and advection. It is imperative, because of the damage to aquatic ecosystems, fisheries and tourism, that the environmental conditions that trigger and control harmful algal blooms be sufficiently understood in order to predict occurrences and mitigate potential effects (Bagheri et al. 1999). Annual average monitoring and management costs for HABs are estimated at $2 million, distributed among twelve states: Alaska, California, Connecticut, Florida, Maine, Massachusetts, New Hampshire, North Carolina, New Jersey, New York, Oregon, and Washington. These costs include the routine operation of shellfish toxin monitoring programs, plankton monitoring, and other management activities (Anderson et al. 2000).

Utilizing ocean color remote sensing offers an effective tool to locate areas rich in phytoplankton concentrations. Phytoplankton, as revealed by ocean color remote sensing, frequently show scientists where ocean currents provide nutrients for plant growth and where fishing industry can find good fishing spots by looking at ocean color images. ln addition, phytoplankton show where pollutants poison the ocean and prevent plant growth, and where subtle changes in the climate affect phytoplankton growth. Since phytoplankton depends upon specific conditions for growth, they frequently become the first indicator of a change in their environment: Increases in temperature due to global climate change can contribute to important changes in phytoplankton composition and abundance. This is considered to be a major pathway of carbon cycling in the ocean and thus essential to global change studies. Since phytoplankton depends upon specific conditions for growth, they

Table 2.2 HABs observed in the New York/New Jersey coastal water, 1959–2010

Division/classes	Species	Tides
Diatoms		
	Asterionella	
	Cerataulina pelagica	
	Chaetoceros sp.	
	Cylindrotheca closterium Leptocylindrus sp.	
	Pseudonitzschia delicatissima Pseudonitzschia seriata	
	Pseudonitzschia pungens multiseries Pseudonitzschia	
	(*Nitzschia*) spp. *Rhizosolenia* sp.	
	Skeletnema costatum	
	Thalassiosira spp.	
	Ceratium tripos Red *Gyrodinium aureolum Green*	
	Katodinium rotundatum Red *Pfiesteria piscicida*	
	Prorocentrum lima	
	Prorocentrum micans Red *Prorocentrum redfieldi*	Red
	Scripsiella trochoidea	
	Aureococcus anophagefferens	Brown
	Olisthodiscus luteus	Red
	Didymocystis sensu Green Nannochloris atomus	Green
	Eutreptia lanowii	Red
Dinoflagellates Pelagophyceae Raphidophy Chlorophytes		
Euglenids		

Source http://nj.gov/dep/dsr/raritanbay/RaritanBib_authorA-Z_4-14-2015.pdf

frequently become the first indicator of a change in their environment. Phytoplankton communities can be used both, as a sensitive bioindicator for water quality regarding nutrients load and as a water quality parameter, which dictate the euthrophication level and toxicity (derived from toxic algae) of the water.

Phytoplankton population in the Hudson/Raritan estuary, the Bight Apex and coastal waters of New Jersey is dominated by netplankton diatoms (e.g., speletonema costatum) during the unstratified winter/spring months (November–April) and by nanoplankton chloropyta (e.g., Nannochloris atomus) during the stratified summer/fall months (May–October). Diatoms typically dominate at all times in the offshore waters of the Bight (Fig. 2.2 and Table 2.1). Dinoflagellate blooms off the

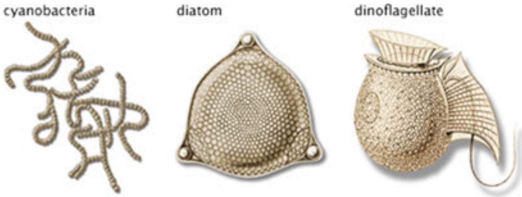

Fig. 2.2 Species of phytoplankton. *Source* http://www1.whoi.edu/images/jgofs_brochure.pdf

New Jersey coast are recurrent events during the summer. Since 1968, red tides have been associated with *Olisthodiscus luteus* (1976, 1978, 1979) and *Prorocentrum micanas* (1968, 1972, 1983). The bloom of *Gyrodinium aureolum* off the coast of southern New Jersey in 1984–85 was termed "green tide" because of it's brilliant green color. *Nannochloris atomus* is another common species that causes green tides in New Jersey waters (USEPA 1986).

Brown tides are caused by the bloom of the *Aureococcus anophageffereus*. It had first appeared in Narragansett Bay, Rhode Island and Long Island's Peconic and Great South Bays. The brown tides occur in the summer months. They can kill shellfish and block sunlight to the underwater plants destroying the habitat of many marine resources. The brown tides have a major effect on the shell fishing industry. In 1985 a brown tide in Peconic Bay reduced a $2 Million scallop industry to a few thousand dollars. Research has shown that iron can stimulate growth of brown tides. Environmental factors such a warmer climate, increased salinity of water and lack of rainfall could contribute to the bloom formations, but the exact causes or cure are not known yet (NY Sea Grant 1998).

In the three centuries since the Governor of New York ordered a sewer system to be constructed in Lower Manhattan, New York City has made considerable progress in protecting public health and improving the water quality of the harbor. Today, strict regulations and community activities are working to protect and restore the Hudson-Raritan Estuary. The restoration of oyster beds is an important part of many projects.

http://www.fondriest.com/environmental-measurements/parameters/water-quality/algae-phytoplankton-chlorophyll/#algae10.

As a result of the clean-up efforts to date, the public has enjoyed greatly increased opportunities for recreational uses such as swimming, boating, and fishing. The improvements in water quality also provide substantial benefits to the local economy through commercial fishing and other water-based revenue-generating activities. Although tremendous ecological improvements have resulted from water pollution control efforts implemented since the 1970s, a number of environmental problems remain to be solved for the Hudson-Raritan Estuary. Some contemporary concerns and issues include, for example, contamination of sediments and restrictions on dredge spoil disposal, remaining fish advisories for human consumption, episodic low dissolved oxygen, the occurrence of nuisance algal blooms and effluent controls on nitrogen discharged to the estuary, and increasing nonpoint source runoff from overdevelopment in the drainage basin of the estuary (NYCDEP 1999).

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