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Voluntary Estuary Monitoring Manual

Chapter 10: Nutrients -- Nitrogen and Phosphorus

March 2006

Chapter 10

Nutrients

Nutrients—especially nitrogen and phosphorus—are key water quality parameters in estuaries. Nutrient concentrations vary according to surrounding land use, season, and geology. Because nitrogen and phosphorus play such important roles in the estuarine ecosystem, it is not surprising that volunteer groups very commonly monitor these two nutrients.

Photos (l to r): K. Register, R. Ohrel, The Ocean Conservancy, E. Ely

Overview

Nutrients—especially nitrogen and phosphorus—are key water quality parameters in estuaries. Depending on their chemical forms (or species), nitrogen and phosphorus can have significant direct or indirect impacts on plant growth, oxygen concentrations, water clarity, and sedimentation rates, just to name a few. Nitrogen's primary role in organisms is protein and DNA synthesis; plants also use this substance in photosynthesis. Phosphorus is critical for metabolic processes, which involve the transfer of energy. Because nitrogen and phosphorus play such important roles in the estuarine ecosystem, it is not surprising that volunteer groups very commonly monitor these two nutrients.

Nutrient concentrations vary according to surrounding land use, season, and geology. This chapter discusses factors that the volunteer monitor should consider when establishing a nutrient monitoring program. Sample monitoring instruments and techniques are described. Finally, an additional monitoring opportunity for volunteers—atmospheric deposition—is introduced.

Why Monitor Nutrients?

Nutrients are chemical substances used for maintenance and growth that are critical for survival. Plants require a number of nutrients—carbon, nitrogen, phosphorus, oxygen, silica, magnesium, potassium, calcium, iron, zinc, and copper—to grow, reproduce, and ward off disease. Of these nutrients, nitrogen and phosphorus are of particular concern in estuaries for two reasons:

- they are two of the most important nutrients essential for the growth of aquatic plants; and
- the amount of these nutrients being delivered to estuaries has increased significantly.

Eutrophication is a condition in which high nutrient concentrations stimulate excessive algal blooms, which then deplete oxygen as they decompose (Figure 10-1). The organic production can also lead to sediment accumulation. Because of the potential impacts of nutrients, citizen monitoring programs often focus on nitrogen and phosphorus as indicators of estuarine health.

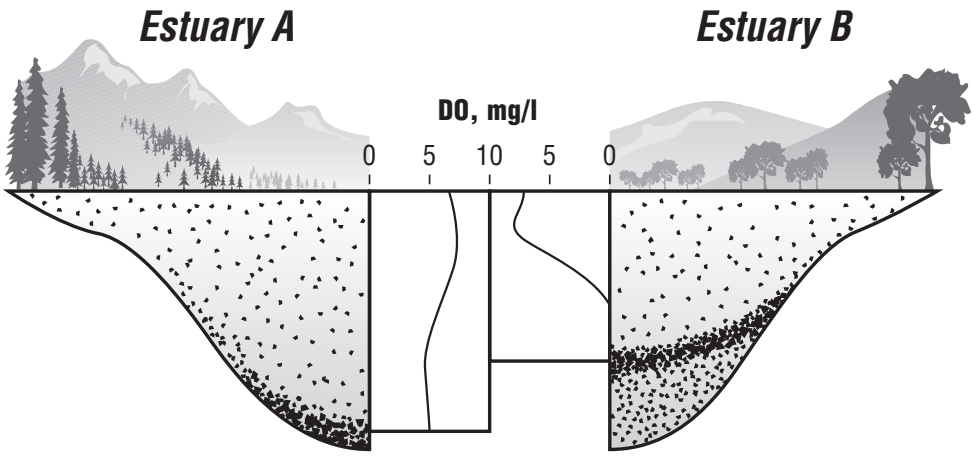

Figure 10-1. Eutrophication. Estuary B receives more nutrient loads than Estuary A. As a result, Estuary B experiences more plant production and organic material accumulation. Dissolved oxygen levels are also lower in Estuary B, especially in deeper water, due to the decomposition of organic matter. *(Adapted from Cole, 1994.)*

Nutrient Sources

Nitrogen and phosphorus enter estuaries from several natural and human-made sources (Figure 10-2). Natural sources of nitrogen and phosphorus in the estuary include:

- fresh water that runs over geologic formations rich in phosphate or nitrate;
- decomposing organic matter and wildlife waste; and
- the extraction of nitrogen gas from the atmosphere by some bacteria and blue-green algae (known as nitrogen fixation).

There are three major manmade or anthropogenic sources of nutrients: atmospheric deposition, surface water, and groundwater. Atmospheric sources include fossil fuel burning by power plants and automobiles. Nutrients from these sources may fall to the land or estuary either directly or along with precipitation. Surface water inputs include point and nonpoint source discharges: effluent from wastewater treatment plants, urban stormwater runoff, lawn and agricultural fertilizer runoff, industrial discharges, and livestock wastes. Groundwater sources are primarily underwater seepage from agricultural fields and failing septic systems.

The Role of Nutrients in the Estuarine Ecosystem

Figures 10-3 and 10-4 illustrate the nitrogen and phosphorus cycles, respectively. Although nutrients are essential for the growth and survival of an estuary's plants, an excess of nitrogen and phosphorus may trigger a string of events that seasonally deplete dissolved

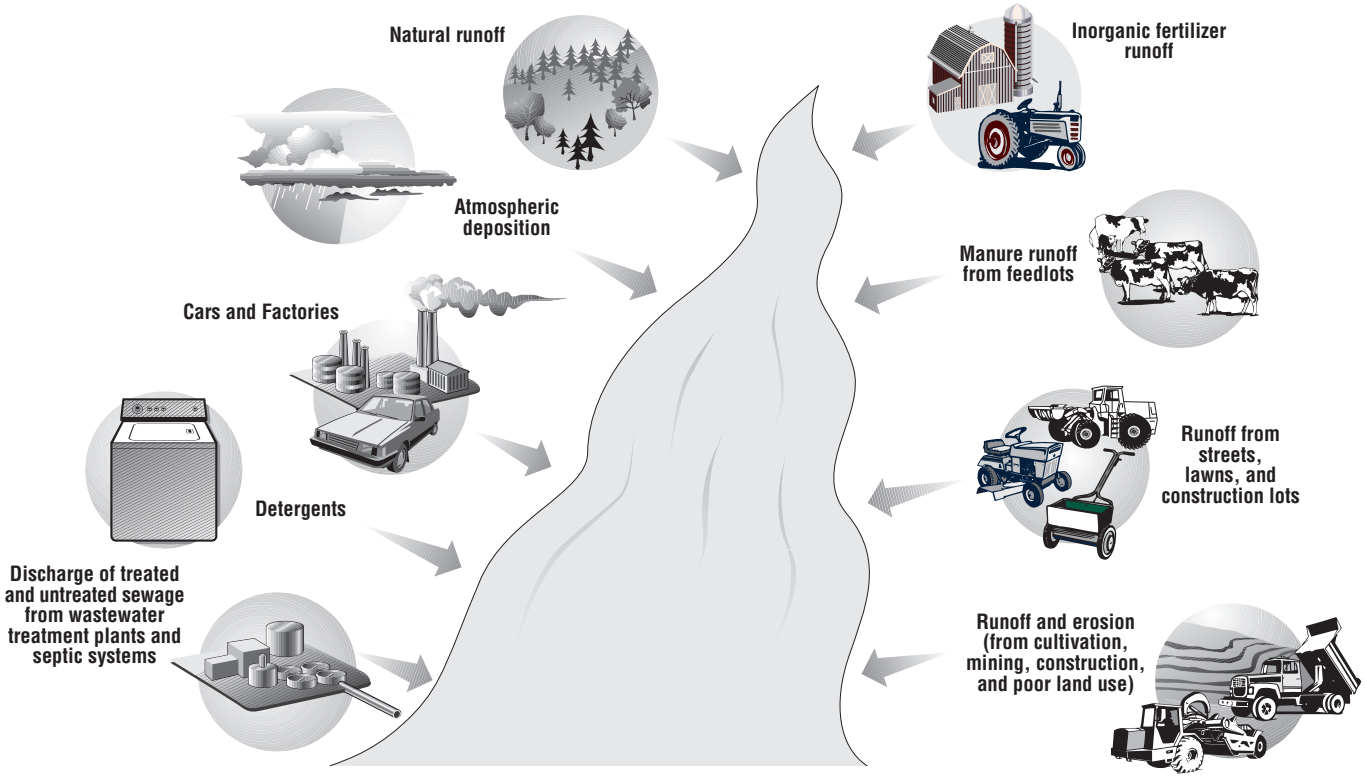

Figure 10-2. Typical nutrient sources to an estuary.

oxygen (DO) in the water (see Chapter 9). As stated earlier, an overabundance of such nutrients can lead to uncontrolled growth of phytoplankton (minute floating plants) or algae—these are often referred to as blooms.

Water clouded by thick patches of these tiny plants does not allow sunlight to penetrate to the bottom. Submerged aquatic vegetation (see Chapter 18) requires light for photosynthesis; if the plants' fronds (leaves) are covered or if the water is too cloudy during much of the growing season, these plants will die.

When algae and phytoplankton die, they are decomposed by oxygen-consuming bacteria. Especially slow-moving waterbodies with insufficient mixing may become **hypoxic** (low in oxygen). Under the worst conditions, the bottom waters of an estuary turn **anoxic** (without oxygen). Excessive nutrient concentrations have been linked to hypoxic conditions in over 50 percent of U.S. estuaries. Even coastal ocean areas, such as the Gulf of Mexico, have been impacted, endangering economically and ecologically important fisheries (USGS, 1999).

High nutrient concentrations have also been linked to harmful or nuisance phytoplankton blooms—such as "red tides" and "brown tides"—some of which produce harmful toxins (see Chapter 19). Nutrients are also believed to be one cause for the growth of the potentially toxic dinoflagellate *Pfiesteria*, found in estuaries along Atlantic coasts (USGS, 1999). These events may result in fish and shellfish kills and be harmful to human health.

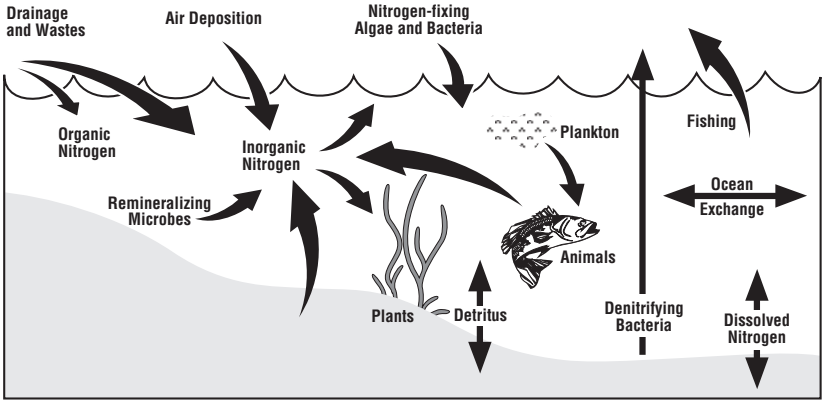

Figure 10-3. The nitrogen cycle *(adapted from USEPA, 1987).*

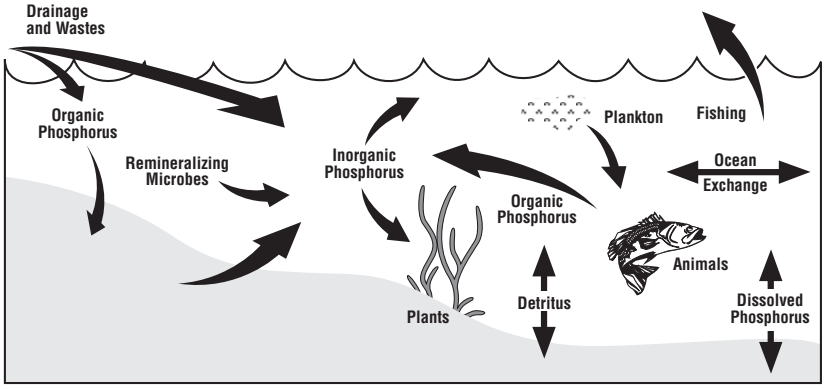

Figure 10-4. The phosphorus cycle *(adapted from USEPA, 1987).*

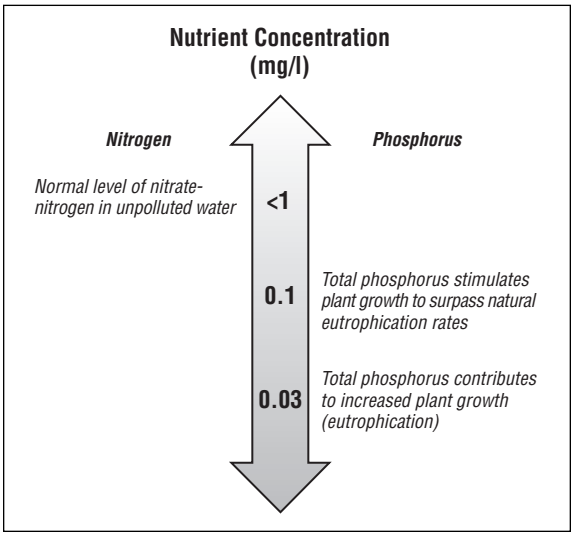

Figure 10-5. Significant levels of nutrients in aquatic systems *(Campbell and Wildberger, 1992).*

Levels of Nutrients

Nutrient concentrations are always in flux, responding to changes in:

- precipitation and amount of runoff;
- fertilizer or manure application rates;
- estuary flushing rates;
- water temperature;
- biological activity in the estuary; and/or
- the status of other water quality parameters.

Figure 10-5 shows significant levels for nutrients in estuarine waters.

Nutrient concentrations are usually greatest during spring and early summer, when fertilizer use and water flow from tributaries and irrigation activities are high.

High nutrient concentrations can also be detected during seasonal low-flow conditions (USGS, 1999). During winter low-flow periods, for example, the lack of land and aquatic plant uptake combined with contributions from groundwater can result in high nitrogen levels. Nutrient levels downstream from urban areas may also be high during low-flow periods. At these times, contributions from point sources can be greater relative to streamflow, and dilution is less (USGS, 1999).

Nutrient levels also vary among watersheds. Natural features (e.g., geology and soils) and land management practices (e.g., drainage and irrigation) can affect the movement of nitrogen and phosphorus over land, creating local and regional effects on estuarine water quality (USGS, 1999).

Tidal stage may also cause fluctuations in nutrient levels, but many volunteer programs have found that "chasing the tides" does not yield enough additional information to make the effort worthwhile. ■

Sampling Considerations

Chapter 6 summarized several factors that should be considered when identifying monitoring sites, where to monitor in the water column, and when to monitor. In addition to the considerations in Chapter 6, a few additional ones specific to nutrient monitoring are presented here.

When to Sample

In setting up a nutrient monitoring plan, the program manager should ensure that the effort will continue for several seasons. Since the workings of an estuary are complex, a mere year or two of nutrient data is insufficient to capture the variability of the system. In fact, a couple of years of unusual data may be quite misleading and tell a story very different from the long-term situation (note the variability in Figure 10-6).

Volunteers should sample nutrients on a weekly basis, although biweekly sampling will still yield valuable information. However, sampling at a small number of sites every week or two cannot possibly capture the constantly changing water quality of an entire estuary. The key to effective nutrient monitoring is to sample at a sufficiently frequent interval and at enough representative sites so that the data will account for most of the inherent variability within the system. In temperate climates, some programs have eliminated wintertime measurements when aquatic plants are dormant and the effects of nutrients are not so marked. A few measurements during the winter, however, will provide a baseline of nutrient levels that can be compared to the rest of the year's data.

Where to Sample

If the monitoring program is designed to pinpoint trouble spots in the estuary, the program manager should cluster monitoring sites where point and nonpoint sources of nutrients appear to enter the water. Such sites might include an area near the discharge pipe of a wastewater treatment plant or adjacent to an agricultural area where fertilizers are applied or livestock congregate.

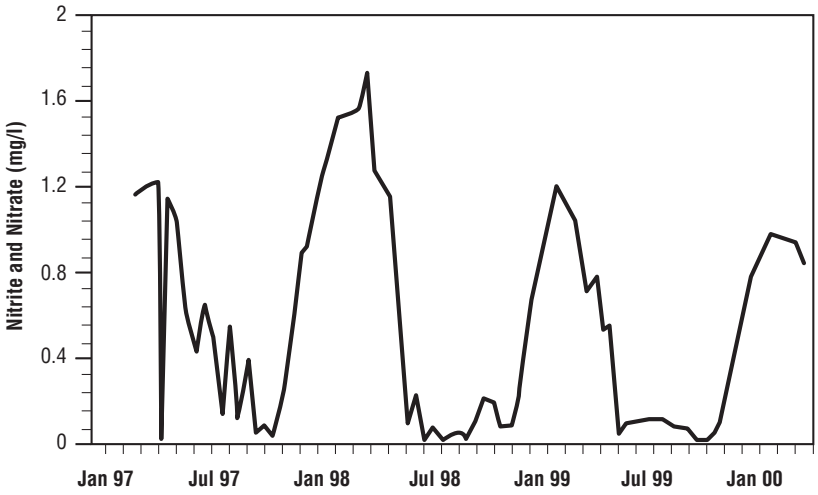

Figure 10-6. Seasonal fluctuations of nitrite and nitrate—two forms of nitrogen—in a typical mid-Atlantic estuary.

Because nutrient levels often vary with depth, especially during the summer when the estuary is well-stratified, volunteer groups may wish to collect samples at different depths. Van Dorn and Kemmerer samplers (see Chapter 7) are commonly used to collect these kinds of samples. In addition, there are several water samplers designed primarily for collecting samples at different depths. Appendix C provides a list of equipment suppliers.

Special Consideration: The Different Forms of Nutrients

Nitrogen and phosphorus come in many different chemical forms, or **species**, which are determined by a number of environmental conditions. Measuring each nutrient species can help identify its source into the estuary. Therefore, volunteer efforts to measure different nutrient species can provide significant information to resource managers.

Table 10-1. Examples of nitrogen species and notes about potential sources *(adapted from Phinney, 1999).*

Nitrogen Species	***Notes About Possible Species Sources***
Nitrate (NO_3^-), Nitrite (NO_2^-) and NO_x ("nox")	• Make up 70 percent of total nitrogen inputs from groundwater to smaller watersheds in the Chesapeake Bay • Make up approximately 15 percent of total nitrogen found in agricultural fertilizers • NO_2^- is generally a short-lived nitrogen species that is measured in low oxygen environments • NO_x from fossil fuel burning makes up at least 25 percent of atmospheric nitrogen inputs into coastal waters (Paerl and Whiteall, 1999)
Ammonium (NH_4^+) and unionized ammonia (NH_3)	• Make up 5.8 percent of total nitrogen in lawn fertilizer • Make up 20 percent of total nitrogen in agricultural fertilizers • Primary nitrogen component from animal feedlot operations (AFOs)
Urea (an organic form of nitrogen)	• Makes up 12 percent of total nitrogen in lawn fertilizer • Makes up 38-45 percent of total nitrogen in agricultural fertilizers

Nitrogen Forms and Impacts

Although nitrogen makes up about 80 percent of the earth's atmosphere, it is inaccessible to most terrestrial and aquatic organisms. Some types of bacteria and blue-green algae, however, can "fix" nitrogen gas, converting it to an inorganic nitrogen form—thereby making it available to other organisms.

In the estuary, nitrogen exists in a variety of chemical (e.g., ammonium, nitrate, and nitrite) and particulate and dissolved organic forms (e.g., living and dead organisms). Table 10-1 summarizes information about different nitrogen species and their connection to surrounding land activities.

The quantity and form of nitrogen in the water can also closely relate to dissolved oxygen levels. Bacteria are able to convert nitrogen into different nitrogen species and gain energy from the process. Through **nitrification**, some bacteria transform ammonium into nitrite and then to nitrate. This biological process consumes oxygen. When nitrification is inhibited by low dissolved oxygen conditions, ammonia or nitrite forms of nitrogen may accumulate.

Through **denitrification**, bacteria convert nitrate to nitrite and then to nitrogen gas. This process occurs under anoxic conditions and helps rid the system of excess nitrogen.

Nitrate and urea are highly soluble in water, a characteristic which facilitates their transport to the estuary by runoff. Ammonium is also soluble in water; it can be transformed to ammonia in low oxygen environments and escape to the atmosphere. All of these nitrogen species promote phytoplankton, algae, and bacterial blooms (Phinney, 1999). Certain nitrogen species can have other adverse impacts. At high concentrations, nitrates are toxic to eelgrass, and ammonia is toxic to fish (Maine DEP, 1996).

Phosphorus Forms and Impacts

Phosphorus also exists in the water in several forms: organic phosphate, orthophosphate (inorganic, dissolved phosphorus), total phosphorus (dissolved and particulate), and polyphosphate (from detergents). Orthophosphate in the water comes from fertilizers and is the form commonly measured. Organic phosphate results from plant and animal waste. Decomposition of dead plants and animals also adds organic phosphorus to the water. In general, excess phosphates can enter an estuary from water treatment plants, sewage, soils, agricultural fields, animal feedlot operations, and lawns.

Many phosphorus species attach to soil particles and are, therefore, transported to the estuary with eroded soil. Especially high phosphorus loads are often delivered during periods of high runoff from storms or irrigation activities.

Under oxygenated conditions, phosphate will

form chemical complexes with minerals such as iron, aluminum, and manganese and fall to the bottom sediments. In cases when this nutrient is found mostly in sediments, water column concentrations may not provide a full picture of nutrient loads and impacts. If the bottom water in an estuary has no oxygen, however, phosphate bound to the sediments is released back into the water. This release can fuel yet another round of phytoplankton blooms.

Choosing a Sampling Method

A dilemma arises for program managers when deciding upon the appropriate method for measuring nutrient levels in an estuary. On one hand, kits for nitrogen and phosphorus can be imprecise; on the other, submitting prepared samples for lab analysis is costly and time consuming. Program managers frequently arrange to have a college or professional lab donate its time and facilities to the volunteer effort.

If the data are intended to supplement state or federal efforts, it is wise to confer with the agency beforehand to determine an acceptable monitoring method. Whatever sampling method is chosen, program managers should periodically compare the citizen monitoring data to duplicate samples analyzed by another method under laboratory conditions.

The following sections provide an overview of possible nutrient analysis methods, along with each method's advantages and pitfalls.

Test Kits

Several companies manufacture kits for analyzing the various forms of nitrogen and phosphorus. While the kits are not precise or accurate when nutrient levels are low, the manager may choose to use them when deemed appropriate given the program's data objectives. The kits rely on a color comparison in which the volunteer matches the color of a prepared water sample to one in a set of provided standards. The subjectivity of each volunteer's decision as well as ambient light levels will influence the results to some degree.

Kits are suitable for identifying major nutrient sources, such as wastewater and animal feedlots, where levels are generally higher than the surface water in the estuary. Areas where concentrations routinely exceed concentrations of 1 mg/l are good candidates for kit analysis.

While the kits are generally easy to use, many state and federal agencies will reject nutrient data derived from their use because of their imprecision and subjective nature. In some cases, data that are collected from the use of kits may be helpful as a screening tool.

Spectrophotometer

A spectrophotometer measures the quantity of a chemical based on its characteristic absorption spectrum. This is accomplished by comparing the collected sample to a reference sample, also called a **standard**. Spectrophotometers are generally quite accurate although the instruments are expensive to purchase and maintain. Programs with ample funds for equipment may want to consider purchasing this reliable instrument, which costs from $1,000 to $6,000. Because reagents and standards are required, the volunteer program will have an added expense of a few hundred dollars.

The instrument requires proper maintenance and precise calibration; therefore, the program manager or someone familiar with this equipment must oversee its care and use.

Colorimeter

A colorimeter compares the intensity of color between the sample and a standard in order to measure the quantity of a compound in the sample solution.

Cheaper than a spectrophotometer, electric colorimeters offer citizen programs a reasonably priced alternative. They are quite accurate, fairly easy to use, and can provide direct meter readout. Colorimeters range in price from $250 to $2,000.

Like the spectrophotometer, this instrument can be used for forms of both nitrogen and

phosphorus. The colorimeter is a more affordable alternative for those programs that prefer a method less costly than the spectrophotometer and more accurate than the kits.

Similar to a spectrophotometer, a colorimeter requires standard maintenance and reagents, which must be purchased on a regular basis. The colorimeter provides accurate data only when properly maintained and precisely calibrated by a professional.

Laboratory Analysis

Analysis of nutrients by a professional laboratory is by far the most accurate means of obtaining nutrient data. Most laboratories institute strict quality assurance and quality control methods to ensure consistently reliable results. A college or professional lab may offer its services free of charge to the volunteer program.

If the program decides to use lab analysis, it must ensure that its volunteers adhere to strict guidelines while collecting samples. Sloppy field collection techniques will result in poor data no matter how sophisticated the lab may be. ■

Reminder!
To ensure consistently high quality data, appropriate quality control measures are necessary. See "Quality Control and Assessment" in Chapter 5 for details.

How to Monitor Nutrients

General procedures for collecting and analyzing samples for nutrients are presented in this section for guidance only; they do not apply to all sampling methods. **Monitors should consult with the instructions that come with their sampling and analyzing instruments. Those who are interested in submitting data to water quality agencies should also consult with the agencies to determine acceptable equipment, methods, quality control measures, and data quality objectives (see Chapter 5).**

Before proceeding to the monitoring site and collecting samples, volunteers should review the topics addressed in Chapter 7. It is critical to confirm the monitoring site, date, and time; have the necessary monitoring equipment and personal gear; and understand all safety considerations. Once at the monitoring site, volunteers should record general site observations, as discussed in Chapter 7. A visual assessment of phytoplankton density is particularly recommended to aid nutrient data interpretation—nutrient concentrations in a water sample may be low because phytoplankton are utilizing the nutrients.

STEP 1: Check equipment.

In addition to the standard sampling equipment and apparel listed in Chapter 7, the volunteer should bring the following items to the site when sampling for nutrients:

Procedure A—Equipment for test kit analysis

- fully stocked nitrogen and phosphorus kits, with instructions for use;
- clean polypropylene sample bottles or scintillation vials (60 ml) (see Chapter 7 for details on cleaning reusable sampling containers);
- water sampler (if collecting samples from other than the surface); and
- appropriate type of equipment and water for making sample dilutions.

Procedure B—Equipment for preparing sample for laboratory analysis

- clean polypropylene sample bottles or scintillation vials (60 mg/l) (see Chapter 7 for details on cleaning reusable sampling containers);
- filter assembly and supporting equipment (many laboratories require filtered samples);
- water sampler (if collecting samples from other than the surface);
- ice cooler with ice packs to keep samples cool and in darkness; and
- properly labeled preservation chemicals.

Sampling Hint:

If using a boat to reach the sampling location, make sure that it is securely anchored. It is best not to bring up the anchor until the sampling is completed since mud (with associated nutrients) may become stirred into the water.

STEP 2: *Collect the water sample.*

Volunteers must follow strict guidelines to prevent contamination of the sample. For example, it is preferable to use a standard sampling bottle rather than a simple bucket since a washed and capped bottle is less likely to become contaminated than an open container.

Chapter 7 reviews general information about collecting a water sample using a bottle or Whirl-pak bag. Volunteers using bottles should be sure to:

- Rinse the bottle by pushing it into the water in a forward motion, holding the container by the bottom. This technique will keep water contaminated by skin oils and dirt from entering the mouth. Fill the bottle a quarter full and swish the water around the inside, making sure to cover all inside surfaces. Pour out the water on the down-current side of the boat and away from the actual sampling site. Rinse the cap as well.
- After rinsing, push the bottle back into the water in the same manner to collect a sample for analysis.
- Fill the bottle to the shoulder, leaving an airspace. Cap the bottle.
- If the samples are not to be measured that day, they should be preserved according to the requirements specified by the test kit manufacturer, laboratory conducting the analysis, water quality agency, etc. The preservation technique may vary according to the type of nutrient and the method by which it is measured.
- Store the container in a cold, dark ice chest to minimize bacterial activity and phytoplankton growth.
- Filtered samples may require a polypropylene syringe and filter that can be screwed on. Bottle rinsing should be done with filtered water before the final sample is added.

NOTE: Volunteers using test kits may prefer to place the kit's test tube or bottle directly into the water to collect the sample. Eyedroppers are helpful in filling the test tube to the marked line.

STEP 3: *Measure nutrients or prepare sample for laboratory analysis.*

Procedure A—Elements of test kit analysis

- Conduct the test as soon as possible after collecting the water sample. As the sample sits, organisms living in the water will use up nutrients, changing the nutrient concentrations in the water.
- Before starting the analysis, double-check that the bottles, test tube or sample bottle, and any other equipment that will come in contact with the sample are clean. Reagents should be maintained at about 20°C to yield the best results.
- Make sure the sample water is well mixed.

- Follow the protocol for each nutrient type as outlined in the instructions accompanying the kit.
- Immediately record the results on the data sheet.

Procedure B—Prepare sample for laboratory analysis

Volunteers may need to filter the sample, depending on the nutrient species being analyzed. This activity removes the particulate nutrient fraction from the dissolved fraction. Individual laboratories may require different filtering techniques; therefore, volunteer groups should consult with their laboratory to determine how samples should be filtered.

STEP 4: *Clean up and send off data.*

Volunteers should thoroughly clean all equipment, whether using the test kit or the lab preparation method. Follow laboratory or test kit instructions for cleaning. Allow the equipment to air dry before storing it. If volunteers used the filtration technique, they should detach the filter unit from the syringe, unscrew it, and clean all parts. The paper filter can be thrown away.

Properly dispose of wastes generated during the performance of tests (see Chapter 7).

Make sure that the data sheet is complete and accurate. Volunteers should make a copy of the completed data sheet before sending it to the project manager in case the original data sheet becomes lost.

After preserving the samples, follow laboratory guidelines for packing and shipping them to the analytical lab. This step should be done as soon as possible.

Warning!

The interpretation of nutrient concentration data must be done with care. While high nutrient levels suggest the potential for explosive algal growth, low levels do not necessarily mean the estuary is receiving less nutrient input. Large quantities of nutrients may flow into the estuary and be quickly taken up by phytoplankton. Zooplankton, in turn, graze upon the phytoplankton. Phosphorus may also bind with minerals in the sediment, which settle to the bottom, but may be reintroduced to the water column under low oxygen conditions.

In this scenario, although water nutrient concentration is low, the quantity of nutrients tied up in sediment and biomass (living matter) is high. Chlorophyll analysis is needed to quantify the phytoplankton biomass and interpret the low nutrient concentrations.

Special Topic: Atmospheric Deposition of Nutrients

Over the past 30 years, scientists have collected a large amount of convincing information demonstrating that air pollutants can be deposited on land and water, sometimes at great distances from their original sources. Atmospheric deposition, then, can be an important contributor to declining estuarine water quality.

What Is Atmospheric Deposition and How Does It Occur?

Nitrogen pollutants released into the air are carried by wind away from their place of origin. These pollutants come from manmade sources such as fossil fuel burning, industrial processes, cars and other forms of transportation, fertilizer, and the volatilization of animal wastes. Air deposition can also come from natural sources of emissions.

Atmospheric deposition occurs when pollutants in the air fall on the land or water. Pollution deposited in snow, fog, or rain is called **wet deposition**, while the deposition of pollutants as dry particles or gases is called **dry deposition**. Air pollution can be deposited into waterbodies either directly from the air onto the surface of the water or through indirect deposition, where the pollutants settle on the land and are then carried into a waterbody by runoff.

How Much Water Pollution from Nutrients Is Atmospheric?

Nitrogen is one of the most common air deposition pollutants, especially in the eastern United States. Since 1940, human activity has doubled the rate of nitrogen cycling through the global atmosphere, and the rate is accelerating (Vitousek et al., 1997). Depending on the waterbody and watershed being considered, it is estimated that roughly a quarter of the nitrogen in an estuary comes from air sources (Paerl and Whiteall, 1999). Table 10-2 shows estimated nitrogen sources in the Chesapeake Bay watershed.

Table 10-2. Estimated sources of nitrogen in the Chesapeake Bay *(Alliance for the Chesapeake Bay, 1997).*

Waterborne point sources (e.g., industry, sewage treatment plants, etc.)	25%
Runoff from land* (e.g., farms, lawns, city streets, golf courses, etc.)	50%
Air sources* (e.g., electric power plants, vehicles, municipal waste combustors, etc.)	25%

**This estimate of air sources includes indirect air deposition that reaches the bay as runoff from forests, streets, farmland, and anywhere else it is deposited.*

In the Chesapeake Bay region, it is estimated that 37 percent of the nitrogen entering the bay from air sources comes from electric utilities; 35 percent from cars and trucks; 6 percent from industry and other large sources of fossil fuel-fired boilers; and 21 percent from other sources such as ships, airplanes, lawnmowers, construction equipment, and trains (Alliance for the Chesapeake Bay, 1997).

Some other estuaries have also attempted to estimate how much of the nitrogen in their water comes from air sources, including both direct and indirect deposition (see Table 10-3).

Table 10-3. Amount and percentage of nitrogen entering the estuarine systems due to atmospheric deposition *(NEP Web site).*

Bay or Estuary	Million Tons of Nitrogen	% of Total Nitrogen
Albemarle-Pamlico Sounds	9	38-44
Delaware Bay	8	15
Delaware Inland Bays*	-	21
Long Island Sound	12	20
Massachusetts Bays*	-	5-27
Narragansett Bay*	0.6	12
Sarasota Bay*	-	2
Tampa Bay*	1.1	28

** Indicates measurement of direct deposition to water surface only.*

What Can Volunteers Do?

Presently, atmospheric deposition monitoring by volunteers is in its early stages. One potential procedure that may interest volunteer groups is a passive sampler that measures ammonia concentrations (Greening, 1999). The samplers are small disks that are set out for several days (up to one week), collected, and then sent to a laboratory for analysis. The procedure is still being developed and refined.

Another way volunteers can assist with atmospheric deposition monitoring is to measure rainfall. Rainfall measurements in watershed sub-basins are critical in determining the contribution of wet deposition to estuarine nutrient concentrations. Precipitation monitoring can also be instrumental in determining potential causes for other pollutants (e.g., sediments).

Steps for Monitoring Precipitation

- Place a rain gauge in an open area away from interference from overhead obstructions and more than one meter above the ground (see Chapter 7). Avoid obstructions making angles greater than 45^{o} from the top of the gauge.
- Check the gauge after each rainfall, record the amount of precipitation and the time of measurement, and then empty the gauge. If the gauge sits after a rainfall, evaporation can falsify the measurement.
- Make sure that the data sheet is complete and accurate. Volunteers should make a copy of the completed data sheet before sending it to the project manager in case the original data sheet becomes lost. ■

References and Further Reading

Portions of this chapter were excerpted and adapted from:

U.S. Environmental Protection Agency. Web site: http://www.epa.gov/owow/oceans/airdep/index.html

Other references:

Alliance for the Chesapeake Bay. 1997. *Air Pollution and the Chesapeake Bay.* White Paper of the Alliance for the Chesapeake Bay. 16 pp.

American Public Health Association (APHA), American Water Works Association, and Water Environment Federation. 1998. *Standard Methods for the Examination of Water and Wastewater.* 20th ed. L.S. Clesceri, A.E. Greenberg, A.D. Eaton (eds). Washington, DC.

Campbell, G., and S. Wildberger. 1992. *The Monitor's Handbook.* LaMotte Company, Chestertown, MD. 71 pp.

Cole, G. A. 1994. *Textbook of Limnology.* 4th ed. Waveland Press, Prospect Heights, IL.

Dates, G. 1994. "Monitoring for Phosphorus or How Come They Don't Tell You This Stuff in the Manual?" *The Volunteer Monitor* 6(1).

Ellett, K. 1993. *Chesapeake Bay Citizen Monitoring Program Manual*. Alliance for the Chesapeake Bay. Richmond, VA. 57 pp.

Greening, H. 1999. "Atmospheric Deposition Monitoring." In: Meeting Notes—U.S. Environmental Protection Agency (USEPA)/Center for Marine Conservation (CMC) workshop: *Volunteer Estuary Monitoring: Wave of the Future*. Mobile, AL: March 17-19, 1999.

Katznelson, R. 1997. "Nutrient Test Kits: What Can We Expect?" *The Volunteer Monitor* 9(1).

Kerr, M., L. Green, M. Raposa, C. Deacutis, V. Lee, and A. Gold. 1992. *Rhode Island Volunteer Monitoring Water Quality Protocol Manual.* URI Coastal Resources Center, RI Sea Grant, and URI Cooperative Extension. 38 pp.

LaMotte Chemical Products Company. Undated. *Laboratory Manual for Marine Science Studies.* Educational Products Division, Chestertown, MD. 41 pp.

Maine Department of Environmental Protection (DEP). May 1996. *A Citizen's Guide to Coastal Watershed Surveys.* 78 pp.

Paerl, H. W., and D. R. Whiteall. 1999. "Anthropogenically-Derived Atmospheric Nitrogen Deposition, Marine Eutrophication and Harmful Algal Bloom Expansion: Is There a Link?" *Ambio* 28(4): 307-311.

Phinney, J. 1999. "Nurients and Toxics." In: Meeting Notes—U.S. Environmental Protection Agency (USEPA)/Center for Marine Conservation (CMC) workshop: *Volunteer Estuary Monitoring: Wave of the Future*. Astoria, OR: May 19-21, 1999.

Stancioff, E. November 1996. *Clean Water: A Guide to Water Quality Monitoring for Volunteer Monitors of Coastal Waters.* Maine/New Hampshire Sea Grant Marine Advisory Program and Univ. of Maine Cooperative Extension. Orono, ME. 73 pp.

U.S. Geological Survey (USGS). 1999. *The Quality of Our Nation's Waters-Nutrients and Pesticides.* USGS Circular 1225. 82 pp.

Vitousek, P.M., J. Aber, R.W. Howarth, G.E. Likens, P.A. Matson, D.W. Schindler, W.H. Schlesinger, and G.D. Tillman. 1997. "Human Alteration of the Global Nitrogen Cycle: Causes and Consequences." *Issues in Ecology*. No. 1, Spring 1997. Ecological Society of America, 15 pp.

Web sites:

Air Deposition

National Estuary Program (NEP): http://www.epa.gov/owow/estuaries/airdep.htm