The Volunteer Monitor

**The National Newsletter of Volunteer Water Quality Monitoring**
**Volume 10, No. 2, Fall 1998**

Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

# Issue Topic: Monitoring Estuaries

## Table of Contents

The following articles appear in this edition of *The Volunteer Monitor*
(not all graphs and figures available)

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## Rotating co-editors

The Volunteer Monitor has a permanent editor and volunteer editorial board. In addition, a different monitoring group serves as co-editor for each issue.

This issue was coedited by the Friends of Casco Bay. Friends of Casco Bay's Citizen Stewards Water Quality Monitoring Program, established in 1993, has trained over 250 volunteers to gather baseline data from 106 sites in Casco Bay, following EPA-approved quality assurance protocols. The data assists local and state planners in making sound management decisions for Casco Bay.

*Great Bay Watch volunteer Liz Sizemore at her sampling site.*
Photo by Ann Reid.

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## Next issue: Restoration

The Spring 1999 issue of the newsletter, focusing on restoration, will be coedited by the Delaware RiverKeeper Network. If you think you might like to contribute an article, please call first to discuss it with the editor (address below).

## About *The Volunteer Monitor*

*The Volunteer Monitor* newsletter facilitates the exchange of ideas, monitoring methods, and practical advice among volunteer environmental monitoring groups across the nation.

*The Volunteer Monitor* is published twice yearly. The newsletter is also available online at http://www.epa.gov/owow/volunteer/vm_index.html.

Reprinting material from *The Volunteer Monitor* is encouraged. Please notify the editor of your intentions, and send us a copy of your final publication.

Address all correspondence to: Eleanor Ely, Editor; ellieely@aol.com.

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# Let Us Go Down to the Sea

## How Monitoring Changes from River to Estuary

*by Linda Green*

Many stream monitoring programs begin in the upper portion of their watersheds. Eventually they may decide to expand their program downstream to where the river meets the sea. How will their program change as they move into the estuary, the very rich and complex region where salt and fresh water mix? Estuary monitoring can be characterized as a mixture of river and lake monitoring techniques--liberally salted.

Estuaries differ from rivers in many regards. First and foremost, estuaries are subject to tides and the mixing of salt and fresh water. Any successful estuary monitoring program must take into account the stage of tide when scheduling training sessions and sampling times. ("It's really annoying to schedule a team of volunteers to meet at a cove, only to realize when you get there that it's low tide and everyone has to walk across half a mile of mudflats," says Peter Milholland, Citizen Stewardship Coordinator for Friends of Casco Bay.) Tide charts are readily available and should be a standard part of any program coordinator's toolkit. The fact that high tide occurs at different times in different parts of the estuary undeniably complicates scheduling. New Hampshire's Great Bay Watch schedules sample collection for low and high tides at each station on each monitoring date--which translates into different sampling times for each location!

Estuaries are complex, with a wide variety of environments that are constantly

changing. When the tide is rising, incoming salt water does not mix uniformly with fresh water. Fresh water is lighter (less dense) than salt water and tends to stay nearer the surface. The result is layering, or stratification, which may necessitate sampling at several depths--particularly for dissolved oxygen, nutrients, and salinity.

Estuaries are home to a fascinating variety of living organisms. Of primary interest to consumers are shellfish--clams, oysters, mussels, and scallops. In areas where shellfish (whether naturally grown or farmed) are harvested and eaten, two major human health concerns are likely to assume a prominent place on the monitor's agenda: bacterial and viral contamination, and shellfish poisoning. Special regulations and methods pertain to monitoring bacteria in shellfishing waters. Shellfish poisoning is even more frightening than microbial contamination since it can be rapidly fatal, and the toxins are not destroyed by cooking. Recent volunteer efforts to monitor the toxigenic algae that cause shellfish poisoning are described on "Early Warning System" for Shellfish Poisoning.

Let's take a quick look at some key water quality variables you're likely to monitor in estuaries, and see how they differ from their freshwater counterparts.

**Salinity:** Salinity is the concentration of salts in water. It isn't usually monitored in rivers or lakes, unless there is a connection with salt water or concerns about excessive road salting. Salinity changes with the tides and the amount of fresh water flowing into the estuary. It is often the major determinant of what lives where. Salinity is usually measured in parts per thousand (ppt). Drinking water is usually less than 0.5 ppt, seawater about 35 ppt. Salinity can be determined by measuring the physical properties of water, using a refractometer or a hydrometer; by a chemical test kit; or by an electronic meter.

*Dick Prince (left) and Russ Cookingham monitor water quality for the Coalition for Buzzards Bay.*
Photo by Tony Williams.

A refractometer measures the change in the direction of light as it goes from air into water. The measurement itself is simple, involving only a drop of water, but the refractometer costs several hundred dollars.

Many volunteer monitoring groups use hydrometers to measure salinity. A hydrometer actually measures the density of the water (the more salt in the water, the more dense it will be). Used in conjunction with a mandatory water temperature measurement (the cooler the water, the denser, down to 39¡F) the hydrometer reading can be converted to

salinity. This method is fairly simple and inexpensive.

(For more on measuring salinity, see "Salinity Testing Methods" in *The Volunteer Monitor*, Spring 1993.)

**Dissolved Oxygen:** Dissolved oxygen is critical for sustaining life in all aquatic ecosystems. In estuaries the oxygen content may change rapidly within a few hours, making site selection and timing of measurements critical. Stratification may also be occurring, requiring measurement at different depths. Commonly available kits such as those by LaMotte or Hach need no modification for analysis of dissolved oxygen in salt water. However, most meters require knowledge of the salinity content in order to properly calibrate the meter.

If you are interested in converting the dissolved oxygen concentration (usually expressed as mg/l or parts per million) to *percent saturation* (amount of oxygen in the water compared to the maximum it could hold at that temperature), you must take salinity into account. As salinity increases, the amount of oxygen water can hold decreases. This is a substantial difference. For example, at 20°, 100% saturation for fresh water is at a dissolved oxygen level of 9.09 mg/l. At the same temperature, 100% saturation for water with 36 ppt salinity is at 7.34 mg/l. *Standard Methods*[1] provides tables of dissolved oxygen saturation at various salinity concentrations.

**Nutrients:** For folks monitoring fresh water (whether rivers or lakes), the nutrient of primary concern is usually phosphorus. In estuaries, the nutrient of concern is usually nitrogen. So a program that's been monitoring a river might want to consider adding measurements of total nitrogen, nitrate-nitrogen and even ammonium-nitrogen to the suite of nutrients they measure.

Laboratory procedures for nitrogen and phosphorus are similar for fresh or salt water; however, when testing saltwater samples it's very important to use artificial seawater rather than fresh water in making up the standards. Nutrient test kits have the same limitation in estuaries as in freshwater systems--namely, they cannot detect low levels.

**Water Clarity:** In the case of measuring water clarity, monitors moving from a river to an estuary may well find that their options just got better. The Secchi disk, a simple tool widely used to measure lake water clarity, usually can't be used in rivers because of the current and the shallow water depth. Therefore river monitors generally measure turbidity with either a turbidimeter or a so-called turbidity tube (which actually measures transparency of the sample). But in an estuary, the water is often deep enough to permit use of a Secchi disk. Note that you can't directly compare turbidity readings to Secchi readings, since a turbidimeter measures light scattering in a water sample whereas a Secchi disk measures transparency of the entire water column.

**pH:** If you use a meter to measure pH, the techniques are the same whether you're testing salt or fresh water. However, if you use a colorimeter, you must use a correction factor (available from the manufacturer) to compensate for the effects of salinity. The Friends of Casco Bay built the pH correction factor (for LaMotte's cresol red method) into their data entry software, so the pH is automatically corrected.

**Temperature:** This key measurement is made the same way in salt or fresh water. As discussed above, temperature is of particular importance for accurately determining salinity using a hydrometer.

**Chlorophyll:** Many monitoring groups measure chlorophyll as an indicator of the amount of algae in water. Although the kinds of microscopic algae that live in estuaries are different from their freshwater counterparts, the chlorophyll collection and analysis procedures are the same.

**Submerged Aquatic Vegetation (SAV):** SAV can serve as an overall indicator of an estuary's health. Aquatic plants need relatively clear water so that sunlight can reach them. Sedimentation, nutrient enrichment, and disease can all cause declines in SAV. Techniques for monitoring SAV are often similar to those used in freshwater ecosystems. (For more on SAV monitoring, see SAV Hunt.)

**Bacteria:** EPA, which regulates recreational waters, recommends enterococci as the indicator for marine recreational waters. Shellfishing waters are regulated by the National Shellfish Sanitation Program (NSSP), which requires fecal coliforms as the indicator and "most probable number" as the analytical technique. (For more on bacteria testing, see Bacteria Testing Part 1.)

**Macroinvertebrates:** Although macroinvertebrates live in estuaries, using them as indicators of ecosystem health is more problematic than in streams. Estuaries support different invertebrate communities than freshwater systems, and many of the key freshwater indicators are not present in estuaries. In addition, collection is more difficult, given the tidal fluctuations and the muddy bottom. Finally, data analysis tools for relating macroinvertebrate communities to ecosystem health have not been as well developed for estuaries as for streams.

This quick overview highlights some changes your program may make as you move downstream to where the river meets the sea. An excellent source for additional information is EPA's publication *Volunteer Estuary Monitoring: A Methods Manual.* (Free; order from NCEPI at 800-490-9198; ask for publication 842-B-93-004. Also available online at http://www.epa.gov/owow/monitor/estuarvm.html.)

As Esperanza Stancioff reflected in an earlier *Volunteer Monitor* (Fall 1994), "The complexity of estuarine systems means monitors will need to expend extra time and effort to carefully design their studies, and probably extra money as well. While this may cause frustration at the outset, all in all the increased complexity and challenges are what make estuarine monitoring a refreshingly unique and interesting experience."

*(Thanks to Meg Kerr for contributions to this article.)*

***Linda Green*** *is the Program Director for University of Rhode Island Watershed Watch and a member of The Volunteer Monitor editorial board. She may be reached at 401-874-2905; riww@uriacc.uri.edu.*

### What Is an Estuary?

*An estuary is a partially enclosed body of water formed where freshwater from rivers and streams flows into the ocean, mixing with the salty sea water.*

--National Estuary Program website

Estuaries come in all shapes and sizes and go by many different names--bays, lagoons, inlets, sounds, tidal rivers, coves. (Note that not all water bodies by those names are necessarily estuaries. The defining feature of an estuary is the mixing of fresh and salt water.) Although influenced by tides, estuaries are protected from the full force of ocean waves, winds, and storms by fingers of land, mud, or sand that buttress their vulnerable seaward sides.

Estuaries support unique communities of plants and animals, specially adapted for life at the margin of the sea. Tens of thousands of birds, mammals, fish, and other wildlife depend on estuaries as places to live, feed, and reproduce.

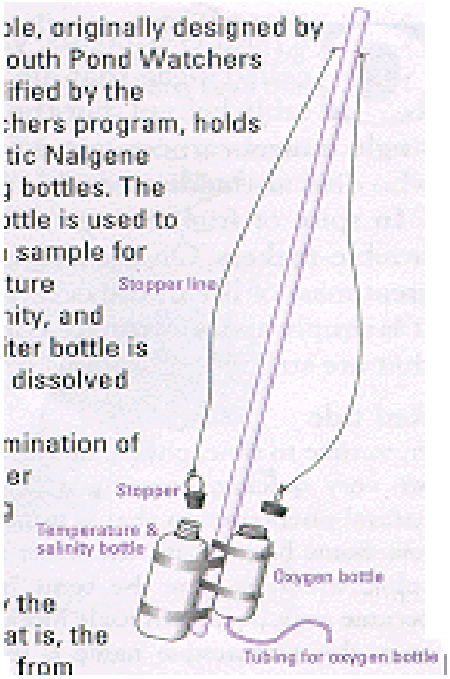
Estuaries transform with the tides. At high tide, seawater submerges the plants and floods creeks, marshes, mudflats, or mangroves, until what once was land is now water. The incoming waters seemingly bring back to life organisms that have sought shelter from their temporary exposure to the non-aquatic world. As the tides ebb, organisms return to their protective postures.

***Excerpted and adapted from:***
*National Estuary Program website*

*(http://www.epa.gov/owow/estuaries/nep.html")*
*National Estuarine Research Reserve System website*
*(http://inlet.geol.sc.edu/nerrsintro.html)*

## Sample Collection Pole

*Paul Krawczyk, a volunteer with the Coalition for Buzzards Bay, holds his sampling pole.*
Photo by Tony Williams.




Because estuaries are often stratified, with a wedge of saltwater underlying a layer of fresh water, monitors may want to collect samples at different depths. Volunteers with the Coalition for Buzzards Bay Baywatchers program in Massachusetts use the sample collection pole shown above to collect one set of samples 6 inches below the water surface and another set 1 foot above the bottom.

The pole, originally designed by the Falmouth Pond Watchers and modified by the Baywatchers program, holds two plastic Nalgene sampling bottles. The 1-liter bottle is used to collect a sample for temperature and salinity, and the 0.5-liter bottle is used for dissolved oxygen.

Determination of the proper sampling depth is complicated by the tides (that is, the distance from the surface to "1 foot above the bottom" will be quite different at high and low tides). To find the correct depth, on each sampling trip the monitors first drop their Secchi disk all the way to the bottom, then subtract one foot from that measurement.

For instructions on making and using the sample collection pole, contact

Tony Williams at 508-999-6363; cbuzzard@capecod.net.

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[1] American Public Health Association. 1998. *Standard Methods for the Examination of Water and Wastewater*, 20th ed.

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# "Early Warning System" for Shellfish Poisoning

In both U.S. coasts, volunteer monitors are on the lookout for toxic phytoplankton--certain species of single-celled algae that are responsible for shellfish poisoning. Several types of shellfish poisoning are known (see table below), but the most notorious is paralytic shellfish poisoning (PSP), caused by a toxin so potent that a single mussel can contain a fatal dose. A 1987 PSP outbreak in Guatemala killed 26 people, including two children who died at the dinner table within 15 minutes of eating contaminated shellfish.

In spite of frightening stories like this, it would be a big mistake to conclude that phytoplankton in general are trouble-makers. On the contrary, these microscopic algae constitute the base of the marine food chain, supporting the great mass of life in the ocean. Phytoplankton also produce (through photosynthesis) much of the oxygen we breathe. It is simply an unfortunate coincidence that out of the thousands of species of phytoplankton a few produce substances that are strongly poisonous to humans.

**Red tide**

From time to time, phytoplankton proliferate very quickly, creating a "bloom"--a natural phenomenon that is usually harmless. Some blooms tint the water a reddish color, which is how the term "red tide" became associated with toxic blooms. However, this picturesque name is misleading because there's no reliable connection between red-colored water and toxicity. (If it were that simple, there would be no need for *The Volunteer Monitor*s.) Toxic blooms can be red, but they can also be brown, green, or--most insidious of all--completely invisible. Ditto for nontoxic blooms.

**Human illnesses**

Shellfish (mussels, clams, oysters, and scallops) feed by taking in large quantities of water and filtering out the nutritious bits--mainly phytoplankton. When they feed on a toxigenic species of phytoplankton, they accumulate the toxin in their tissues. Since the shellfish themselves aren't harmed, they look quite normal to unsuspecting humans--but if those humans eat the shellfish, they can become sick, with symptoms depending on the phytoplankton species involved (see table) and the amount of toxin consumed.

Coastal states maintain a constant vigilance to prevent outbreaks of shellfish poisoning. Since there's no way to control the toxic blooms, protective programs focus on making sure that no one consumes toxic shellfish. State shellfish agencies regularly test shellfish so they can detect toxicity before it rises to dangerous levels and close shellfish beds in time to prevent illness.

**Some Toxic Phytoplankton Important in the U.S.**

| Phytoplankton | Illness Caused | U.S. Outbreaks | Symptoms |
|---|---|---|---|
| *Alexandrium* | PSP (paralytic shellfish poisoning) | New England; West Coast (including Alaska) | Numbness of lips and fingers; lack of coordination. Respiratory failure in severe cases. Can be fatal. |
| *Pseudonitzschia* | ASP (amnesic shellfish poisoning) | No human illness reported in U.S.* | Abdominal cramps, disorientation. Permanent memory loss in severe cases. Can be fatal. |
| *Gymnodium breve* | NSP (neurotoxic shellfish poisoning) | Southeast coast; Gulf of Mexico | Gastroenteritis; pailful amplification of sensation. No deaths. |
| *Dinophysis* | DSP (diarrhetic shellfish poisoning) | No human illness reported in U.S. | Gastroenteritis. Nonfatal. |

*Human illness on Canadian east coast; marine animal illness on U.S. West Coast.

**The idea for a volunteer network**

The inspiration and moving force behind volunteer phytoplankton monitoring is Sherwood Hall, a seafood toxin researcher at the U.S. FDA in Washington, DC. Part of Hall's job is to provide guidance to states in managing their shellfish programs. Confronted with increasing toxic blooms (see Toxic Blooms on Increase?) and

diminishing state agency resources, Hall searched for a solution and came up with the concept of a "volunteer observer network" that could provide additional data to help spot toxic blooms. The impetus to turn this idea into reality came from a dramatic incident in California.

In the fall of 1991, seabirds--cormorants and brown pelicans--in Monterey Bay began showing signs of a mysterious illness. Extensive detective work finally uncovered the cause--a phytoplankton called *Pseudonitzschia* that had never before been known to cause a toxic bloom on the West Coast. In fact, it had never been known to cause a toxic bloom anywhere in the world until, just four years earlier, a bloom of another species of *Pseudonitzschia* had killed three people and made hundreds sick in eastern Canada. The new illness was named amnesic shellfish poisoning (ASP) because some victims suffered a permanent loss of short-term memory.

Alarmed by the new threat in Monterey Bay, marine biologists up and down the West Coast began looking for *Pseudonitzschia*--and became even more alarmed when they discovered that the bloom extended along most of the coast and was also affecting other marine creatures, such as lobsters (though no human cases were reported). "The enormity and extent of it set us back on our heels," says Hall.

The 1991 episode, Hall says, convinced him that "if we had to pay people to take all the samples, there was no way to do an adequate job of detecting PSP, let alone ASP and other types. We would bankrupt ourselves. To stay ahead of these episodes, we had to get all the available resources together, and that included volunteers. There was just no alternative." So Hall designed techniques--based on what he himself had used as "an impoverished graduate student"--that volunteers could use to sample for toxic phytoplankton.

**Methods for volunteers**

Even though state agencies and volunteer monitors have the same ultimate goal--to catch toxic blooms in time to protect public health--they don't monitor the same thing. The agencies rely primarily on testing shellfish tissues for toxicity, in a labor-intensive procedure that involves first going out at low tide (which could be at midnight or 3 a.m.) to collect specimens, then processing the shellfish tissue and analyzing it with a mouse bioassay.

The volunteers, on the other hand, focus their efforts one step back in the cycle. Instead of looking at shellfish, they monitor the water column for toxic phytoplankton. Their information complements the agencies' shellfish toxicity testing in several ways. First, shellfish toxicity assays are specific to a particular toxin (most often PSP), whereas the volunteers are looking for any toxigenic species of phytoplankton. Second, volunteer observations can provide an early warning. Toxic phytoplankton typically show up in

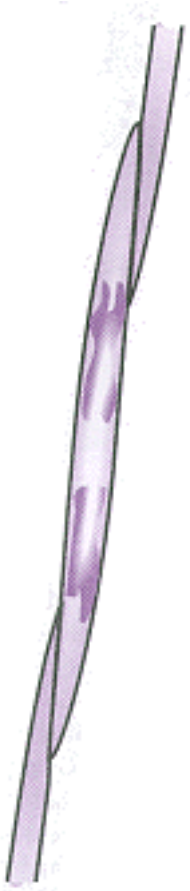
the water one to several days before shellfish themselves become toxic; in addition, algae blooms often start somewhere else and then move into a shellfishing area. "If you know where the toxin phytoplankton are and when," says Hall, "you have a better idea of where to focus your shellfish monitoring effort and which toxins to look for." Finally, Hall points out, the volunteer data can fill a scientific information gap since "for most of our coasts we have only sparse and intermittent data on phytoplankton populations. The volunteers have the potential to provide a comprehensive longterm baseline."

"Light, quick, and easy" was Hall's guiding philosophy for volunteer monitoring methods. "Forget about precise quantitative counts, such as a biology researcher would do," says Hall. "The idea is to be able to take lots of samples and get a qualitative idea--ain't got none, got a few, got a bunch. By being able to take more samples, more frequently, in more locations, we can far better define which plankton are where, and when."

In the protocol Hall devised, samples are collected in a plankton net and can be immediately examined with a hand-held field microscope (about the size of a camera) to screen for toxic phytoplankton. Though the method is simple, it's not especially cheap, at least by volunteer monitoring standards--nets run about $120, and good quality field microscopes about $600.

**The first volunteer program**

In the wake of the 1991 incident, the FDA provided California with emergency funding to expand its monitoring program, and Hall encouraged the state to develop a volunteer component. Gregg Langlois, a biologist at the California Department of Health Services (CDHS) in Berkeley, took on the challenge of setting up the nation's first volunteer toxic phytoplankton monitoring program.

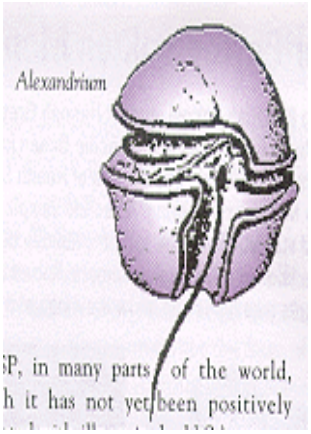


*Pseudonitzchia*

Today CDHS's program involves about 40 monitors per year at sites all up and down the California coast. Hall's office provides technical support, training, and materials. The volunteers preserve their samples and ship them (via overnight courier) to CDHS, where Pat Smith identifies the phytoplankton. Many of the volunteers also do their own microscopic identification, using field scopes and manuals supplied by CDHS. They are trained to recognize a variety of phytoplankton species, particularly the toxigenic genera *Alexandrium* (which causes PSP), *Pseudonitzschia*, and *Dinophysis* (which causes diarrhetic shellfish poisoning, or DSP, in many parts of

the world, though it has not yet been positively associated with illness in the U.S.).

For practical reasons, the majority of CDHS's volunteers sample from shoreline sites, such as piers, but the few who are able to sample offshore can provide especially valuable data since blooms tend to start out at sea and move shoreward. In Morro Bay (located halfway between San Francisco and Los Angeles), high school students have the opportunity to lower their nets into the open ocean, thanks to Coast Guard Ensign Erny Lowry, who takes them out in a Coast Guard boat. (For more on the Morro Bay students, see "Volunteer Phytoplankton Monitors at Work.")



*Alexandruim*

"We're not trying to replace our traditional shellfish program," Langlois emphasizes. "We're just trying to supplement it, and get a jump on toxic blooms." The volunteers sample at more sites than CDHS staff can reach and have provided early warning of several *Pseudonitzschia* blooms, enabling CDHS to step up shellfishing sampling in the areas identified by volunteers.

Last May, a large *Pseudonitzschia* bloom in Monterey Bay was linked to illness and death in sea lions and seals. As it happened, scientists at Monterey Bay Aquarium Research Institute were testing the water at about the same times as CDHS's volunteers. "Even though our volunteers were just using qualitative screening methods, their data matched really well with the quantitative data gathered by the researchers," Langlois notes with pride. "They caught the early stages of the bloom at the same time, and showed the peak at the same time."

**Maine takes off**

In 1996, Sherwood Hall approached Paul Anderson at Maine Department of Marine Resources (DMR) to discuss the idea of setting up a volunteer phytoplankton monitoring network in the state. From that point, events moved so rapidly that Hall was somewhat flabbergasted. "Maine took off like wildfire," he says. "I went up there hoping to stir up a little interest and found out that all I had to do was stand out of the way--it was an explosion of enthusiasm."

The quick response came about because Maine already had in place a well-organized statewide network of trained volunteer monitors (unlike California, where volunteers for the phytoplankton project had to be recruited "from scratch"). Back in 1988, Maine communities had started monitoring shellfish beds for bacteria, as well as physical and chemical water quality parameters. By 1996, 1,000 volunteers were actively involved in

Maine's Clean Water/Partners in Monitoring Program, jointly coordinated by the University of Maine Cooperative Extension and the Maine State Planning Office. These volunteers were ready and eager for a new challenge.

Currently about 20 groups (80 individuals) are monitoring phytoplankton in Maine. They sample at least once a week, from April to November, mainly at sites where DMR collects shellfish samples. Maine's program got a big boost in September 1998, when Wendy Norden was hired to fill the newly created fulltime position of phytoplankton coordinator, funded by a grant from the Maine Outdoor Heritage Fund.

In Maine, all the volunteers perform the microscopic identification themselves; they send a preserved specimen to DMR only if they have a question. Many simultaneously test their sites for temperature, salinity, and dissolved oxygen (because of Maine's history of volunteer monitoring, they are already trained and equipped to perform these tests). DMR is analyzing this data to look for correlations between water conditions and algae blooms.

"It takes a while for volunteers to get comfortable identifying the algae," says Norden. "There can be 10 or 15 different kinds in a sample. We try to give them lots of support." Volunteers start off by attending phytoplankton identification workshops taught by scientists from Bigelow Laboratory for Ocean Sciences and FDA. After the training session winds up with a few exciting rounds of Plankton Jeopardy ("We like to make training fun," says Norden), the volunteers take home preserved specimens of toxic species to use for reference. Once the volunteers begin sampling, they are supported by regular site visits from Norden and DMR staff members, who help with identification and answer questions.

Maine volunteers have seen several *Alexandrium* blooms before toxins showed up in shellfish. This summer, a volunteer team in Eastport were able to watch *Alexandrium* spread from site to site and increase in numbers for a couple of weeks until shellfish became toxic and DMR closed the beds. (By the way, this dedicated group of volunteers, led by Will Hopkins, keeps tabs on five sites twice a week--which entails 100 miles of driving each time.) This type of advance warning gives DMR a "heads up," allowing the agency to sample shellfish sooner and more frequently. The volunteers' data also provides new insights into the timing of blooms, such as how fast the phytoplankton multiply in the water and how long it takes for toxicity to show up in shellfish.

One surprise has been the amount of *Dinophysis* the volunteers are seeing. In some samples, almost all the phytoplankton are *Dinophysis*. "We knew it was here in Maine," says Norden, "but we had no idea of the abundance." No one knows yet whether this finding has implications for human health, but DMR is following up by testing shellfish

for DSP toxin.

Although the volunteers don't perform quantitative counts of phytoplankton, as a researcher would, the scope of their dataset gives it a unique value to scientists. "There's no way the scientific community could replicate the kind of coverage--weekly sampling up and down the coast--that the volunteers are providing," says Bigelow Laboratory oceanographer Maureen Keller, who's also a science advisor to the volunteer program. "Their data lets us know where and when to sample more thoroughly, and the long-term dataset they are building will help us identify trends."

**Other states**

Sherwood Hall's goal is to create a volunteer phytoplankton monitoring network covering all U.S. coastal areas. In addition to the California and Maine projects described above, there's an active phytoplankton observer network in Massachusetts, coordinated by Lynn Sherwood at the Division of Marine Fisheries. Hall is also working with agencies in other New England and West Coast states to start volunteer programs.

Before volunteer phytoplankton monitoring can be established in the Gulf Coast states, a technical hurdle will have to be overcome. In those regions, the biggest threat is *Gymnodinium breve*, which causes neurotoxic shellfish poisoning (NSP). Unfortunately, this species is too fragile to be reliably collected with a net. "The cells just self-destruct and turn into unrecognizable mush," says Hall, who hopes to develop a method suitable for volunteers to sample this delicate organism.

## Resources

*A Guide to Common Marine Organisms Along the Coast of Maine.* 1998. Field guide to Maine marine invertebrates, macroalgae (seaweeds), and phytoplankton. $10 + $3 shipping. Order from University of Maine Cooperative Extension (address below).

*Field Guide to Common Marine Phytoplankton in California.* 4-page picture key produced by California Dept. of Health Services for use by volunteers. Available from Gregg Langlois at CDHS (address below).

"The Plankton Net: Maine's Phytoplankton Monitoring Newsletter." Brand-new quarterly newsletter covering Maine's volunteer program. For a free subscription contact Wendy Norden (address below).

A training video, color pictures of phytoplankton, additional materials, and technical advice are available from Sherwood Hall at the Washington Seafood Laboratory (address below).

Smith, D.L. 1977. *A Guide to Marine and Coastal Plankton.* Kendall/Hunt, Dubuque,

IA. Covers both phytoplankton and zooplankton.

Tomas, Carmelo R., ed. 1997. *Identifying Marine Phytoplankton.* Academic Press, 525 B St., Suite 1900, San Diego, CA 92101; http://www.apnet.com/.

Anderson, Donald M. Red Tides. Scientific American, August 1994, pp. 62-68. Highly readable overview by an expert in the field.

Woods Hole Oceanographic Institution website: http://www.redtide.whoi.edu/hab/.

### Toxic Blooms on Increase?

Scientists have observed an increase in toxic phytoplankton blooms, both in the U.S. and worldwide, since the early 1970s. In the U.S., over the last 25 years we've had more frequent blooms, caused by more different species, and affecting larger geographic areas.

No one is sure of the explanation. In some cases, pollution is implicated--in Hong Kong, for example, blooms have become more frequent as nutrient levels in the water have increased. But other blooms seem unrelated to pollution and may be due to increased dispersal of the phytoplankton, both by natural causes and by human activities. Researchers also point out that with better detection methods, more people looking, and better communication among scientists, it's no wonder we're finding more blooms.

*(For more, see http://www.redtide.whoi.edu/hab/.)*

**To find out more about the programs covered in this article, please contact:**

Gregg Langlois or Pat Smith, CA Department of Health Services, 2151 Berkeley Way, Rm. 118, Berkeley, CA 94704; 510-540-3423; glangloi@ix.netcom.com.

Wendy Norden, University of Maine Cooperative Extension, 235 Jefferson St., P.O. Box 309, Waldoboro, ME 04572; 207-832-0343; wnorden@umce.umext.maine.edu.

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The Volunteer Monitor

**The National Newsletter of Volunteer Water Quality Monitoring**
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## In California...

Morro Bay High School student Hannah Gray lowers a 2-meter plankton net off the side of a Coast Guard boat in the Pacific Ocean just outside Morro Bay. One sample will be sent to the California Department of Health Services laboratory in the mailing tube that Stacy Marple is preparing. A second sample is taken back to the Morro Bay Coast Guard station, where the students identify the phytoplankton with the help of a microscope hooked up to a video camera. Robert Jenkins focuses the microscope while other students take notes and make drawings of the organisms.

## ...and Maine

Christine Feurt and her daughter Kelly (8 years old) regularly monitor several inlets to the Gulf of Maine. After transferring the sample from their 1-meter plankton net to a plastic baggie, they use a capillary tube to draw up a small amount of sample. The capillary tube is placed on the stage of a field microscope and examined immediately at 100X magnification.

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# Bacteria Testing Part 1

## Methods Primer

A lot of volunteer monitors are confused about bacteria testing--and no wonder. Several EPA-approved methods are available, each with its own pros and cons but all fairly demanding in terms of required equipment, procedures, and time commitment. Then there are some newer, non-EPA-approved, simplified methods--but how reliable are they?

Part 1 of this article reviews the basic principles of the traditional, approved methods, including the four indicators and two analytical methods most commonly used. In Part 2 we'll take an on-the-ground look at what methods volunteer groups are actually using, including both traditional and simplified methods.

**Indicators**

A number of pathogenic (disease-causing) viruses, bacteria, and protozoans can enter a water body via fecal contamination. Human illness can result from drinking or swimming in water that contains pathogens, or from eating shellfish harvested from such waters.

Unfortunately, direct testing for pathogens is impractical. Pathogens are rarely present in large numbers, and many are difficult to cultivate in the lab. Instead, microbiologists look for "indicator" species--so called because their presence indicates that fecal

contamination may have occurred. The four indicators most commonly used today (total coliforms, fecal coliforms, E. *coli*, and enterococci) are bacteria that are normally prevalent in the intestines and feces of warm-blooded animals, including humans. The indicator bacteria themselves are not usually pathogenic.

**How good are the indicators?**

All the indicators are easy to grow in the lab, and all will be present in large numbers if fecal contamination has occurred. So far, so good. Unfortunately, though, there are some problems with the indicators. One is the question of source. All the indicators can come from animals (pets, livestock, wildlife) and some can also come from plants or soil. (For an in-depth discussion, see "Interpreting Fecal Coliform Data: Tracking Down the Right Sources" in *The Volunteer Monitor*, Fall 1997.)

Another problem is that none of the indicators accurately reflects the potential for human health effects (though some do a better job than others, as we'll see below). The majority of swimming-related illnesses are caused by viruses--whereas all the indicators are bacteria, which don't closely model viral transport and survival. Because of these and other complications, microbiologists are still looking for better indicators. In the meantime, volunteer monitors and public health agencies alike must do their best with the indicators we have.

**Total coliforms and fecal coliforms**

Both the total coliforms and the fecal coliforms are "tried-and-true" indicators, used since the 1920s by agencies charged with protecting public health. The total coliforms are a group of closely related bacterial genera that all share a useful diagnostic feature: the ability to metabolize (ferment) the sugar lactose, producing both acid and gas as byproducts.

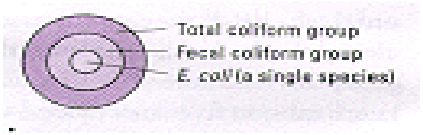
The total coliform group is not very useful for testing recreational or shellfishing waters. That's because some species in this group are naturally found in plant material or soil, so their presence doesn't necessarily indicate fecal contamination. (Total coliforms are useful for testing drinking water, where contamination by soil or plant material would be a problem.)

A more fecal-specific indicator is the fecal coliform group, which is a subgroup of the total coliforms. (However, even this group includes some species that can have a nonfecal origin--for example, Klebsiella pneumoniae, which grows well in paper pulp and is sometimes found in high concentration near paper mills.) Fecal coliforms are widely used to test recreational waters, and they are the only indicator approved by the FDA's National Shellfish Sanitation Program (NSSP) for classifying shellfishing waters.

In the lab, fecal coliforms are distinguished from total coliforms by their ability to carry

out lactose fermentation at 44.5°. (Tests for total coliforms are incubated at 35°. The 44.5° incubation temperature inhibits all except the fecal group.) The temperature must be maintained within narrow limits (+ 0.2°).

**E. *coli***




E. *coli* is a single species within the fecal coliform group. As an indicator, it has two advantages over the fecal coliforms: (1) It is more fecal-specific (E. *coli* occurs only in the feces of warm-blooded mammals); and (2) EPA studies (EPA 1986) showed that in fresh water E. *coli* correlated more closely with swimming-related illness. For these reasons, EPA began recommending in 1986 that states use E. *coli* as an indicator for freshwater recreational areas. (In spite of EPA's recommendation, many states still use fecal coliforms--partly for the sake of continuity, so that new data can be directly compared with historical data.)

**Enterococci**

The enterococci are another group of bacteria found primarily in the intestinal tract of warm-blooded animals. They are unrelated to the coliforms (for one thing, enterococci are spheroid whereas coliforms are rod-shaped). EPA recommends enterococci for testing marine recreational waters because of their superior correlation with swimming-related illness. However, as far as we are aware, no volunteer monitoring programs are currently using this indicator--perhaps in part because the EPA-approved mE method for enterococci requires incubation at 41° (so if you want to test for fecal coliforms or E. *coli* in addition to enterococci, you need two separate incubators), and the mE medium is expensive and contains a toxic ingredient.

**Analytical methods**

Two basic methods are used in testing water for bacteria: membrane filtration and most probable number (MPN). You can "mix and match" methods and indicators--that is, you can use either method for any of the indicators, simply by varying such factors as media used and incubation temperature.

*Connecticut River Watch Program volunteer Charles Renshaw pours a water sample into the membrane filtration apparatus.*
Photo by Eleanor Ely

**Membrane filtration**

In the membrane filtration technique, the water sample is pulled through a filter by means of suction (which can be supplied by an electric or hand vacuum pump or, for a very low-tech alternative, a syringe). Because the filter pores are too small for bacteria to pass through, bacteria are caught on top of the filter. How much sample you filter depends on how many bacteria you think are in the sample; your goal is to achieve a plate with an optimal number of colonies (see "Bacteria Testing Q & A").

The filter is then placed in a petri dish on top of a solid nutrient medium. This can be either an agar medium or simply an absorbent pad soaked with a broth medium. After incubation, visible colonies will appear on the filter paper surface. Each colony has grown from a single bacterial cell, so by counting the colonies you can obtain a count of the bacteria present in the water sample. Results are reported as cfu/100 ml (cfu = colony forming units).

The medium used depends on which indicator you are looking for. Microbiological media are designed to encourage the growth of specific target organism(s) and inhibit other types. Many also contain ingredients that give the target organisms a distinctive appearance, such as a color. For fecal coliforms, mFC medium is used; fecal coliforms will show up as blue colonies while other types are gray or cream-colored. To obtain counts for both fecal coliforms and *E. coli*, use mTEC medium. On mTEC, both fecal coliform and *E. coli* colonies initially appear yellow; after urease reagent is added the *E. coli* stay yellow while the other fecals turn magenta. Both mFC and mTEC are incubated at 44.5° to select for the fecal coliform group.

**Most probable number (MPN)**

We don't know of any volunteer monitoring groups who actually perform the classic "most probable number" (MPN) technique, which is labor-intensive, takes up a lot of incubator space, and requires up to four days for a final result. However, it's important for volunteer groups--particularly those that monitor estuaries--to be aware of this method because MPN for fecal coliforms is the only method that is NSSP-approved for classifying shellfish-growing waters.

Unlike membrane filtration, which gives you a plate of colonies to count, MPN does not yield a direct count of bacteria. Instead, the water sample is added to a series of tubes that contain a liquid medium. After incubation, each tube shows either a positive or negative reaction for the target organism. (In the case of fecal coliforms, for example, a positive tube is one that shows growth and gas.) A second step is required to "confirm" the positive tubes. The number of confirmed positives corresponds to a statistical probability that the sample contained a certain number--the "most probable number"--of bacteria. The accuracy of the MPN method can be increased by inoculating more tubes and by using several dilutions of the water sample.

One advantage of the MPN method is that it is unaffected by turbidity in the sample, whereas in membrane filtration the filter can become clogged by sediment, algae, etc.

**What levels are significant?**

Interpreting bacterial data is tricky. There's a lot of variability in the test procedure, as well as in the environment, so you can't draw a firm conclusion based on just one sample. Microbiologist Gerri Miceli (see "Bacteria Testing Q & A") points out that

environmental waters almost always contain some level of fecal coliform bacteria and strongly recommends that volunteer groups do routine baseline monitoring so they know what is normal for their water body. "Take samples during different weather patterns," she advises. "Get a feel for what's normal when it's dry and what's normal when it's wet." Miceli also points out that bacterial counts will be higher when flow is low (because bacteria will be more concentrated).

Water quality standards vary state to state, so volunteers monitors should consult their state agencies. The following criteria are offered as rough guidelines. These criteria are not designed to evaluate a single sample; they apply to the geometric mean1 of several counts. So don't panic if you see one high count--first take more samples and see if the count remains high. (The geometric mean is used for bacterial data because it reduces the effect of a few high values.)

**Recreational waters (EPA criteria):**

- **Fresh Water:**

  *E. coli*.....126 cfu/100 ml
  (membrane filtration with mTEC)
  enterococci.....33 cfu/100 ml
  (membrane filtration with mE)

- **Marine Water:**

  enterococci.....35 cfu/100 ml
  (membrane filtration with mE)

- **Fresh or marine water:**

  fecal coliforms.....200 cfu/100 ml
  (membrane filtration with mFC)

**Shellfishing waters (NSSP criteria):**

fecal coliforms.....14/100 ml
(MPN)

## References


U.S. EPA. 1986. *Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters.* EPA 440/5-84-002. EPA Office of Water. Available from NTIS (800-553-6847); ask for PB-86-158-045.

U.S. EPA. 1985. *Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filtration Procedure.* EPA 600/4-85-076. Available from NTIS (800-553-6847); ask for PB-86-158-052.

American Public Health Association. 1998. *Standard Methods for the Examination of Water and Wastewater*, 20th edition. APHA, P.O. Box 753, Waldorf, MD 20604.

[1] To calculate the geometric mean, convert the counts to logs, average the logs, then take the antilog of the average.

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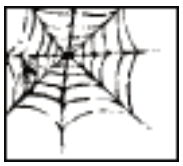

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# Bacteria Testing Part 2

## What Methods Do Volunteer Groups Use?

While any volunteer group that monitors a swimming area has a reason to be concerned about bacteria levels, estuary monitoring groups have an additional, very pressing concern--shellfish safety. So it makes sense that Maine citizen groups responding to shellfish bed closures in local estuaries were among the first volunteer monitors to tackle bacteria testing. Back in 1988 these volunteers, with support from Esperanza Stancioff at the University of Maine Cooperative Extension, set up shop in high school laboratories and began using membrane filtration to test water samples for fecal coliform bacteria.

Of course, not all volunteer programs do their own labwork for bacteria; many send their samples to professional labs for testing. However, this article will focus on the techniques used by groups who do their own analysis.

Why do volunteer groups decide to do bacteria testing themselves? Reasons include the freedom to sample wherever they please (if volunteers are collecting samples for an agency the agency may select the sites); self-sufficiency (as opposed to depending on ongoing support from an outside lab); and the opportunity for more community involvement and ownership of the data. Cost is a factor too: unless you find a lab that will donate the analysis, charges run $10-25 per sample, whereas Maine groups spend approximately $2 for each sample they process themselves.

## Sanitary Shoreline Surveys

Testing for bacteria is only one facet of ensuring shellfish safety. Another important component of any state shellfishing program is the sanitary shoreline survey, a physical examination of coastal properties to identify pollution sources.

To conduct a shoreline survey, the survey team visits every dwelling within 500-700 feet of the shoreline. At each property, the surveyors talk to the owner about septic disposal; examine the septic system; look for pipes, drainages, or other pollution sources (such as animal husbandry); and collect water samples if needed.

Doing a shoreline survey requires tact, thoroughness, and good observation skills. It's a job that volunteer monitors can and do perform. Since 1993, Maine's Department of Marine Resources (DMR) has trained volunteers to conduct the surveys; and in New Hampshire, Great Bay Watch volunteer monitors have assisted the state's Health and Human Services Department with shoreline surveys for the past three years.

Paul Anderson, DMR's Public Health Division Director, says that he impresses on volunteers the fact that decisions to open or close shellfishing beds will be based, in part, on their work. "We're dealing with public health," he says. "I want the monitors to realize how serious this work is." (For more on Maine's program, see "Land Use Surveys" in *The Volunteer Monitor*, Fall 1994.)

**Resource**

Maine Department of Marine Resources. 1998. *Shellfish Sanitation Program Volunteer Manual*, 2nd edition. Includes instructions for shoreline surveys. Limited copies available; for information please contact Sherry Hanson, Volunteer Coordinator, Maine DMR, 207-633-9401; sherry.hanson@state.me.us.

*Volunteers with New Hampshire's Great Bay Watch collect a water sample as part of a sanitary shoreline survey.*

**The classic method: Membrane filtration for fecal coliforms**

Membrane filtration for fecal coliforms, using mFC medium, was the method chosen 10 years ago by the Maine volunteers, and it still remains the method most widely used by volunteer groups. Volunteer programs select this method because it's EPA-approved, it conforms to what many state labs use, and it is a long-established, well-recognized method. For programs that monitor shellfishing waters, membrane filtration for fecal coliforms represents a practical way to approximate the methods used by their state shellfishing lab. State shellfish labs, in accordance with NSSP mandate, use MPN (most probable number) for fecal coliforms; the volunteers use the same indicator but not the cumbersome MPN method.

Incubation at 44.5°C is the crux of membrane filtration with mFC, since the ability to grow and ferment lactose at 44.5°C is the key distinguishing feature of the fecal coliform group. To obtain accurate counts, the temperature must be held absolutely steady (within 0.2°C)--a bit too warm, and the fecal coliforms can't grow; a bit too cool, and the nonfecals start growing. The least expensive incubator that will do the job is a good-quality waterbath incubator--not a cheap piece of equipment, unfortunately. (Air incubators capable of holding the temperature are even more expensive.) Some volunteer programs have tried building their own waterbath incubators, with mixed success (see Update: Homemade Waterbath Incubators). Another option is to purchase a reconditioned waterbath incubator. Check the Yellow Pages or ask local labs to recommend companies that specialize in used and reconditioned lab equipment.

**mTEC: Fecal coliforms AND *E. coli***

Membrane filtration with mTEC agar provides counts for both fecal coliforms and *E.*

*coli*, but the procedure is extra-challenging because it involves all the same steps described above for fecal coliforms, and then some. The plates have to be incubated at two temperatures (first 35°C and then 44.5°C), and after incubation a special reagent has to be used to distinguish the *E. coli* colonies from the other fecal coliforms.

River Watch Network, a Vermont-based organization that works with a number of river monitoring groups, recommends this method to many of the groups they advise. RWN Science Coordinator Geoff Dates believes the extra effort to obtain an *E. coli* count is worthwhile because of the higher correlation of *E. coli* with swimming-related illness in fresh water. The ability to report both fecal coliforms and *E. coli* has proved especially useful for interstate groups like the Merrimack River Watershed Council, which sends data to one state (New Hampshire) that uses *E. coli* as the indicator and another (Massachusetts) that uses fecal coliforms. For more on the mTEC method and how RWN groups are using it, see *The Volunteer Monitor*, Fall 1992.

Unquestionably, equipment requirements present the biggest hurdle to volunteer groups who want to use an EPA-approved method. The two approved methods volunteers use--membrane filtration with mFC and with mTEC--both require a waterbath incubator, an autoclave (for sterilizing equipment), and membrane filtration apparatus. On the other hand, once the initial investment is made, routine testing by these methods is inexpensive. Many volunteer programs arrange to use high school or university laboratories to sterilize equipment, prepare media, incubate plates, and dispose of wastes. (As an added bonus, teachers and students can usually be recruited as volunteers.) Others set up the equipment at a central program lab.

**Simplified methods for total coliforms and *E. coli***

Seeking an easier alternative to the approved methods, several volunteer monitoring groups have started using some relatively new products with simpler equipment requirements. These products are:

- Colilert (from IDEXX Laboratories), which uses a modified MPN approach
- Coliscan Easygel and Coliscan-MF Membrane Filtration Kit (from Micrology Labs), which are plate-count methods

The big advantage of these simplified methods is that they make it possible for individual volunteer monitors to perform the tests in their own homes. Incubation is at 35°C (or even at room temperature--see below), and since temperature is not critical for these methods, a waterbath is not required.

However, there are a couple of important caveats to keep in mind:

1. These methods are not EPA-approved for recreational waters (though Colilert is

approved for drinking water) and thus are appropriate for screening only.

2. None of the quick methods provides a fecal coliform count. (Don't be misled by the Coliscan literature, which uses the terms "*E. coli*" and "fecal coliform" interchangeably.) They only give counts for total coliforms and *E. coli*. Does this matter? It depends on how you want to use your data--for example, do you want to share data with a state lab that uses the fecal coliform indicator?

**Colilert**

In IDEXX Laboratory's Colilert method, the water sample is added to tubes of liquid media. As with the classic MPN method, the more tubes inoculated, the more sensitive the count. The volunteer programs we spoke to are using just 5 tubes--enough for a rough screen.

Results are read after 24 hours' incubation at 35°C. The medium turns yellow if total coliforms are present and fluoresces under UV light when E.coli is present. The one expensive item needed is a professional-quality UV lamp, which runs several hundred dollars.

In California, volunteer "Bac-Attackers" with the Friends of the Estuary/Morro Bay National Estuary Program Volunteer Monitoring Program use Colilert to monitor E.coli levels in freshwater seeps to Morro Bay. Labwork is done in a converted closet at the Morro Bay NEP office.

Also in California, several chapters of Surfrider Foundation (a surfer organization) use Colilert to monitor the surfzone. The Surfrider volunteers carry out the test in their homes, using inexpensive egg-hatching incubators. Glen Kent, Chair of Surfriders' Ventura County Chapter, estimates that supplies run about $5 per sample and reports that members like Colilert because it's quick and simple to set up at home and the results are easy to interpret.

**Coliscan**

Both of Micrology Lab's Coliscan products make use of a patented medium on which total coliform

*A closet at the Morro Bay National Estuary Program office serves as a microbiology lab for volunteer "Bac Attackers" like Al Pardo, above.*
Photo by Eleanor Ely.

*Christine Braun, another "Bac Attacker," uses a UV light to read Colilert Results.*
Photo by Eleanor Ely.

colonies other than E.coli appear pink and E.coli colonies appear purplish blue.

With the Coliscan-MF Membrane Filtration Kit, water samples are processed by the usual membrane filtration technique and the filter is placed on the special Coliscan medium.

*Smithville High School student Crystal Dudley pours a sample into an Easygel plate. The school participates in Colorado River Watch Network's monitoring program.* Photo by Jason Pinchback.

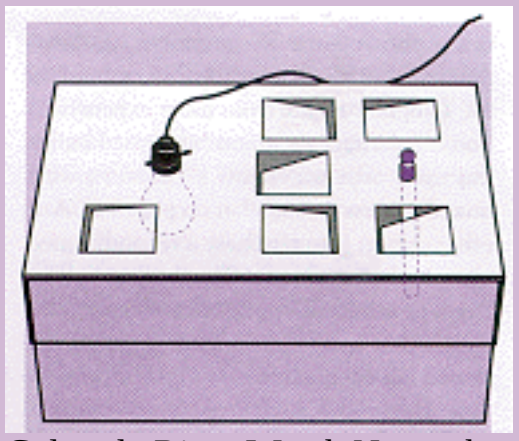
Coliscan Easygel is a very easy pour-plate method. You simply add the water sample (unfiltered) directly to a bottle of liquid Coliscan medium, mix it, and pour it into a special petri plate which is coated with a substance that causes the medium to gel. Note that Easygel is appropriate only for counts higher than about 20 cfu/100 ml, since there is no filtration step to concentrate the bacteria, and the maximum sample water volume is 5 ml.

For both Coliscan-MF and Easygel, the manufacturer recommends an incubation temperature of 35°C but says that plates can also be incubated at room temperature (though growth will be slower). However, microbiologist Gerri Miceli (see accompanying article, "Bacteria Testing Q & A") points out that room temperature can vary with season or even day to day, making it difficult to compare results obtained at different times. Using an incubator ensures a consistent temperature.

Miceli also notes that the Coliscan medium allows noncoliforms to grow, and that these other bacteria could outcompete coliforms for nutrients, causing lowered total coliform and E.coli counts.

Last year, the Colorado River Watch Network (a volunteer monitoring program sponsored by the Lower Colorado River Authority) began investigating both Coliscan products. Previously, says CRWN Quality Control Coordinator Jason Pinchback, the volunteers had been using the membrane filtration method for fecal coliforms, incubating the plates in homemade waterbath incubators. Problems with the incubators (see Update: Homemade Waterbath Incubators), combined with a desire to switch to *E. coli* as an indicator because of its better correlation with illness, prompted CRWN to try Coliscan.

Pinchback experimented with both Easygel and Coli-scan-MF. He found colony-counting somewhat tricky with the Easygel because many colonies are embedded in the agar (since it's a pour plate). Nevertheless, he concluded that Easygel is "an excellent screening tool, self-contained and relatively inexpensive." In only the second week of trial testing, the Easygel detected high counts at one site; when Pinchback contacted the city of Austin he learned that a recent sewage leak had occurred a mile upstream from the site. "Right off the bat it did its job," comments Pinchback. Currently CRWN volunteers are using Easygel to monitor 12 river sites. They incubate the plates in their homes, using simple incubators made from cardboard boxes (see illustration).



Colorado River Watch Network volunteers use simple homemade incubators like the one shown above for 35°C incubation of their Coliscan Easygel plates. The incubator is made from a box approximately 12 x 12 x 18 (the size in which copier paper is packed) and heated by a 40-watt bulb. Vent flaps cut in the box can be adjusted to achieve the correct temperature, which is monitored by a thermometer kept in the box.

*For more information, please contact Jason Pinchback, CRWN, LCRA, P.O. Box 220, MS H219, Austin, TX 78767; 512-473-333, ext. 7859.*

**Which method should you use?**
In deciding what method to use, many questions must be considered. A few of these are:

- How do you hope to use your data?
- Will you be testing fresh or marine water?
- Will you be testing water where shellfish are harvested?
- What methods does your state lab currently use?
- Do you have access to laboratory facilities?
- What kind of equipment can you afford?

All the methods discussed in this article have the potential to yield useful data. The key point is to *match the method with the intended use.* Groups that want their data used by state agencies generally try to use an EPA-approved method that is the same as, or similar to, what the state labs use. Groups that are primarily interested in raising community awareness and/or screening for high counts may find that a simpler, non-approved method is adequate for their needs. For example, Surfrider volunteers who use Colilert publish their results in local newspapers and present them at public meetings. "Our work has really raised awareness," says Kent. "When you used to say 'pollution' people thought of oil. Now people understand about bacteria, about runoff."

## Resource

"Processing Fecal Coliform Samples." Video (13 minutes). High school student volunteers with the Great Bay Watch program in New Hampshire demonstrate step-by-step the membrane filtration method for fecal coliform analysis, using mFC medium. Order from Great Bay Watch, Kingman Farm/UNH, Cooperative Extension Sea Grant, Durham, NH 03824; 603-749-1565. $12 + $3 shipping.

Stancioff, Esperanza. 1996. *Clean Water: A Guide to Water Quality Monitoring for Volunteers Monitoring Coastal Waters.* Includes instructions for fecal coliform testing (membrane filtration). University of Maine Cooperative Extension and Sea Grant. Order from UMCE, 235 Jefferson St., P.O. Box 309, Waldoboro, ME 04572; 207-832-0343; $10 + $3 shipping.

Mitchell, Mark, and William Stapp. 1997. *Field Manual for Water Quality Monitoring: An Environmental Education Program for Schools.* 11th Edition. Kendall/Hunt. Includes instructions for fecal coliform testing (membrane filtration). Order from GREEN, 206 S. Fifth Ave., Suite 150, Ann Arbor, MI 48104; 313-761-8142. $19.95 + $2 shipping.

River Watch Network. 1996. *"Escherichia coli (E. coli) Membrane Filter Procedure."* Available for $1 from RWN, 153 State St., Montpelier, VT 05602; 802-223-3840.

Behar, Sharon. 1997. *Testing the Waters: Chemical and Physical Vital Signs of a River.* Includes a general discussion of bacteria testing (no step-by-step procedures). River Watch Network. Available for $25 from RWN (address above).

Dates, G. and Schloss, J. 1998. *Data to Information.* Includes discussion on interpreting bacteria data. For ordering information see "Make Sense of Your Data."

U.S. EPA. 1997. *Volunteer Stream Monitoring: A Methods Manual.*
U.S. EPA. 1993. *Volunteer Estuary Monitoring: A Methods Manual.*
Both the above manuals from EPA contain general information about bacteria testing, including how to collect samples, but neither covers laboratory procedures. Free. Order from NCEPI at 800-490-9198 (for the stream manual, ask for publication 841-B-97-003; for the estuary manual, ask for 842-B-93-004).

## Related Articles in Past Issues of *The Volunteer Monitor*

Fall 1991: "Doing Your Own Lab Analysis for Fecal Coliforms," by Esperanza Stancioff.

Fall 1992: "Testing for *E. coli* Bacteria," by Geoff Dates; "Fecal Coliform Monitoring in the U.S. and Around the World," by Miriam Zweizig; "Windsurfers and Surfers Test Water."

Fall 1997: "Interpreting Fecal Coliform Data: Tracking Down the Right Sources," by George Heufelder.

## Suppliers

*For membrane filtration supplies:*

- Hach Company, Loveland, CO, 800-227-4224; http://www.hach.com/.
- Millipore Corporation, Bedford, MA, 800-221-1975 or 800-645-5476; http://www.millipore.com/.

*For Coliscan products:*

- Micrology Laboratories, Goshen, IN, 888-327-9435; http://www.micrologylabs.com/.

*For Colilert:*

- IDEXX Laboratories, Westbrook, ME, 800-321-0207.

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# Bacteria Testing Q & A

*by Gerri A. Miceli*

*(Microbiologist Gerri Miceli operated a public health microbiology lab in Rhode Island for six years, during which time she advised and volunteered for several New England volunteer monitoring groups.)*

**Once you begin testing water samples for bacteria, you will undoubtedly encounter those "unexplained circumstances" and situations that will prompt you to ask, "What does this mean?!" Following are some of the most common questions I've been asked by volunteer monitoring groups that I have advised.**

***Q: Which is better for sample collection, a plastic bottle or a "Whirl-Pak" bag?***
Both methods meet the basic criteria of being both sterile and nontoxic. The pre-sterilized, disposable Whirl-Pak bags are convenient, but I generally prefer the plastic bottles (Nalgene brand are widely used). They can be washed and re-used practically indefinitely, which makes them cheaper in the long run, and they're easier to work with because they stand up on the benchtop. However, they need to be sterilized in an autoclave, which may require the assistance of a certified lab. (Be sure the bottle you purchase is autoclavable--some plastics are not.)

***Q: What does it mean when I get a high count?***
The first thing to do is go back to the same location and take more samples. Note which direction the water is flowing and take several samples further upstream, especially if you notice something out of the ordinary. If some or all of these sample results are very

high too, then you should follow your organization's procedures--for example, calling your state agency to notify them.

A little detective work plays a big role in determining where contamination is coming from and whether it's of human origin. Always make observations--the presence of animals and birds, abundant leaf matter, any strange debris, any unusual smells, etc. Also note weather conditions since results can vary tremendously if it is raining.

Remember too that variability and unusual test results will occur, and that a low level of fecal coliform is not abnormal, especially since wildlife frequent our waterways. A long-term monitoring effort will provide baseline information about a sampling site and will enable you to quickly recognize any unusual results.

***Q: What exactly am I looking at and counting anyway?***
A single bacterium in the water sample that is caught on the filter, if able to grow on the medium, can grow at a fast rate. Some bacteria can multiply every 20 minutes, so after 24 hours, when you pull out your plates, you are looking at a clump of about a million bacteria--visible to the naked eye!

***Q: I am using the membrane filtration method. Why do I see . . .***
***(a) a big blob of growth only on one spot on the filter?***
This may occur when the sample aliquot being analyzed is small (1-10 ml) and is not distributed evenly on the filter. To ensure even distribution, be sure to add enough buffer or rinse water (5-10 ml) to the funnel prior to adding the sample--and prior to applying the vacuum. The sample will disperse in the buffer (picture the way a small dollop of cream spreads out in a cup of coffee), and the colonies should be evenly distributed on the filter.

***(b) all the growth on only one side of the filter?***
The funnel base may be clogged so the vacuum is only pulling through one part of the base. Remove the base and thoroughly clean it of any buildup. It is recommended to clean funnels and bases periodically.

***(c) colonies that look runny and oblong?***
First, you may be incubating the plates in the wrong position. Plates should be incubated in an inverted position--that is, media side up--so that condensation will fall down on the cover, not on the growing colonies. Second, excessive moisture may remain on the filter if it is removed before all the sample is filtered. This may cause the bacterial growth to spread out. These "spreaders" should be counted as one colony.

***Q: There's a lot of background growth. Can I still count all my target colored colonies?***

There is a maximum number of total colonies allowable on a plate. For the small-size membrane filtration plates, 80 (or even 60, depending on the method) is the maximum. The larger plates used with Coliscan Easygel can accommodate up to 300 colonies.

All those organisms compete for the limited nutrients in the medium. The ones that grow are those that were able to outcompete the others. This competition may mask what the actual numbers are. If the total number of colonies exceeds the allowable number, the count is invalid and the result should be reported as an estimate based on the quantity of sample analyzed and the plate size.

***Q: I have a hard time assessing if a colony is the "right" color.***
Including positive and negative control organisms when you analyze your samples will give you a reference to compare to. It takes practice to learn which questionable colonies are positive for your method. When starting out, it's a good idea to pick a representative colony that you are unsure about and verify what it is, perhaps with help from a professional lab. This is especially helpful if an entire plateful of a strange-looking colony appears. Identifying what it is may uncover an unknown problem in the area, or point to a problem with your quality control.

On mTEC medium (before you add the urease reagent) some yellow colonies are bigger, some are smaller, and some are pinpoint, but they should all be considered fecal coliform colonies. Some may even start to turn a brown-yellow.

Plates of mFC media are usually easy to count; the one potential problem is crowding, because the colonies are big and flat.

Pour plates (such as the Coliscan Easygel plate) can be difficult to read since colonies grow both on top of and within the medium. The colonies may be smaller and more difficult to assess when there is a lot of growth. Total coliforms appear pink-red, E.coli appears purple, and non-coliforms, which are also able to grow, are usually green or white. Lots of background growth may interfere with "reading" the plates.

***Q: How do I store a plate that I want to send to a laboratory?***
If you want to send a plate to a lab for help with identification, place it in a ziplock bag labeled as a "biohazard" and store it in the refrigerator, media-side up. Transport the plate to a laboratory as soon as possible, but the plates can be stored for a week or longer in the refrigerator because the cold temperature slows bacterial growth.

***Q: I gave another laboratory a duplicate sample bottle and their results are very different! Why?***
First, be clear about what you are duplicating. If you collect two separate samples from the same site, you are replicating collection. Since organisms are not homogenous in the

environment, it is very possible that two separate grabs from the same area may yield different results.

Most often, what volunteer groups really want to replicate is the analysis. Never use two separate grab samples to test for comparability of analysis with another laboratory. Collect a single sample in a large container (you may need to buy a few larger sample bottles for this purpose), mix it well, then immediately pour half into another sterile container which you will provide to the other laboratory for analysis. Both laboratories should use the same test method, and preferably both should analyze the sample at approximately the same time. If the results are not within acceptable limits of variability, determine where something could have gone wrong. (Note: Defining acceptable limits of variability is a complex problem; consult with a professional lab for guidance.) Common problems include not mixing the sample well enough prior to analysis, not measuring accurately, and incorrect incubation temperature.

***Q: What minimum quality control should I be doing?***

This could be the subject of an entire article! Briefly, you should maintain records of positive and negative controls, incubator temperatures, and split sample results. Maintaining proof that your results were generated in a consistent, reproducible manner that adheres to the requirements of the method will allow others to accept your results. Quality control testing shouldn't take too much extra time, but it will instill confidence that you are producing valid data.

***Q: Can I combine my results with others in my program who are using a different method?***

No. When reporting results, it is necessary to specify the method used, the media used, and the lower limit of detection (the smallest number of test bacteria that could be found considering the method and the quantity of sample). Different methods have different precision and recovery ability. It is important to separate results that were generated by different test methods and under different conditions.

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## Update: Homemade Waterbath Incubators

In the Spring 1993 issue of *The Volunteer Monitor*, an article from Colorado River Watch Network (CRWN) described how to build a waterbath incubator from a nonstyrofoam cooler. A subsequent letter to the editor (Spring 1994 issue) contained some refinements to the design.


Photo by James Buratti.

For several years, CRWN volunteers used these incubators in their homes as part of the test procedure for fecal coliform bacteria, a method requiring incubation at 44.5° +/- 0.2°. However, the incubators proved to be somewhat problem-prone--and since they were kept in volunteers' homes, they had to be brought in to the CRWN office for repairs. CRWN's Steven Hubbell reports that "from a program manager's perspective, the incubators can be more of a headache than a blessing. Problems include leaking, temperature fluctuations, heating element burnout, and electrical shocks." Partly because of the incubator problems, CRWN is now switching to the Coliscan Easygel method, which doesn't require 44.5° incubation (see preceding article).

Though the homemade waterbath incuba-tors may not be for everyone, under some circumstances they can be used successfully. For example, Gil and Marilyn Alexander at the Montana Science Institute report that theirs has worked well for over five years. The Alexanders offer the following advice (for more information, contact them at cfli@metnet.mt.gov or msi@mt-science.org):

- Install the aquarium heater horizontally in the bottom of the cooler and seal with 100% silicone.
- Some aquarium heaters automatically shut off before reaching the required temper-ature. The more expensive type works best.
- Install a small aquarium bubbler near the top, with the hose extending to the bottom near the heater. This helps distribute the heat evenly.
- Achieve the required temperature and keep it stable for at least one day before incubating plates.
- Plates must be kept dry and submerged in order to maintain a constant temperature. Put plates into ziplock bags, then seal inside small Tupperware containers that are weighted to stay below the water surface.

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## Make Sense of Your Data

Often, raw monitoring data is no more than a collection of numbers. How do you find the story hidden there? Making data meaningful is the topic of a new guidebook, *Data to Information,* written expressly for volunteer monitoring groups by two veterans in the field, Geoff Dates (River Watch Network) and Jeff Schloss (University of New Hampshire Lakes Lay Monitoring Program).

The book is packed with practical, realistic examples based on the authors' years of experience with volunteer monitoring. Topics covered include using data-management software, summarizing data with simple statistics, creating effective tables and graphs, and developing conclusions and recommendations from your data. Although the manual is subtitled "A Guide Book for Coastal Volunteer Water Quality Monitoring Groups in New Hampshire and Maine," almost all the information is equally relevant to noncoastal monitoring and to any region of the country.

The guidebook (73 pages + appendices) is available from University of Maine Cooperative Extension, 235 Jefferson St., P.O. Box 309, Waldoboro, ME 04572; 207-832-0343; $10 (includes shipping).

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## Resource for Estuary Monitoring

*Note:* See also specific resources for monitoring toxic phytoplankton, bacteria 1, 2, and SAV.

**Volunteer Monitoring Manuals**
U.S. EPA. *Volunteer Estuary Monitoring: A Methods Manual.* 1993. Discusses important estuary issues and provides guidance for monitoring dissolved oxygen, nutrients, phytoplankton, submerged aquatic vegetation, and bacteria. 176 pages. Free; order from NCEPI at 800-490-9198 (ask for publication 842-B-93-004). Also available online at http://www.epa.gov/owow/monitor/estuarvm.html.

Stancioff, Esperanza. 1996. *Clean Water: A Guide to Water Quality Monitoring for Volunteer Monitors of Coastal Waters.* University of Maine Cooperative Extension/Sea Grant. Written for volunteer monitors in Maine; covers quality assurance, watershed surveys, physical and chemical parameters (salinity, dissolved oxygen, nutrients, and more), and fecal coliform bacteria by membrane filtration. 73 pages. Order from UMCE, 235 Jefferson St., P.O. Box 309, Waldoboro, ME 04572; 207-832-0343; $10 + $3 shipping.

Meeker, Bonnie S., and Reid, Ann S. *Great Bay Watch: A Citizens Water Quality Monitoring Program.* 1990 (updated annually). Designed for volunteers in New Hampshire's Great Bay Watch Program; contains explanations and instructions for measuring Secchi transparency, pH, salinity (hydrometer), dissolved oxygen, and fecal coliforms (membrane filtration). 92 pages. Order from Great Bay Watch, Kingman

Farm/UNH, Cooperative Extension Sea Grant, Durham, NH 03824; 603-749-1565; ann.reid@unh.edu; $15 + $3 shipping.

**Other Resources**

National Estuary Program (NEP) Homepage: http://www.epa.gov/owow/estuaries/nep.html. Descriptions of NEP and individual NEP estuaries; estuary information; "Coastlines" newsletter (see above); and links to other resources including EPA's Volunteer Estuary Monitoring manual (see above).

Maine Coastal Program. 1991 (revised 1998). *The Estuary Book.* Overview of estuarine-related issues with emphasis on planning and management. Covers estuarine ecology and wildlife, consequences of development, shellfish bed closures, and more. 48 pages. Free. Order from Paul Dest, Maine State Planning Office, 184 State St., Augusta, ME 04333; paul.dest@state.me.us.

*Coastlines.* Quarterly newsletter covering issues of interest to the coastal environmental community. To subscribe, contact Coastlines, Urban Harbors Institute, 100 Morrissey Blvd., Boston, MA 02125; fax 617-287-5575; coastlines@umbsky.cc.umb.edu. Free. Also available online at http://www.epa.gov/owow/estuaries/coastlines/.

U.S. EPA. *National Estuary Program Monitoring Guidance.* 1992. EPA 842-B-92-004. Designed to help staff at National Estuary Programs develop and implement a monitoring program for their estuary. Available from NCEPI, 800-490-9198, or at http://www.epa.gov/owow/estuaries/guidance.

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# SAV Hunt

## Citizens Keep Track of Bay Grasses

*by Kathryn Reshetiloff* Armed only with small rakes, several citizens have ventured into a sea nettle-infested creek of the Chesapeake Bay searching underwater for an often elusive quarry. What would bring these people out into the waist-deep water on this steamy July afternoon? They are part of the "SAV Hunt," an annual effort coordinated by the U.S. Fish and Wildlife Service to locate, identify, and map submerged aquatic vegetation--or SAV for short. Referred to locally as bay grasses, SAV is a critical component of this estuarine ecosystem, providing habitat for wildlife and cleaning pollutants out of local waterways.

The SAV Hunt is used to "ground-truth" the results of the SAV Aerial Survey conducted annually by Virginia Institute of Marine Science (VIMS). While the VIMS survey provides invaluable information about the location and extent of SAV beds, aerial photographs have some limitations. They miss small beds; they don't tell you what species are growing; and sometimes what looks like an SAV bed in the photo turns out to be something else entirely, such as algae growing on underwater rocks or riprap. The SAV Hunters' on-the-ground observations fill in the missing information.

*Ruppia maritima*

Volunteers select the area they want to survey. They receive a


*Vallisneria americana*
wild celery

map of that location, showing where SAV has been found in aerial surveys and previous SAV Hunts. Each volunteer also receives a field guide with line drawings, color photographs, and descriptive text to help them identify the species. Since most SAV grows in water 3 to 6 feet deep, wading or using a shallow draft boat are recommended when trying to locate these grasses. (For more on techniques, see "SAV Hunter's Guide".)

widgeon grass

**Why monitor SAV?**

Bay grasses once formed immense underwater meadows, covering up to 600,000 acres in the Chesapeake Bay and its tidal tributaries. Then, with increasing development and nutrient pollution in the late 1960s and early 1970s, and Tropical Storm Agnes in 1972, the huge grass beds began to decline. Excess nutrients spawn algae blooms that cloud the water, reducing sunlight the plants need to grow. Sunlight is also blocked when sediment from erosion becomes suspended in the water column. The bay grasses simply cannot grow in this darkened environment. Chesapeake Bay SAV hit at all-time low of about 40,000 acres in 1984.

Efforts to restore the water quality in the Chesapeake Bay watershed have had a positive effect on the grasses. SAV recovered to 73,000 acres in 1993, but has fallen again slightly in recent years (69,200 acres in 1997).

Why do citizens care about SAV? These underwater grass beds serve as critical habitat for many types of aquatic life. Barnacles and scallop larvae attach to the leaves and stems of eelgrass in the salty waters of the lower Bay. Fish such as bluegill and largemouth bass live in the freshwater grasses of the upper Bay. Minnows, small anadromous fish like juvenile striped bass, and blue crabs seek protection as well as food in the grass beds.

*Potamogeton perfoliatus*
redhead grass

These plants provide food for diverse communities of waterfowl, fish, shellfish, and invertebrates. Microscopic zooplankton feed on the decaying underwater plants and, in turn, are food for larger Bay organisms, such as fish and clams. In the fall and winter, migrating waterfowl search the sediment for nutritious seeds, roots, and tubers. Redhead grass and widgeon grass are favored foods of ducks of the same names, as well as many other waterfowl.

Like a canary in a coal mine, SAV is an indicator of local water quality. In fact, healthy grass beds can actually improve water quality. The plants filter and trap sediment, which

can cloud the water and bury bottom-dwelling organisms such as oysters. SAV also absorbs nitrogen and phosphorus--nutrients which, when present in excess, promote harmful algae blooms. Like all green plants, bay grasses produce oxygen, a precious and sometimes decreasing commodity in many aquatic ecosystems.

**Use of data**

The volunteers' data are a vital supplement to the VIMS aerial survey. Not only can volunteer ground-truthers locate small beds not visible from the air, but they can find beds of early-growing species such as horned pondweed that may have died off before the aerial photo was taken. Some ground-truthing is done by resource agency personnel, but volunteers cover many areas not covered by professional staff. VIMS combines ground-truth data from all sources into their final SAV maps. Information about SAV species identification has been used to develop a computer model of SAV growth.

*Zostera marina* eelgrass

A new Maryland law bans clam dredging in SAV beds, and the information provided by citizens helps identify those areas that are now off-limits to clam dredging. Natural resource agencies use the information to help target SAV protection and restoration, and local planning agencies use it when considering approval for construction projects that may affect aquatic resources.

***Kathryn Reshetiloff*** *is a biologist for the U.S. Fish and Wildlife Service, 177 Admiral Cochrane Drive, Annapolis MD 21401; 410-573-4582; kathy_reshetiloff@fws.gov.*

Resource

Hurley, Linda M. *Field Guide to the Submerged Aquatic Vegetation of Chesapeake Bay*. 1992. U.S Fish & Wildlife Service, Chesapeake Bay Estuary Program, Annapolis, MD. Drawings, color photos, and descriptions. 52 pages. Single copies available at no charge from Kathryn Reshetiloff (see above) or Peter Bergstrom ("SAV Hunter's Guide").

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# SAV Hunter's Guide

## (for Chesapeake Bay)

*by Peter Bergstrom (The following is excerpted from instructions prepared for the Chesapeake Bay SAV Hunt. For the complete instructions, see http://www.fws.gov/r5fws/md/cbfo.htm.)*

There is no one "right" way to hunt for SAV, but following these directions will minimize the chance of recording false negatives, which means concluding an area has no SAV when in fact some was present.

**1. Maps**
Obtain the most recent quad map(s) of the site from the Virginia Institute of Marine Science aerial SAV survey (maps are available on the Web at http://www.vims.edu/bio/sav). Each Chesapeake quad is flown once per year, near the peak of growth for most of the SAV species present. The aerial survey does not pick up small beds, beds in small creeks, or species that die back before the photo is taken, so ground-truth information is an essential supplement to it.

**2. Boat**
You can use a canoe or kayak, or a johnboat or skiff with outboard motor (shallowest draft possible). Larger boats or sailboats are not recommended because they can't get into shallow water and passengers are too far from the water.

**3. Rake**

A rake is needed to collect samples for identification. Recommended are:

*Laura Hamilton with sago pondweed on a double-sided throw rake.*
Photo by Peter Bergstrom.

- For shallow water: short, cheap bamboo rake sold for getting leaves off shrubs (plastic tines don't snag as much SAV).
- For deeper water: double-sided "throw rake" on a rope (made from a "lawn thatch" rake). You can throw it out away from the boat or off a pier, or "troll" from a moving boat; it picks up fairly tall, branched plants but won't pick up short, unbranched plants.

(A regular metal garden rake with stiff tines works but is less effective, because it only picks up the denser beds and won't go deeper than the handle length.)

**4. Gear**

Shoes for wading; mask and snorkel or SCUBA if available; wet suit if needed for protection from cold water or sea nettles; polarized sun glasses to help you see under the water; GPS if available (Magellan Pioneer, $100, works well).

**5. When to hunt**

0. ***Dates.*** Look during the peak biomass of the species of interest. This is usually May 15 through June 15 for horned pondweed (spring species), and July 15 through September 15 for other lower salinity species. In Chesapeake Bay, eelgrass grows in spring and fall but dies back in the summer. In general, if you are finding lots of SAV then it's probably a good time to look.

1. ***Times.*** If at all possible, look ***within two hours of low tide on a sunny day when the water is fairly clear.*** You'll find many more beds if you can spot them visually--raking "blind" is very slow business. In areas with heavy boat traffic, look on a weekday since boats tend to cloud the water.

**6. Where to hunt**

Locate SAV beds shown on the survey map and identify species if possible. Also look for SAV outside the mapped beds in shallow areas (2 meters deep or less).

**7. How to hunt**

If the tide is low and the water fairly clear, stand up in the boat (if this is safe) and use

polarized sunglasses to look for dark patches on the bottom, or calmer patches of surface water surrounded by ripples (the calm water may overlie an SAV bed). If you see either, go over and investigate by raking or wading. If you can't see the bottom (the tide is too high and/or the water too murky), you'll have to fall back on raking or wading sites that seem likely, including those with mapped SAV.

*Bob Jenkins, a SAV Hunt volunteer since 1987, with a crab net used to find wild celery.* Photo by Peter Bergstrom.

To find all the species in a mixed bed (some have 6-7 species in a small area) wade it slowly at low tide, raking with a small bamboo rake. For some species (e.g., eelgrass in summer when it is short) you will need to snorkel or use SCUBA, since no rake picks them up reliably.

Record species found and locations on a map and/or record locations from GPS. Do not record floating specimens; they may have come from elsewhere. Place samples you can't identify in ziplock baggies; later you can consult resources such as the MD Department of Natural Resources online identification key (http://www.dnr.state.md.us/bay/sav/key/) or get expert assistance.

***Peter Bergstrom,*** *a biologist with the U.S. Fish and Wildlife Service in Annapolis, chairs the SAV Workgroup of the Chesapeake Bay Program and has assisted with the SAV Hunt since 1995. He may be reached at 410-573-4554; peter_bergstrom@mail.fws.gov.*

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# Monitoring an Alaskan Estuary (or, You Thought YOU Had Problems)

*Laruie Daniel testing Kachemak Bay water quality.*
Photo by John Mouw.

## Monitoring in the Sub-Arctic Winter

*by Laurie Daniel*

Winters in southcentral Alaska are long, dark and cold, with an emphasis on long. But the winters here on Kachemak Bay are also stunningly beautiful and very much alive. Water quality monitoring for a cadre of local citizens becomes a challenging adventure when the water turns opaque with rime, the light becomes a study in gray, and the extreme tides carry icebergs to your feet!

It's really not the limited light or the icebergs that create the biggest challenge, but the cold--cold water and cold air. Imagine sticking your thinly gloved hands into freezing water and then trying to manipulate your instruments, let alone a pencil or even just a bottle cap. We tend to wear rubber dishwashing gloves for sampling up here. Neoprene may be the way to go, but you lose a lot of dexterity. And forget the high-tech variations of "winter" gloves--we've tried them all. Next, think about nestling those little bottles of sample water for the dissolved oxygen tests right up under your arms, between the many layers you've wrapped yourself in, just to keep them from freezing up while settling. You struggle with a hydrometer that won't spin or float for all the ice that's rapidly forming in your sample and clinging to the sides of the cylinder. How do you manage to read a meniscus through the sludge line with your eyes tearing up from the chilling sea breeze?

In the fall of 1996, Cook Inlet Keeper volunteer monitors began collecting baseline data on water quality in Kachemak Bay, an arm of Cook Inlet. The program will eventually expand to monitoring the entire Inlet. For more information, contact Cook Inlet Keeper, P.O. Box 3269, Homer, AK 99603; 907-235-4068; keeper@xyz.net.


You do it with laughter and the camaraderie of your teammates struggling alongside you--lots of laughter at their antics and even more at your own, and laughter at the ridiculousness of it all as you wonder, "What are we doing out here?" Laughter keeps everyone happy and warm no matter what the weather. Through it all there is a sense of awe at the pulse of life that is Kachemak Bay in the depth of winter, at its continually changing face and moods. Marine and terrestrial birds and mammals wander closer than during the rest of the year, the shades of green and brown in the forest stand out in stark relief against the frozen land, and the ever-changing expanse of sky bends and reflects the light over the winterscape, leading your eye to see the familiar in completely new and different ways.

We live and play in the long, dark, cold winters around Kachemak Bay, so why not dedicate a bit of time each month to checking the Bay's pulse? Find out how cold the water really is, how much oxygen it can hold when it's that cold, how quickly it begins freezing up in the open air even with all that salinity. We enjoy the friendship and

endure the elements for the sake of the Bay that so clearly sustains us all.

*Cook Inlet Keeper volunteer monitor **Laurie Daniel** also works as a biologist with the newly established Kachemak Bay National Estuarine Research Reserve in Homer, AK.*

## Wild Encounters

*by Emily Johngren*

We never know who we'll run into each time we hike down to our monitoring sites. Usually, it's a fellow human, sometimes with a domestic companion like a dog or a horse. But, sometimes the encounter is of the wild variety.

I think the porcupines are more startled than we are, and the spruce grouse aren't usually too happy with us traipsing through their dinner table. Then one day there was the moose mother and calf. They just stared at us, and wouldn't move for anything. Trouble was, they were standing in the middle of the trail we needed to take back home--and moose will charge to protect their young. We waited. They watched and chewed. Finally, too cold to wait anymore, we took a detour through the swampy bog that borders our neighborhood.

*Emily Johngren at her monitoring site.*
Photo by Steve Hackett.

Still, I'd take a moose over a bear any day. If a moose comes after you, you can try to get behind a tree because she can't run around obstacles very well. But if for some reason a bear attacks, your defense is to play dead if it's a brown bear and fight back if it's a black bear. Fight back?!? We've seen many signs of bear during the summer, but we always make a lot of noise so we don't have to meet one in person. We may feel like fools when we run into other humans after we've been singing or yelling, but it's worth the embarrassment to avoid a dangerous bear encounter.

***Emily Johngren** runs her own business, a cleaning service, and has been volunteering with Cook Inlet Keeper for a year and a half.*

## Water Tower

*by Gerald Friday*

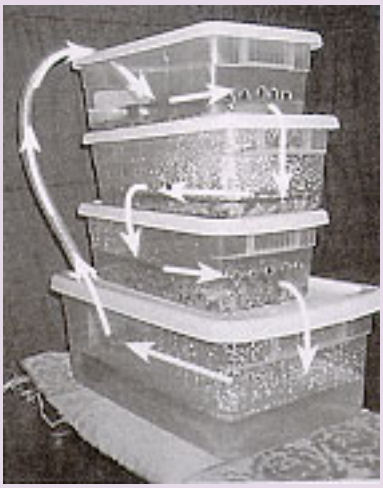
The "water tower" shown at right is an inexpensive see-through creek model, made from clear plastic storage boxes, that I use with my students at Marquette University High School in Milwaukee. It consists of three or four shoe-size boxes stacked on top of a larger sweater box.

The shoeboxes each have a row of holes drilled in one end. Water flows out the holes and into corresponding holes in the lid of the box beneath. The boxes are stacked in an alternating pattern, resulting in a zigzag flow of water. (Additional holes may be drilled high up on the box sides, to permit air to enter.) A submersible pump moves the water via a plastic tube from the bottom container to the top box. I use a 70 gal/hr Becker pump, model M60AUL (designed for use in a small water fountain display), that costs about $20.

To create riffles and runs, add river substrate--stones, gravel, and sand. If the substrate is well below the water surface, this will be a run. For a riffle, the substrate should be at the water surface. The large box is the pool. Once the model is assembled, add river water and turn on the pump. When the water is flowing through, seed the "creek" with aquatic insects.

The model can be easily disassembled so teams of students can each receive one container to observe and study. A popular activity for my students has been to observe the adaptations possessed by aquatic arthropods for feeding, respiration, and clinging to the substrate in fast currents.

Because the model is so inexpensive, you can make several, then do experiments to compare the effects of different flow rates, substrates, levels of organic matter, etc. These kinds of experiments make excellent science fair projects.



Materials:

- Plastic Storage Boxes
- Submersible pump
- Tubing
- River substrate (stones, gravel, sand)
- River water and macroinvertebrates

For more information, please contact Gerald Friday, Marquette University High School, 3401 West Wisconsin Ave., Milwaukee, WI 53208; 414-933-7220; friday@muhs.edu. Readers are also encouraged to visit the website that my students and I have created, at http://muhs.edu/activities/riverstudies/index.html.

***Gerald Friday*** *is a Biology teacher at Marquette University High School.*

## GREEN Revamps Its Monitoring Software

*by Mark Patrick*

GREEN has just completed a major redesign and enhancement of its RiverBank water quality monitoring software. The new version, RiverBank 4.0, incorporates suggestions from volunteer monitors, teachers, and other users.

With RiverBank 4.0, data such as site information, land use analysis, water quality test results, and benthic macroinvertebrate data are entered through user-friendly screens. The program automatically calculates water quality indicators such as Q-values and pollution tolerance indices. It generates reports analyzing and comparing data, and it can create pie, bar, line, and scatterplot graphs. You can also customize the program to suit your own needs.

A simplified version, RiverBank Lite, has been specifically designed to complement GREEN's Low Cost and Standard Water Monitoring Kits (see below). You can enter results for the eight tests contained in these kits and immediately obtain a snapshot of your stream's health. RiverBank Lite is especially recommended for younger students who are inexperienced with analyzing data.

RiverBank 4.0 and RiverBank Lite are expected to be available in January 1999, on a single CD which will cost about $40-50. For more information, please contact GREEN, 206 South Fifth Avenue, Suite 150, Ann Arbor, Michigan, 48104; 734-761-8142; green@green.org.

***Mark Patrick*** *is GREEN's Business Manager.*

## Micro-Mini Low-Cost Monitoring Kit

In a remarkable feat of miniaturization, GREEN (Global Rivers Environmental Education Network) has packed everything needed for measuring eight water quality parameters into a plastic canister about the size of a large coffee-to-go cup. The kit, designed as an introduction to the GREEN program, costs $25 plus shipping and includes enough materials to test 10 water samples.

The low-cost kit, which is manufactured by LaMotte Company, utilizes nontoxic tabletized reagents for testing dissolved oxygen, biochemical oxygen demand, nitrate, phosphate, pH, and total coliform bacteria. It also includes equipment for measuring temperature and turbidity.

Potential users should be aware that this is a very basic kit, appropriate for screening only. It won't provide the level of accuracy or quality assurance that can be obtained with more sophisticated (and expensive) methods. For example, the total coliform method doesn't give a bacterial count--it only tells you whether or not the sample contains over 200 total coliforms/100 ml. The dissolved oxygen test has just three possible readings: 0, 4, or 8 ppm. Moreover, the tiny instruction booklet gives only the most basic information about the tests (for detailed explanations, see GREEN's Field Guide to Water Quality Monitoring by Mitchell and Stapp).

What the kit does do is bring simple, nonhazardous water quality screening within the reach of just about everyone. According to GREEN's David Schmidt, the low-cost kit has been very popular as a starter kit for schools that want to give water monitoring a try. Many of these schools later "graduate" to one of GREEN's more comprehensive monitoring kits.

For more information, please contact Carolyn Henne at GREEN, ph. 734-761-8142; email chenne@green.org.

## New National Directory Published

The fifth edition of the National Directory of Volunteer Environmental Monitoring Programs is now available. Containing descriptions and contact information for 772 volunteer monitoring programs, the 247-page Directory will be an invaluable networking tool. Appendices list volunteer monitoring resources, national organizations, and the Environmental Protection Agency's national and regional volunteer monitoring coordinators.

The Introduction provides statistics, charts, and tables that put volunteer monitoring into perspective. Want to know what are the most commonly measured parameters, or which states have the most volunteer monitors? You'll find it here, together with information about funding, use of monitoring data, types of environments monitored, and more.

Any monitoring program that is listed in the Directory will automatically be mailed a copy (look for it in January). The Directory database will also be available on EPA's volunteer monitoring Website, at www.epa.gov/owow/monitoring/vol.html. The printed Directory is free and may be ordered from EPA's National Center for Environmental Publications and Information (NCEPI) at 800-490-9198. Include the EPA publication number, 841-B-98-009, when ordering.

## Missouri Rivers & Streams Conference

Volunteer monitors in the Midwest (EPA Region 7) are invited to attend a conference organized by Missouri Stream Team, to be held June 11-13, 1999, at the University of Missouri-Columbia. Celebrating the 10th anniversary of Missouri Stream Team, the conference is titled "A Decade of Making a Difference - Missouri Stream Teams 1989-1999." Conference planner Sharon Clifford is particularly looking forward to participation by newly formed volunteer monitoring programs in neighbor states of Iowa, Nebraska, and Arkansas. She promises a "very informal and cheap" event, with a majority of the presentations given by citizen volunteers. For more information, call 1-800-781-1989 (voice mail), or send email to nrclifs@mail.dnr.state.mo.us, or visit the Stream Team Homepage: http://www.rollanet.org/~streams/conference/.

## Volunteer Monitoring Listserver

For almost a year now, volunteer monitoring coordinators have been talking to each other online via EPA's volunteer monitoring listserver. Subscribers can bring up questions on any monitoring topic and get feedback from others in the field. For example, a recent question about measuring turbidity set off a lively and informative discussion, with contributions from over a dozen people. Another question that got lots of responses was "How much is a volunteer's time worth?"--that is, when using volunteer monitors' time as part of the match for EPA grants, how do you calculate the value of that time?

The listserver also keeps subscribers informed about upcoming workshops, new publications, funding opportunities, and other useful news.

If you'd like to subscribe, send an email message to: listserver@unixmail.rtpnc.epa.gov. Leave the subject line of your message blank, and in the message type: subscribe volmonitor lastname firstname. You'll receive an acknowledgment and a welcome file by return email.

## Watershed Assistance Grants

EPA's Office of Wetlands, Oceans, and Watersheds recently awarded River Network $300,000 to distribute grants to local watershed partnerships to support organizational development. River Network, a national organization based in Portland, Oregon, supports river and watershed advocates at the local, state, and regional levels to build effective partnerships and organizations. The Watershed Assistance Grants program will distribute grants ranging from $2,000 to $30,000 in 1999 to support watershed partnerships working to protect and restore their watersheds.

To request an application, please contact River Network, Watershed Assistance Grants Program, P.O. Box 8787, Portland, OR 97207; email info@rivernetwork.org. For

additional information on funding opportunities, visit River Network's website at http://www.rivernetwork.org/nonprofi.htm.

## EPA Offers Estuary Monitoring Workshops

*by Joe Hall*

Since 1994, the Environmental Protection Agency's Oceans and Coastal Protection Division has offered free training workshops for leaders of volunteer estuary monitoring programs. The workshops are conducted primarily in National Estuary Program (NEP) study areas. In 1999, this popular and successful program continues with workshops planned for five locations: Santa Monica, California (February); Mobile, Alabama (March); Tom's River, New Jersey (April); San Juan, Puerto Rico (early May); and Astoria, Oregon (late May).

The two-and-a-half-day workshops are based on EPA's Volunteer Estuary Monitoring: A Methods Manual and presented in partnership with the Center for Marine Conservation (CMC) based in Washington, DC. Each workshop is a balanced mix of field work, laboratory exercises, and presentations by local, regional, and national experts.

Workshop topics include quality assurance; publicity and the news media; field and laboratory methods; organizing and training volunteers; data management and presentation; and coordination with local, state and federal agencies.

A typical workshop hosts a wide variety of participants, from veteran leaders of volunteer monitoring groups to those who are just starting a program. The networking aspect of the workshops has provided an invaluable launch pad for continued cooperation among volunteer groups. For example, during a workshop in Tampa, groups decided to work toward statewide agreement on monitoring methods.

The workshops are limited to volunteer monitoring leaders. Participants are selected on a first-come, first-served basis, up to a maximum of 40. Limited support is provided for lodging and transportation as needed. For further information, including exact dates, contact either Ron Ohreal at CMC, 757-496-0920, or Joe Hall at EPA, 202-260-9082, hall.joe@epamail.epa.gov; or watch the Oceans and Coastal Protection Division website at http://www.epa.gov/owow/oceans/.

***Joe Hall*** *is an environmental scientist with EPA's Oceans and Coastal Protection Division, Office of Water.*

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## Washington State Volunteers Fight Spartina

*by Evan Matthews*

Along the shores of Puget Sound, volunteer monitors are battling an invader--the dreaded cordgrass Spartina, one of the greatest threats to the Sound's nearshore habitat. Spartina Watch volunteers try to catch new Spartina infestations while they're still small enough to be controlled by one or two people with a shovel. In 1998, Spartina Watchers carted away over 50 large garbage bags of this destructive plant.

Wait a minute, East Coast readers are probably wondering at this point, What's all the fuss about Spartina? Isn't it really valuable? Doesn't it prevent shoreline erosion by reducing wave energy and trapping sediment in its roots?

I had the same reaction myself when I first arrived in Washington. At the Chesapeake Bay Foundation in Maryland and Save the Bay in Rhode Island (my previous jobs), most of our wetland restoration projects consisted of organizing volunteer crews to plant Spartina to help stabilize shorelines. So how did Spartina go from being one of the good guys to being a bad guy?

The basic problem is that Spartina species are not native to Puget Sound--they were introduced here in the 1940's as "sterile" hybrids that would provide cover for duck hunters and some buffer to farm levees in the

Stillaguamish River delta. Over time, the plants mutated into fertile species--and once they began to spread, there was no native vegetation to stop them. Unlike East Coast estuaries, which are typically bordered by broad meadows of wetland plants, Puget Sound nearshore habitat is predominantly thousands of acres of mudflats devoid of vegetation.

*Whether* Spartina *is a friend or foe depends on where you are. While East Coasters are busy planting* Spartina *to help restore coastal wetlands, West Coasters like this Spartina Watch volunteer work just as hard to dig it up.*
Photo by Evan Matthews.

The same adaptations that make cordgrass so valuable to Atlantic Coast salt marshes create problems in Puget Sound. As Spartina spreads and traps sediment, it lifts the elevation of the mudflats above the intertidal zone, eventually turning them into high back marshes. What used to be nearshore habitat becomes shore habitat, and Puget Sound gets smaller--managers from the Washington Department of Fish & Wildlife estimate that the Sound has lost 650 acres, the equivalent of a strip of Spartina 100 feet wide and 30 miles long. These mudflats are fertile feeding grounds for salmon, shellfish, migrating waterfowl, and shorebirds. As the infestation converts mudflats into vegetated meadows, critical habitat is destroyed.

Spartina Watch volunteers play a vital role in controlling current infestations, preventing further invasion, and restoring destroyed habitats. When volunteers spot a new infestation, they report its location to Adopt a Beach, a nonprofit organization that coordinates Spartina Watch. In turn, Adopt a Beach informs the Washington State Department of Agriculture, the lead agency working to eradicate cordgrasses and restore valuable nearshore habitat. Early detection is critical, since highly infested areas can cost as much as $1,000 to $40,000 per acre for agency staff to control and/or restore.

The Spartina Watch model, which was developed in 1994 by Adopt a Beach, has proven to be an effective outreach and restoration tool. Adopt a Beach is working with over 150 volunteers, as well as other stewardship organizations such as Washington Water Trails Association, to keep watch over Puget Sound and ultimately eliminate Spartina from Washington State

coastal waters.

*Evan Matthews is Stewardship Coordinator for Adopt a Beach, 4649 Sunnyside Ave. N, #305, Seattle, WA 98103; 206-632-1390; aab@halcyon.com.*

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# NEPs, NERRs, and Volunteer Monitors

Across the country, a number of volunteer monitoring programs are linked with one (or both) of two federal estuary programs--the National Estuary Program (NEP) and the National Estuarine Research Reserve System (NERR). Although these two programs have similar names and their missions overlap in some ways, they are quite distinct. The NERR System, started in 1972 and overseen by the National Oceanic and Atmospheric Administration, is fundamentally a research program--"a network of field laboratories designed to study estuarine ecosystems and to improve their management through better information and education." The NEP, begun in 1987 and administered by EPA, is primarily a planning effort.

NERR sites--currently numbering 22, with 3 more to be added early in 1999--are chosen to represent a broad spectrum of estuary types. The Reserves are set aside as protected areas and used by researchers as long-term reference sites.

*Dawn Patrol volunteers Liz Blake (left) and Dorothy Rooney with the dissolved oxygen meter they use for monitoring Morro Bay at dawn.* Photo by Katie Kropp.

The NEP seeks to involve all stakeholders in the community in creating a formal management plan for protecting the estuary and its resources. EPA provides funding and support for a limited period (usually 3 to 5 years) to help the community develop a Comprehensive Conservation and Management Plan, or CCMP, and then provides a reduced level of support to help with implementation. The NEP

encompasses an entire estuary (whereas a NERR site can be just a segment of an estuary). To date, 28 NEP estuaries have been designated.

**NEP**
Most NEPs support volunteer monitoring, but usually the support is indirect, consisting of grants and other assistance to independent volunteer programs. However, at a few NEPs--including the Maryland Coastal Bays, Morro Bay in California, and Tillamook Bay in Oregon--NEP staff are directly involved in administering volunteer monitoring programs.

The Morro Bay volunteers have taken on an impressive variety of activities and seem to have a particular talent for thinking up catchy names for their projects. Bacteria monitors are "Bac Attackers," and those who measure flow rates in tributary creeks are "Flow Pros." The "Drain Rangers" collect runoff samples during the first rains of the season (after the 8- or 9-month dry season, autumn's first storm flushes a large amount of accumulated pollutants from roads and other surfaces) and are on call for any hour, day or night--whenever the first storm arrives. "Dawn Patrol" volunteers kayak into the back bay at dawn to measure dissolved oxygen at the time when levels are lowest, in order to see the "worst-case scenario." All these projects are managed by Morro Bay NEP staff members Regina Wilson and Katie Kropp, as part of a cooperative partnership with a local advocacy group called Friends of the Bay. (*Note:* For more on the Morro Bay Bac Attackers, see Bacteria Testing Part 2: What Methods Do Volunteer Groups Use? - Colilert.)

Cathy Wazniak, staff scientist for the Maryland Coastal Bays NEP, says, "Very early in our planning process we recognized the lack of water quality monitoring data." This data gap was particularly worrisome since eutrophication is one of the biggest problems in the coastal bays. "We had until the end of 1999 to complete our CCMP, but we didn't want to wait that long to start collecting data," says Wazniak. So the NEP moved quickly to establish a volunteer monitoring program, which now numbers 60 volunteers and has just completed its first year of sampling.

When the Tillamook Bay NEP started its volunteer monitoring program, the focus was on testing basic physical and chemical water quality parameters. The emphasis is now shifting to bacteria testing, since bacteria are a more critical problem in the estuary than eutrophication (in many areas, bacteria levels exceed criteria for both recreational use and shellfishing).

NEPs that don't run their own volunteer monitoring projects often work as partners with local volunteer monitoring groups. For example:

- The Great Bay Watch Program in New Hampshire currently receives grants from

the Great Bay NEP for two volunteer monitoring projects: (1) shoreline surveys and (2) surveys in salt marshes, looking for freshwater plants whose presence indicates freshwater intrusion.

- The San Francisco NEP assists a number of grassroots monitoring projects. "There are so many different efforts going on, we finally realized what we really need is a volunteer monitoring coordinator for the whole Bay Area," says Marcia Brockbank, Directory of the San Francisco Estuary Project. Now the Estuary Project has obtained a nonpoint source (319) grant to hire a fulltime coordinator to pull together all *The Volunteer Monitor*ing groups in the watershed.

- Scallops disappeared from Tampa Bay in the early 1960s, due to poor water quality. Now they are slowly coming back. To monitor the scallop population, the Tampa Bay NEP and a nonprofit organization called Tampa Baywatch jointly developed the Great Bay Scallop Search, a one-day event in which some 200 volunteer snorkelers count scallops along set transect lines.

*The Casco Bay NEP subcontracts with community groups to carry out action plans to help the estuary. One such project is water quality testing, conducted by Friends of Casco Bay volunteers like Frank Leavitt.* Photo by Peter Milholland.

**NERR**

The mission of the Research Reserves includes gathering data (both for basic scientific research and to help coastal decision-makers) and improving public awareness. Volunteer monitoring seems made to order to fulfill these goals, and in fact quite a few of the NERRs do run volunteer monitoring programs.

The National Estuarine Research Reserve System has also created a Web-based educational and monitoring program called Estuary-Net. Participants can download a four-part curriculum from the Estuary-Net website (http://inlet.geol.sc.edu/estnet.html), and can also post information, including their monitoring data. A number of schools nationwide participate in Estuary-Net, and many local Reserves provide advice and support, including monitoring equipment. For additional information about Estuary-Net, contact Susan Lovelace at the North Carolina NERR, 252-728-2170.

Here's a brief sampling of NERR-based volunteer monitoring projects from various parts of the country:

- At Wells NERR in Maine, volunteers participate in scientific research projects and also monitor water quality. The volunteers' fecal coliform and shoreline survey data were factors contributing to the opening of clam flats that had been closed for 9 years.

- The Weeks Bay NERR in Alabama participates in Estuary-Net, working with high school students on water quality monitoring and bioassessments. The Reserve also helps coordinate a chapter of Alabama Water Watch (Alabama's statewide volunteer monitoring program).

*High school students participating in a summertime water quality monitoring program at Wells NERR.*
Photo by Scott Orringer.

- Volunteer at Elkhorn Slough NERR (California) can choose from an assortment of interesting projects--assisting with studies of red-legged frogs, observing the behavior of Great Blue Herons and Great Egrets that nest at the Reserve, monitoring the success of an oak restoration project, and testing water quality.

- Waquoit Bay NERR in Massachusetts coordinates two volunteer monitoring programs, one for long-term, year-round water quality monitoring, and one that monitors endangered bird populations and nesting sites.

- At Padilla Bay NERR in Washington State, where waste from dairy farms is a major concern, volunteers track fecal coliform counts and dissolved oxygen levels.
- Since the early 1980s, volunteers at Florida's Rookery Bay NERR have conducted a quarterly bird census. The volunteers walk or canoe along transect lines, recording all birds they see.

For more information:
National Estuary Program website: http://www.epa.gov/owow/estuaries/nep.html

National Estuarine Research Reserve System websites:

http://inlet.geol.sc.edu/nerrsintro.html

http://www.nos.noaa.gov/ocrm/nerr/welcome.html

Association of National Estuary Programs. Preserving Our Heritage, Securing Our Future: A Report to the Citizens of the Nation. 1998. Overview of NEP, plus one-page description of each NEP estuary. 48 pages. Available from Association of National Estuary Programs, 202-554-6288; elizrose@erols.com.

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**Spring 1998 - Monitoring Wetlands**
Wetlands Controversies · Volunteer Wetland Monitoring Around the U.S. · MonitoringTurtles · Amphibian Decline · Protecting Vernal Pools · Salt Marsh Assessment · Wetland Bioassessment · Annotated Bibliography

**Fall 1997 - Community Outreach**
Moving People from Belief to Action · Outreach Ideas from Monitoring Projects · Crafting Your Message · Recruitment and Community Organizing · Media Strategies for Cheapskates
*Technical:* Tracking Sources of Fecal Coliforms; Automated Flow-Through Sampler; Shallow Water Sampler

**Spring 1997 - Methods and Techniques**
High Schoolers Track Down "Most Wanted" Macroinvertebrates · DO Kits · Nutrient Kits · Salinity by Conductivity and Hydrometer · Parallel Testing--Volunteers vs. Professionals · Statistical Analysis · Tracking Fecal Coliform Sources

**Fall 1996 - Wide World of Monitoring**
Health Surveys on U.S.-Mexico Border · Bird Banding: Assuring Quality Data · Monitoring Stream Morphology and Behavior · Beach Surveys · Coral Reefs · Sea Turtles · Air Monitoring
*Technical:* Duckweed Assay for Toxicity Testing

**Spring 1996 - Managing a Volunteer Monitoring Program**
23 Ways to Say Thank You · Getting Started · Developing Volunteer Leaders · Stages of Organizational Development · Strategic Planning · Liability Insurance and Waivers
*Technical:* Lettuce Seed Bioassay; Low-Cost Photometer

**Fall 1995 - Monitoring Urban Watersheds**
Connecting People with Urban Waters · "Urban Watch" Monitors Nonpoint Pollution in Texas · Storm Drain Stenciling · Monitoring Paired Watersheds ·Spanish-Language Monitoring Resources
*Technical:* Calculating pH Statistics; Test Kits for Organic Contaminants; Staff/Crest Gauge; Stream Sentinel ("Fish in a Bottle")

**Spring 1995 - Managing and Presenting Your Data**
Using Data in the Classroom · Common-Sense Data Screening · Designing a Computerized Data Management System · Geographic Information Systems (GIS) · Basic Statistics · Using Graphs · Packaging Data Creatively

**Fall 1994 - Monitoring a Watershed**
Habitat Monitoring · Watershed Delineation · Groundwater · Testing Wells for Nitrate · Special Challenges of Estuary Monitoring · Using Aerial Photographs · Land Use Surveys
*Technical:* Australian "Turbidity Tube"; Low-Cost Van Dorn Sampler

**Spring 1994 - Volunteer Monitoring: Past, Present, & Future**
National Survey Results · Parameters Volunteers Test · History of Volunteer Monitoring · Beyond Water Quality Testing (Beached Birds, Riparian Habitat, etc.) · Mad River Bacteria Data Used by Community · Citizens' Data Helps Set Phosphorus Standards
*Technical:* Phosphorus Monitoring

**Fall 1993 - Staying Afloat Financially**
Drawing Up a Budget · Grassroots Fundraising (Phone-a-thons, Memberships, Events) · Grantwriting for Teachers · Clean Water Act Funding for Volunteer Monitoring · Cooperative Extension Support for Citizen Monitoring · Corporate Sponsors

**Spring 1993 - School-Based Monitoring**
How to Work with Schools · Interdisciplinary Water Monitoring Programs · Carrying Out Action Plans · Computer Networking · Quality Control of Student Data · Student Congresses · Students Against Zebra Mussels
*Technical:* Toxicity Bioassay with Daphnia; Homemade Water Bath Incubator; Salinity Testing; Correcting Hydrometer Readings

**Fall 1992 - Building Credibility**
Study Design · Training & Testing Volunteers · Making Observational Credible: The Mud-Busters · Basics of Quality Control · Maintaining Credibility with Volunteers · Quality Assurance Project Plans
*Technical:* Testing for *E. coli*; Fecal Coliform Monitoring Around the World

**Spring 1992 - Monitoring for Advocacy**
Monitoring Data Lead to Stream Protection Order · Monitors Fight Proposed River Reclassification · Compliance Monitoring · Using NEPA (National Environmental Policy Act) · Influencing "Local Rulers" · Conflict Resolution and Negotiation

**Fall 1991 - Biological Monitoring**
Macroinvertebrates: Canaries of the Stream · Lab Analysis for Fecal Coliforms · Monitoring Aquatic Plants · Monitoring Diseased Eelgrass · Fish as Indicators of Water Quality
*Technical:* Homemade Secchi Disks and Viewscopes

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Recreational waters (EPA criteria):

- Fresh water:
  *E. coli* 126 cfu/100 ml (membrane filtration with mTEC)

  enterococci 33 cfu/100 ml (membrane filtration with mE)

- Marine water: enterococci 35 cfu/100 ml (membrane filtration with mE)

- Fresh or marine water: fecal coliforms 200 cfu/100 ml (membrane filtration with mFC)

Shellfishing waters (NSSP criteria):

fecal coliforms 14/100 ml (MPN)