Office of Water

Volunteer Lake Monitoring

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Foreword

The need to gather information on conditions in our Nation's lakes has never been greater. Local, state, and Federal agencies, as well as private citizens, seek monitoring information for a variety of educational, planning, and regulatory purposes. Unfortunately, public funding and staffing to carry out water sampling activities have not always kept pace with this need.

To fill this information gap, many state agencies have organized cost-effective programs that train local citizens to monitor the quality of their lakes. Volunteer programs have been found to be of enormous value to states, which can gain a baseline of useful information on lakes that might otherwise have gone unmonitored. States also benefit from new partnerships with educated and involved citizens who actively work to protect their lake resources.

Citizen volunteers benefit from monitoring programs as well. Volunteers learn about water sampling, lake biology, and the impacts of land use activities. In gathering information about the condition of their individual lakes, volunteers also often become involved in lake and watershed management activities.

The experience of successful volunteer programs shows us that the spirit of stewardship and teamwork engendered by these volunteer efforts is of great help in protecting our Nation's lakes for future generations to use and enjoy. The U.S. Environmental Protection Agency recognizes the value of these efforts and has developed this methods manual to provide a useful tool to those who are involved, or would like to become involved, in lake monitoring activities.

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Executive Summary

Overview

Increasingly, State, local, and Federal agencies are finding that citizen volunteers are valuable partners in programs to monitor and protect our Nation's water resources. Among the most developed and widespread of these volunteer programs are those that monitor existing or potential lake pollution problems.

The U.S. Environmental Protection Agency (EPA) has supported the volunteer monitoring movement since 1987 by sponsoring two national volunteer monitoring symposia, publishing a newsletter for volunteers and a directory of volunteer organizations, developing guidance manuals, and providing technical assistance. These activities have been designed to help State and other agencies understand the value of volunteer monitoring programs, both as potential sources of credible data and as catalysts for developing an educated and involved citizenry.

The EPA has developed this manual to present specific information on volunteer lake water quality monitoring methods. It is intended both for the organizers of the volunteer lake monitoring program, and for the volunteer who will be actually be sampling lake conditions. Its emphasis is on identifying appropriate parameters to monitor and setting out specific steps for each selected monitoring method. Careful quality assurance/quality control procedures are advocated throughout this manual to ensure that the data collected by volunteers are useful to States and other agencies.

This manual begins by summarizing the steps necessary to plan and manage a volunteer monitoring program, including setting general goals, identifying the uses and users of collected data, and establishing sound quality assurance procedures. Rather than addressing every parameter and method that might be monitored by the citizen volunteer, this manual concentrates special attention on three of the most common lake pollution problems: increased algal growth; increased growth of rooted aquatic plants; and lowered or fluctuating levels of dissolved oxygen. All three are common symptoms of human-induced (cultural) eutrophication. Other lake conditions that can be monitored by volunteers are also briefly discussed including sedimentation, turbidity, lake acidification, and bacteriological condition.

Increased Algal Growth

This manual discusses three parameters most commonly used by volunteer monitoring programs to measure the algal condition of a lake: Secchi disk transparency (a measure of water clarity and, indirectly, of algal density); chlorophyll *a* (a more reliable indicator of algal density); and total phosphorus (a measure of water fertility). Ideally, all three should be measured in a monitor ing program. Step-by-step instructions are provided on sampling procedures.

Increased Growth of Rooted Aquatic Plants

Three procedures are recommended for assessing the overgrowth of rooted aquatic plants: mapping the distribution of plant beds in the lake; estimating the density of plants along a transect line in a selected part of the lake; and collecting plant specimens for professional identification. Specific procedures are outlined.

Lowered or Fluctuating Levels of Dissolved Oxygen

Dissolved oxygen conditions are best characterized by measuring the dissolved oxygen and temperature profiles of the lake (measurements taken from the lake surface to the lake bottom at set intervals).

In addition to discussing specific sampling methods and equipment, this manual outlines a specific volunteer training process. Training the citizen volunteer is an essential component of a successful monitoring program. Time and resources should be budgeted up front to plan, present, and evaluate volun teer training, both at the start of the program and as periodic follow-up and "continuing education." The payoff includes: more effective, involved, and confident volunteers; better data; and more efficient use of the coordinator's (and volunteer's) time and energy.

This manual concludes with advice on how to present volunteer-collected data. After all, a volunteer program is of little value if the generated data are not translated into information useful both to the volunteers and to the managers of the program. Hints and examples are provided on presenting data results to meet the needs and level of knowledge of the data users.

This manual attempts to provide a comprehensive overview of standard lake volunteer monitoring methods. However, it cannot claim to cover every conceiv able approach. Methods and equipment other than those described here may be perfectly acceptable and meet the needs of the programs that employ them.

Reference documents and material from existing lake volunteer monitoring programs are cited at the end of each chapter to provide the reader with addi tional detailed information on methods, limnology, data quality considerations, and program planning. Anyone interested in establishing a lake volunteer monitoring program is strongly encouraged to consult these references and to evaluate the experiences, goals, and techniques of the many successful volunteer lake monitoring programs already underway.

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Chapter 1: Introduction

1.A Purpose of this Manual

The purpose of this manual is to present methods for monitoring important lake conditions using citizen volunteers. This information will be helpful to agencies, institutions, and private citizens wishing to start new volunteer monitoring efforts, as well as those who may want to improve an existing program. The citizen volunteer who uses these techniques will be able to collect reliable data that can be used with confidence for a variety of resource management purposes.

This document is designed as a companion manual to a guide produced by the U.S. Environmental Protection Agency (E PA) entitled *Volunteer Water Monitoring: A Guide for State Managers*. The EPA guide describes the role of citizen volunteer monitoring in state programs and discusses how a state monitoring program can best be organized and administered.

Copies of the EPA's *Volunteer Water Monitoring: A Guide for State Managers* may be obtained by contacting:

U.S. Environmental Protection Agency

Office of Wetlands, Oceans, and Watersheds
Assessment & Watershed Protection Div.
WH-553
401 M Street, S.W.
Washington, D.C. 20460

Volunteer Lake Monitoring: A Methods Manual extends the concepts and procedures developed by the EPA guide and puts them in a "how to do it" context specifically for volunteer lake monitoring programs.

1.B Manual Organization

Volunteer Lake Monitoring: A Methods Manual is organized into eight chapters.

Chapter 1: Introduction
This chapter provides an overview for the manual and discusses planning a lake monitoring program. Topics include setting general goals, identifying uses and users of the data, and developing quality assurance and quality control procedures.

Chapter 2: Focusing on a Lake Condition
This chapter introduces the three lake conditions most suitable for volunteer monitoring: algae; (rooted) aquatic plants; and dissolved oxygen. Other conditions that could be considered for monitoring are also discussed.

Chapter 3: Monitoring Algae

Chapter 4: Monitoring Aquatic Plants

Chapter 5: Monitoring Dissolved Oxygen

Chapter 6: Monitoring Other Lake Conditions

These four chapters identify monitoring parameters that can be used to characterize each of the lake conditions introduced in Chapter 2. Sampling design issues discussed include where and how often volunteers should sample. Procedures for sampling are also defined in a step-by-step manner.

Chapter 7: Training Citizen Volunteers

This chapter defines a training process that can be used to educate volunteers on sampling procedures. Included are sections on how to write a job description for volunteers and how to plan, present, and evaluate volunteer training.

Chapter 8: Presenting Volunteer Monitoring Results

This chapter recommends ways to present the lake monitoring data results using graphs and summary statistics.

CHAPTER 1

1.C Planning a Monitoring Program

The steps necessary to plan and manage a successful volunteer monitoring program are well covered in EPA's *Volunteer Water Monitoring: A Guide for State Managers*. Topics in this guide include how to establish goals, identify data uses and users, assign staff responsibilities, establish a pilot program, prepare a quality assurance plan, and fund a program.

The purpose of this companion manual is not to repeat material presented in the *Guide for State Managers* but rather to provide specific information concerning the administration of a lake monitoring program. To do this adequately, however, a few of the guide's key concepts need to be highlighted in the context of planning a lake monitoring program.

Setting General Goals

Volunteers or agencies that begin a volunteer lake monitoring program face an almost bewildering array of planning decisions. Therefore, EPA has set out certain guidelines to help in planning and implementing volunteer programs.

As a first step, organizers of volunteer programs should establish their general goals. Are they interested in providing credible information on water quality conditions to State and local agencies? Or are they primarily interested in educating the public about water quality issues? Do they wish to build a constituency of involved citizens?

All three goals can be achieved by a well-organized and maintained program, but it is important to determine which of these goals is paramount. This methods manual is directed primarily to those volunteer programs that seek to improve the understanding of lake conditions and protection needs by supplementing State- collected water quality data with credible volunteer-collected data.

Identifying Data Uses

Early in the planning stage, organizers should identify how data collected by the lake volunteer program will be used and who will use it. Data can be used to establish baseline conditions, determine trends in water quality, or identify current and emerging problems.

Prospective users of volunteer-collected data include State water quality analysts, planners, fisheries biologists, agricultural agencies, and parks and recreation staffs; local government planning and zoning agencies; university researchers; and Federal agencies such as the U.S. Geological Survey, U.S. Fish and Wildlife Service, U.S. E PA, and U.S. Department of Agriculture. A planning committee made up of represen tatives from the identified data users should be convened early in the development of a program.

Initially, the planning committee must make several important decisions in the development of a volunteer monitoring program. Basically, the committee must decide:

- What the major goal of the program will be;
- What existing or potential lake condition will be the focus of monitoring;
- What sampling parameters should be used to characterize the selected lake condition;
- What procedures volunteers should use to sample each parameter;
- How volunteers will be trained; and
- How the results of monitoring will be presented.

Once the monitoring program is established, the planning committee should meet periodically to evaluate it, update objectives, and fine-tune activities. This review should ensure that the volunteer monitoring efforts continue to provide useful information to those who need lake data.

Establishing Quality Assurance and Quality Control

Many potential users of volunteer data believe that only professionals can conduct sampling and generate high quality results. This is not true. Given proper training and supervision, dedicated volunteers can conduct monitoring activities and collect samples that yield high quality data. To ensure that this occurs, any volunteer lake monitoring program that seeks to have its data used must adopt effective quality assurance/quality control (QA/QC) responsibilities.

The planning of QA/QC procedures begins with the development of data quality objectives. The objectives are defined by data users and establish the uncertainty that can be tolerated for their specific purposes. There are five major areas of uncertainty that should be evaluated when formulating data quality objectives.

- ***Accuracy*** is the degree of agreement between the sampling result and the true value of the param eter being measured. Accuracy is most affected by the equipment and the procedure used to measure a sample parameter.
- ***Precision***, on the other hand, refers to how well you are able to reproduce the data result on the same sample (regardless of accuracy). Human error in sampling techniques plays an important role in estimating precision.
- ***Representativeness*** is the degree to which the collected data accurately and precisely represent the lake condition being measured. It is most affected by sample site location. For example, if the monitoring objective
- ***Completeness*** is a measure of the amount of valid data obtained versus the amount expected to be obtained as specified by the original sampling design objec tives. It is usually expressed as a percentage. For example, if 100 samples were scheduled, but volunteers only sampled 90 times because of bad weather, broken equipment, and so forth, the completeness record would be 90 percent.
- ***Comparability*** is very important to the manager of a citizen monitoring program because it represents how well data from one lake can be compared to data from another. As part of a statewide or regional report on the volunteer monitoring program, most managers compare one lake to another. It is vital, therefore, that sampling methods and procedures are the same from lake to lake.

When forming data quality objectives, the planning committee must also examine the program budget. Sophisticated analysis of some param eters (yielding high precision and accuracy) usually comes at higher costs in terms of equipment, procedures, laboratory fees, agency time, and citizen training. These higher costs may be worthwhile if the program is oriented toward supplementing agency data collection.

For programs oriented more toward public education and participation, the use of less sensitive equipment and procedures may be in order. In this case, budget money could be better spent for public awareness materials and supporting an increase in citizen monitors. An efficient sampling design is one that balances cost components with acceptable levels of uncertainty in context with program goals and objectives.

It is important to be aware that EPA requires that all its national program offices, regional offices, and laboratories participate in a centrally planned, directed, and coordinated Agencywide QA/QC program. As stated in the EPA document, *Volunteer Water Monitoring: A Guide for State Managers* , "This effort also applies to efforts carried out by the States and interstate agencies that are supported by EPA through grants, contracts or other formalized agreements."

The EPA QA program is based upon EPA Order 5360.1, *"Policy and Program Requirements to Implement the Quality Assurance Program,"* which describes the policy, objectives, and responsibilities of all EPA program and regional offices.

EPA Order 5360.1 also requires State monitoring programs supported by EPA grants to prepare Quality Assurance Project Plans. There are 16 major elements contained in a Quality Assurance Project Plan.

1. **Title Page**: includes the name of the project officer, the immediate supervisor, the funding organization and others with major responsibility for the project.
2. **Table of Contents:** lists the included elements and appendices in the report.
3. **Project Description**: states the purpose of the project.
4. **Project Organization and Responsibility** : identify the structure or organization responsible for the implementation of the program.
5. **QA Objectives**: list the QA objectives for each major measurement parameter for precision, accuracy, representativeness, completeness, and comparability.
6. **Sampling Procedures**: describe how parameters are monitored.
7. **Sample Custody**: identifies chain of custody for field sampling and laboratory operations.
8. **Calibration Procedures and Frequency** : describe methods for maintaining accuracy and preci sion of sampling equipment.
9. **Analytical Procedures**: document how parameters are analyzed.
10. **Data Reduction, Validation, and Reporting** : address the activities involved in an overall data management plan.
11. **Internal Quality Control Checks** : discuss quality control procedures.
12. **Performance and System Audits** : evaluate all components of the measurement system including equipment, personnel, and procedures.
13. **Preventive Maintenance**: ensures there are no gaps in the data gathering activities.
14. **Specific Routine Procedures Used to Assess Data Precision, Accuracy, and Completeness**: identify the methods to calculate precision and accuracy and how calibration and comparability studies are undertaken.
15. **Corrective Action**: identifies limits for data acceptability and corrective procedures if data are found unacceptable.
16. **Quality Assurance Reports**: describe the format and schedule for the submission of reports that assess data accuracy, precision and completeness, the results of QC sessions and audits, and any significant QA problems with recommended solutions.

Data documentation is another crucial aspect of QA/QC procedures. Careful and thorough documentation of any data base used to store and manage volunteer data ensures that it can be used with confidence. Appropriate documentation is especially important if data are to be entered into a State (or other formal) data base.

Volunteer Water Monitoring: A Guide for State Managers provides additional specific direction on developing data quality objectives, quality assurance project plans, and data documentation files. Chapter 8 of this manual further discusses how to analyze and present volunteer data.

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Chapter 2: Focusing on a Lake Condition

2.A Introduction

It is beyond the scope of any monitoring program to sample for every condition that can be found in a lake. Therefore, an initial task is to decide where to focus sampling efforts. This chapter discusses lake conditions that make good candidates for citizen monitoring.

Of all the water quality issues facing lakes nationwide, it is those conditions associated with a phenomenon known as *eutrophication* that cause the greatest concern among lake users. Eutrophication is a term used to describe the *aging* of a lake. This aging process results from the accumulation of nutrients, sediments, silt, and organic matter in the lake from the surrounding watershed.

Eutrophication can be accelerated when human activity occurs in the watershed. If proper controls are not in place, pollutants from agricultural, urban, and residential developments can easily be carried into lakes and their tributaries.

Symptoms of human-induced *(or cultural)* eutrophication are:

- increased algal growth (stimulated by increased supply of nutrients);
- increased rooted aquatic plant growth (stimulated by the increased supply of nutrients as well as the creation of additional shallow growing areas via the accumulation of sediments, silt and organic matter); and
- lower dissolved oxygen concentrations in all or parts of the lake (as a result of increased plant respiration and the decomposition of organic matter by bacteria and other microorganisms. This lack of oxygen can kill fish and other aquatic life).

The emphasis of this manual is on how citizen volunteers can monitor one or more of the lake conditions listed above. These conditions are usually considered symptomatic of cultural eutrophication.

Although related, each condition nevertheless has a unique set of parameters that characterize its attributes. It is important to remember that sampling for one condition will not necessarily yield information about another. If, for example, a lake has an aquatic plant problem, a monitoring program that focuses on algae will not provide the necessary answers to solve that problem.

The reader should be aware that there are several other lake conditions that could be a potential focus for a citizen monitoring program. Four notable candidates are:

- sedimentation on the lake bottom (reduction of water depth);
- sediment turbidity (reduction of water clarity as a result of suspended sediment);
- lake acidification; and
- bacterial pollution of bathing beaches.

Each of these conditions has the potential to severely affect the water quality and recreational use of a lake. In many lakes, they are monitored by agency staff or contracted professionals. These lake conditions can, how ever, be monitored by volunteers.

For this reason, they also will be briefly discussed in this manual.

The following sections provide background on each of the lake conditions that could be considered candidates for a citizen monitoring program.

2.B Algae

Algae are photosynthetic plants that contain chlorophyll and have a simple reproductive structure but do not have tissues that differentiate into true roots, stems, or leaves. They do, however, grow in many forms. Some species are microscopic single cells; others grow as mass aggregates of cells (colonies) or in strands (filaments). Some even resemble plants growing on the lake bottom.

The algae are an important living component of lakes. They:

- convert inorganic material to organic matter through photosyn thesis;
- oxygenate the water, also through photosynthesis;
- serve as the essential base of the food chain; and
- affect the amount of light that penetrates into the water column. Like most plants, algae require light, a supply of inorganic nutrients, and specific temperature ranges to grow and reproduce. Of these factors, it is usually the supply of nutrients that will dictate the amount of algal growth in a lake. In most lakes, increasing the supply of nutrients (especially phosphorus) in the water will usually result in a larger algal population.

Factors that Affect Algal Growth

There are a number of environmental factors that influence algal growth. The major factors include:

- the amount of light that penetrates the water (determined by the intensity of sunlight, the amount of suspended material, and water color);
- the availability of nutrients for algal uptake (determined both by source and removal mechanisms);
- water temperature (regulated by climate, altitude, et cetera);
- the physical removal of algae by sinking or flushing through an outflow;

- grazing on the algal population by microscopic animals, fish, and other organisms;
- parasitism by bacteria, fungi, and other microorganisms; and
- competition pressure from other aquatic plants for nutrients and sunlight.

It is a combination of these and other environmental factors that determines the type and quantity of algae found in a lake. It is important to note, however, that these factors are always in a state of flux. This is because a multitude of events, including the change of seasons, develop ment in the watershed, and rainstorms constantly create "new environments" in a lake.

These environmental changes may or may not present optimal habitats for growth or even survival for any particular species of algae. Consequently, there is usually a succession of different species in a lake over the course of a year and from year to year.

The Overgrowth of Algae

Excessive growth of one or more species of algae is termed a *bloom*. Algal blooms, usually occurring in response to an increased supply of nutrients, are often a disturbing symptom of cultural eutrophication.

Blooms of algae can give the water an unpleasant taste or odor, reduce clarity, and color the lake a vivid green, brown, yellow, or even red, depending on the species. Filamentous and colonial algae are especially troublesome because they can mass together to form scums or mats on the lake surface. These mats can drift and clog water intakes, foul beaches, and ruin many recreational opportunities.

Citizen programs designed to monitor the algal condition of a lake usually require the volunteers to measure:

- the water clarity;
- the density of the algal population; and
- the concentration of the critical algal nutrient, phosphorus.

2.C Aquatic Plants

Aquatic plants have true roots, stems, and leaves. They, too, are a vital part of the biological community of a lake. Unfortunately, like algae, they can overpopulate and interfere with lake uses.

Aquatic plants can be grouped into four categories:

- *Emergent* plants are rooted and have stems or leaves that rise well above the water surface. They grow in shallow water or on the immediate shoreline where water lies just below the land surface. They are generally not found in lake water over two feet deep.
- *Rooted floating-leaved* plants have leaves that rest on, or slightly above, the water surface. These plants, whose leaves are commonly called lily pads or "bonnets," have long stalks that connect them to the lake bottom.
- *Submergent* plants grow with all or most of their leaves and stems below the water surface. They may be rooted in the lake bottom or free-floating in the water. Most have long, thin, flexible stems that are supported by the water. Most submergents flower above the surface.
- *Free-floating* plants are found on the lake surface. Their root systems hang freely from the rest of the plant and are not connected to the lake bottom.

Through photosynthesis, aquatic plants convert inorganic material to organic matter and oxygenate the water. They provide food and cover for aquatic insects, crustaceans, snails, and fish. Aquatic plants are also a food source for many animals. In addition, waterfowl, muskrats, and other species use aquatic plants for homes and nests.

Aquatic plants are effective in breaking the force of waves and thus reduce shoreline erosion. Emergents serve to trap sediments, silt, and organic matter flowing off the watershed. Nutrients are also captured and utilized by aquatic plants, thus preventing them from reaching algae in the open portion of a lake.

Factors that Affect Aquatic Plant Growth

There are many factors that affect aquatic plant growth including:

- the amount of light that penetrates into the water;
- the availability of nutrients in the water (for free-floating plants) and in the bottom sediments (for rooted plants);
- water and air temperature;
- the depth, composition, and extent of the bottom sediment;
- wave action and/or currents; and
- competition pressure from other aquatic plants for nutrients, sunlight, and growing space.

The Overgrowth of Aquatic Plants

Excessive growth of aquatic plants is unsightly and can severely limit recreation. Submergents and rooted floating-leaf plants hinder swimmers, tangle fishing lines, and wrap around boat propellers. Fragments of these plants can break off and wash up on beaches and clog water intakes.

For many species, fragmentation is also a form of reproduction. An overgrowth problem can quickly spread throughout a lake if boat propellers, harvesting operations, or other mechanical actions fragment the plants, allowing them to drift and settle in new areas of the lake.

Free-floating plants can collect in great numbers in bays and coves due to prevailing winds. Emergent plants can also be troublesome if they ruin lake views and make access to open water difficult. In addition, they create areas of quiet water where mosquitoes can reproduce.

Citizen monitoring programs designed to characterize the aquatic plant condition usually:

- map the distribution of plant beds in the lake;
- estimate the density of plants along a transect line in a selected area; and
- collect specimens for professional identification.

2.D Dissolved Oxygen

The amount of oxygen in the water is an important indicator of overall lake health. In fact, much information can be learned about a lake by examining just this parameter.

Oxygen plays a crucial role in determining the type of organisms that live in a lake. Some species, such as trout, need consistently high oxygen concentrations to survive. Other aquatic species are more tolerant of low or fluctuating concentrations of oxygen.

Oxygen is supplied naturally to a lake by:

- the diffusion of atmospheric oxygen into the water; and
- the production of oxygen through photosynthesis by aquatic plants and algae.

Oxygen is easily dissolved in water. In fact, it is so soluble that water can contain a greater percentage of oxygen than the atmosphere. Because of this phenomenon, oxygen naturally moves (diffuses) from the air into the water. Agitation of the water surface by winds and waves enhances this diffusion process.

Vertical mixing of the water, aided by winds, distributes the oxygen within the lake. In this manner, it becomes available to the lake's community of oxygen-breathing organisms.

Water temperature affects the capacity of water to retain dissolved oxygen. Cold water can hold more oxygen than warm water. Therefore, a lake will typically have a higher concentration of dissolved oxygen during the winter than the summer.

Factors that Determine Dissolved Oxygen Concentration

There are a number of factors that determine the amount of oxygen found in a lake including:

- climate;
- water temperature and thermal stratification of the water column;
- wind and waves that create movement on the surface and aid diffusion from the atmosphere;
- the amount of algae and aquatic plants (oxygen is added to the water as a by-product of photosynthesis);
- the amount of respiring life forms including algae, aquatic plants, fish, bacteria, fungi, and protozoans (respiration removes oxygen from the water and produces carbon dioxide);
- the rate at which organic matter reaches the lake bottom and is decomposed by respiring microorganisms (influenced by growth and death rates of life forms in the lake and the input of organic material from incoming streams and surface runoff);
- the oxygen content of incoming ground water and surface streams; and
- the shape and depth of the lake basin.

Fluctuating Oxygen Concentrations

Oxygen is essential for aquatic life. Without oxygen, a lake would be an aquatic desert devoid of fish, plants, and insects. For this reason, many experts consider dissolved oxygen to be the most important parameter used to characterize lake water quality.

Algae and aquatic plants produce oxygen as a by-product of photosyn thesis but also take in oxygen for respiration. Respiration occurs all the time, but photosynthesis occurs only in the presence of light. Consequently, a lake that has a large population of algae or plants can experience a great fluctuation in dissolved oxygen concentration during a 24-hour period.

During a sunny day, photosynthesis occurs and can supersaturate the water with oxygen. At night, plants no longer produce oxygen; however, they continue to consume oxygen for respiration. In some lakes after dark, dissolved oxygen can be depleted by the plants at a rate faster than it can be diffused into the lake from the atmosphere. In extreme cases, the oxygen in the water can become depleted. This lack of oxygen will cause fish and other aquatic organisms to suffocate.

Extreme fluctuations of dissolved oxygen concentrations place great stress on the oxygen-breathing creatures in the lake. Only tolerant species can survive in this type of environment. Unfortunately, tolerant species are usually the least desirable for recreational purposes. Carp are an example of a tolerant fish. Trout, on the other hand, are highly intolerant of fluctuating oxygen levels.

In addition to the impact on living organisms, the lack of oxygen in a lake also has profound effects on water chemistry and eutrophication. To explain this situation, one must understand the temperature cycle, how it affects water density, and the phenomena of *lake overturn* and *thermal stratification* .

The Temperature Cycle

Most U.S. lakes with a depth of 20 feet or more stratify into two tempera ture-defined layers during the summer season. The water in the upper layer (*epilimnion*) is warm, well lit, and circulates easily in response to wind action. The deep layer (*hypolimnion*) is dark, cold, more dense, and stagnant.

These two layers are separated by a transition zone (*metalimnion)* where temperatures change rapidly with depth. The metalimnion functions as a barrier between the epilimnion and the hypolimnion.

The magnitude of the temperature difference between the two layers defines how resistant they are to mixing. A large temperature difference means that the layers are stable and that it would take a great deal of wind energy to break down the stratification and mix the layers.

In the fall, lowered air temperatures eventually cool the waters in the upper layer to a point where they become the same temperature (and density) as the lower layer. At this time, the resistance to mixing is removed and the entire lake freely circulates in response to wind action. This action is known as *fall overturn*.

Layers again form during the winter. However, it is the upper zone that is slightly colder than the deeper layer. In the spring, increasing air temperatures warm the upper layer to a point that it becomes the same temperature as the bottom zone. Wind action then mixes the entire lake and *spring overturn* occurs.

Oxygen Depletion in the Lower Layer

Bacteria, fungi, and other organisms living on the lake bottom break down organic matter that originates from the watershed and the lake itself. Algae, aquatic plants, and animals all provide food for these *decomposers* when they excrete, shed, and die. Like higher forms of life, most decomposers need oxygen to live and perform their important function.

The mixing action of spring and fall overturn distributes oxygen through out the water column. During summer stratification, however, the lower layer is cut off from the atmosphere. There is also usually too little light to support photosynthesis by algae or aquatic plants. Therefore, with no supply source, what oxygen there is in the lower layer can be progressively depleted by an active population of decomposers.

When the dissolved oxygen concentration is severely reduced, the bottom organisms that depend on oxygen either become dormant, move, or die. Fish and other swimming organisms cannot live in the lower layer. As a result, trout and other game fish that require deep, cold water and high oxygen levels may be eliminated from the lake altogether.

Other Problems Caused by Lower Layer Oxygen Depletion

Oxygen depletion in the lower layer occurs "from the lake bottom up." This is because most decomposers live in or on the lake sediments. Through respiration, they will steadily consume oxygen. When oxygen is reduced to less than one part per million on the lake bottom, several chemical reactions occur within the sediments. Notably, the essential plant nutrient, phosphorus, is released from its association with sediment-bound iron and moves freely into the overlying waters.

If wind energy breaks down a lake's stratification, this phosphorus may be transported into the upper layer where it can be used by algae and aquatic plants. This internal pulse of phosphorus (often termed *internal loading*) can thus accelerate algal and aquatic plant problems associated with cultural eutrophication.

Iron and manganese are also released from the sediments during anoxic (no oxygen) periods. These elements can cause taste and odor problems for those who draw water from the lower layer for drinking or domestic purposes.

Fortunately, many of the negative effects of anoxic conditions are eliminated during overturn. As the waters of the lake are mixed and re-oxygenated, many of the constituents released from the sediments chemically change and precipitate back on to the lake bottom. Others are reduced in concentration by their dilution into the waters of the entire lake.

Overturns do also bring nutrients back up to the surface where they become available to the algae. Therefore, it is not unusual to see algal blooms associated with overturns.

Citizen monitoring programs designed to characterize the dissolved oxygen condition in lakes have volunteers:

- measure dissolved oxygen from the surface to bottom; and
- measure water temperature from the surface to bottom.

These temperature and dissolved oxygen profiles help define the thermal layers and identify any oxygen deficit within the water column.

2.E Other Lake Conditions

Sediment Deposition

The gradual filling-in of a lake is a natural consequence of eutrophication. Streams, stormwater runoff, and other forms of moving water carry sand, silt, clays, organic matter, and other chemicals into the lake from the surrounding watershed. These materials settle out once they reach quieter waters. The rate of settling is dependent on the size of the particles, water velocity, density, and temperature.

The sediment input to a lake can be greatly accelerated by human develop ment in the watershed. In general, the amount of material deposited in the lake is directly related to the use of watershed land. Activities that clear the land and expose soil to winds and rain (e.g., agriculture, logging, and site development) greatly increase the potential for erosion. These activities can significantly contribute to the sediment pollution of a lake unless erosion and runoff is carefully managed.

Sediment material from the watershed tends to fertilize aquatic plants and algae because phosphorus, nitrogen, and other essential nutrients are attached to incoming particles. If a large portion of the material is organic, dissolved oxygen can decrease as a result of respiration of decomposers breaking down the organic matter.

Sedimentation also can ruin the lake bottom for aquatic insects, crustaceans, mussels, and other bottom-dwelling creatures. Most important, fish spawning beds are almost always negatively affected.

The input of sediments to a lake makes the basin more shallow, with a corresponding loss of water volume. Thus, sedimentation affects navigation and recreational use and also creates more fertile growing space for plants because of increased nutrients and exposure to sunlight.

Citizen volunteer programs that focus on sedimentation generally measure sediment buildup over time at a few select sites (e.g., near the mouth of a stream).

Sediment Turbidity

Not all sediment particles quickly settle to the lake bottom. The lighter, siltier particles often stay suspended in the water column or settle so lightly on the bottom that they can be easily stirred up and resuspended with even slight water motion. This causes the water to be turbid and brownish in appearance. Sediment blocks light from penetrating into the water column. It also interferes with the gills of fish and the breathing mechanism of other creatures.

Volunteer programs that focus on sediment turbidity will usually monitor water clarity and the amount of suspended solids in the water.

Lake Acidification

Acidity is a measure of the concentration of hydrogen ions on a pH scale of 0 to 14. The lower the pH, the higher the concentration of hydrogen ions. Substances with a pH of 7 are neutral. A reading less than 7 means the substance is acidic. If the pH is greater than 7, it is basic (alkaline). Because the pH scale is logarithmic, each whole number increase or decrease on the 0 to 14 scale represents a 10-fold change in acidity.

Acidic lakes occur in areas where the watershed soils have little natural buffering capacity. Acidic deposition (commonly called acid rain) and other artificial or natural processes can further contribute to lake acidity. Most aquatic plants and animals are sensitive to changes in pH. Thus, acidic lakes tend to be clear because they contain little or no algae. Fish are also thought to be negatively affected by lowered pH. In fact, many acidic lakes have no fish populations.

Acid rain occurs in areas where the combustion of fossil fuels increases the concentration of sulfuric and nitric acids in the atmosphere. These acids can be transported thousands of miles and eventually deposited back to earth in rain or snow.

Acidity may also enter lakes from drainage that passes through naturally acidic organic soils. These soils may become more acid through land use practices such as logging and mining.

Acidic drainage from abandoned mines affects thousands of miles of streams and numerous lakes throughout Appalachia. Acid mine drainage also occurs in the Midwest coalfields of Illinois, Indiana, and Ohio, and in coal and metal mining areas of the western United States.

Volunteer programs that focus on acidification generally sample for pH and alkalinity. These are two measurements that provide an indication of the acid/base status and the buffering capacity of the water, respectively.

Bacteriological Conditions at Beaches

The sanitary quality of bathing beaches is a special concern to swimmers. There are a wide variety of disease-causing bacteria, viruses, parasites, and other microorganisms that can enter the water and be trans mitted to humans. Some are indigenous to natural waters. Others are carried from wastewater sources including septic systems and runoff from animal and wildfowl areas. Infected swimmers themselves are also a source of pathogens.

The ideal way to determine potential health hazards at natural bathing beaches is to test directly for disease-causing organisms. Unfortunately, the detection of these organisms requires very complex procedures and equipment. In addition, there are hundreds of different kinds of pathogens; to test for each one would be impractical. Most public health officials, therefore, simply test for the presence of an *indicator organism*. The relative abundance of the indicator organism in a sample can serve as a warning of the likely presence of other, more dangerous pathogens in the water.

Citizen volunteer programs that focus on bacterial quality at bathing beaches as the lake condition to be monitored generally sample for one or more indicator organisms throughout the swimming season.

The indicator organisms most often chosen for monitoring are fecal coliform bacteria or enterococci bacteria. The latter group of bacteria is more disease-specific and may be most appropriate for routine sample analy sis. Usually, health departments recommend weekly sampling for bathing areas.

Swimmer's Itch

In some regions, *schistosome cercarial dermatitis* or swimmer's itch is a problem condition. Swimmer's itch is caused by a parasitic flatworm that lives in the bloodstream of a host aquatic bird species. The eggs of the flatworm are passed into the lake in the excrement of the bird.

Once in the water, the eggs will hatch and the larvae searches for and penetrates into a certain species of snail. The larvae grows in the snail and eventually emerges as a second larval stage known as a cercaria.

The cercaria normally penetrates the skin of the host species of
bird and the life cycle begins again. The cercaria can also, by
mistake, penetrate the skin of swimmers. Since humans are not the
host needed for growth, the larvae soon dies. Although harmless,
the cercaria can leave the swimmer with an itchy welt for a few days.

Because of the prevelance of swimmer's itch in some regions, another
potential candidate for citizen monitoring can be the presence of
cercaria in bathing beach waters.

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Office of Water

Volunteer Lake Monitoring: A Methods Manual

Chapter 3: Monitoring Algae

3.A Algal Condition Parameters

Monitoring the algal condition in lakes is the focus of the majority of citizen volunteer monitoring programs operating today. There are three prominent reasons for this decision.

- Most citizen volunteers desire lakes that have clear water with a slight blue tinge. Deviation from this accepted standard raises public interest about water quality. In many lakes, it is the algae population that decreases clarity and colors the water.
- Parameters commonly used to measure the algal condition of a lake can be sampled easily by volunteers using basic equip ment.
- Parameters that measure the algal condition form the basis for many commonly used trophic state indices. These indices provide a quantitative means of describing the level of lake aging (eutrophi cation). Using a trophic state index, program officials can rank lakes according to the results of the monitoring program.

Three parameters are most often used by citizen monitoring programs to measure algal conditions in lakes.

- **Secchi disk transparency**
  This parameter is a measurement of water clarity. In many lakes, a reduction of clarity occurs as the algal population grows. In these cases, a Secchi disk reading can be used an idirect measure of algal density.
- **Chlorophyll *a***
  This parameter is a more reliable indicator of algal quantity because chlorophyll *a* is a chemical extracted directly from the algal cells present in a water sample.
- **Total phosphorus**
  This parameter is an essential plant nutrient that stimulates the growth of algae in many lakes (the more phosphorus in the lake, the more algae). By measuring phosphorus concentration, monitors can get an indication of water fertility.

Each of the three parameters, if measured by itself, will not provide a complete picture of the algal condition of a lake. Measured together, how ever, they can provide valuable information about the relationship between water fertility and algal growth. Volunteers are especially interested in how algal growth affects water clarity, the lake trait most noticed by the majority of lake residents and users.

Secchi Disk Transparency

First developed by Professor P.A. Secchi in 1865 for a Vatican-financed Mediterranean oceanographic expedition, the Secchi disk has since become a standard piece of equipment for lake scientists. It is simply a weighted circular disk 20 centimeters (about eight inches) in diameter with four alternating black and white sections painted on the surface.

The disk is attached to a measured line that is marked off either in meters (subdivided by tenths of meter), if using metric units, or feet (subdivided by tenths of feet or inches), if using English units.

The Secchi disk is used to measure how deep a person can see into the water. It is lowered into the lake by the measured line until the observer loses sight of it. The disk is then raised until it reappears. The depth of the water where the disk vanishes and reappears is the Secchi disk reading.

In extremely clear lakes, disk readings greater than 10 meters can be measured. On the other hand, lakes affected by large amounts of algal growth, suspended sediments, or other conditions often have readings of less than one-half meter.

In some shallow lakes, it is impossible to get a Secchi disk reading because the disk hits the bottom before vanishing from sight. This means the true Secchi disk reading is greater than the depth of the lake in that particular location.

Citizen volunteers in the United States are most comfortable with

English units of measurement. Scientists, however, usually report lake measurements in metric units.

In general, citizen monitoring programs should use metric units
when reporting results, especially if a program goal is to provide
information to government agencies. Even if the data will be used
for educational purposes, incorporating metric units into the sampling protocol will introduce the volunteers and the public to
the scientific way of monitoring lakes.

Unfortunately, Secchi disk data are among the most abused and misinterpreted measurements in monitoring programs because people often directly equate Secchi disk readings with algal density. There are, how ever, many other factors found both inside and outside the lake that affect how deep a person can see into the water.

Inside the lake, water transparency can be reduced by:

- microscopic organisms other than algae;
- natural or unnatural dissolved materials that color or stain the water; and
- suspended sediments.

Factors outside the lake can also affect a Secchi disk reading. These outside factors can include:

- the observer's eyesight and other sources of human error;
- the angle of the sun (time of day, latitude, season of the year);
- weather conditions (cloud cover, rain); and

- water surface conditions (waves, sun glare, surface scum).

In sum, the Secchi disk should always be considered simply as an instrument to measure water transparency. Algae can play an important role in reducing transparency; however, this assumption must be proven by measuring a parameter directly associated with the algal population. For many citizen monitoring programs, this parameter is chlorophyll *a*.

Chlorophyll a

Chlorophyll *a* is the green photosynthetic pigment found in the cells of all algae. By taking a measured sample of lake water and extracting the chlorophyll *a* from the algae cells contained in that sample, monitors can get a good indication of the density of the algal population.

The chlorophyll *a* concentration cannot be considered a precise mea surement of algal density, however, because the amount of chlorophyll *a* found in living cells varies among algal species. Thus, two lakes can have identical densities of algae yet have significantly different concentra tions of chlorophyll *a* because they are dominated by different species.

Direct comparability, even within a single lake, is further complicated by the fact that the amount of chlorophyll *a* in an algal cell varies with light conditions. Healthy algal cells constantly try to maintain chlorophyll concentrations at a level for maximum photosynthetic efficiency. Chlorophyll in a cell usually decreases during high light conditions and increases during the night or low light conditions.

Similarly, a cell that is sinking down into the water column (away from the sun) may also produce more chlorophyll to compensate for the lower light levels found at greater depths. Changing seasons also create higher or lower light conditions according to the position of the sun which, in turn, affects chlorophyll production.

Despite these drawbacks, the ease of sampling and relatively low cost of analysis makes chlorophyll *a* an attractive parameter for characterizing the algal density in lakes, especially for volunteer monitoring programs.

Chlorophyll *a* is analyzed in a laboratory from a sample collected by a volunteer. The simplest protocol is to ship the water sample to the labora tory for analysis.

Alternatively, some citizen monitoring programs have volunteers pass a measured volume of lake water through a filtering apparatus containing a prepared filter paper disk. The filter paper lets the water pass through but retains the algae cells on its surface. The volunteer then removes the disk and places it in a special tube to be forwarded to the laboratory for chlorophyll *a* analysis.

In some instances, this procedure may produce lower than actual results for chlorophyll *a* concentrations if the filtering procedure is not followed exactly. QA/QC considerations will determine if this method is a feasible alternative for a volunteer program.

Total Phosphorus

Phosphorus is one of several essential nutrients that algae need to grow and reproduce. In many lakes, phosphorus is in short supply. Therefore, it often serves as a limiting factor for algal growth.

Phosphorus migrates to lake water from only a few natural sources. As a result, lakes located in pristine wilderness settings rarely have problems with algal blooms. Humans, on the other hand, use and dispose of phosphorus on a daily basis. Phosphorus is found in such common items as fertilizers, foods, and laundry detergents.

Lakes with developed watersheds often receive a portion of this human-generated phosphorus through runoff, septic leachate, and other sources. This phosphorus fertilizes the water and can stimulate increased algal growth.

Algae most readily consume a form of phosphorus known as orthophosphate, the simplest form of phosphorus found in natural waters. In fact, orthophosphate is so quickly taken up by a growing algal population that it often is found only in low concentrations in lakes.

Phosphorus is found in lakes in several forms other than orthophosphate. For example, when phosphorus is absorbed by algae, it becomes organically bound to a living cell. When the cell dies, the phosphorus is still bound to particles even as it settles to the lake bottom. Once the decomposer organisms break down the cell, the phosphorus can become attached to calcium, iron, aluminum, and other ions.

Under anoxic conditions, chemical reactions can release phosphorus from the sediments to the overlying waters. Spring or fall overturn may then redistribute it back to the surface where it can be taken up by another algal cell.

Phosphorus, therefore, is in a constant state of flux as environmental conditions change and plants and animals live, die, and decompose in the lake. Because the forms of phosphorus are constantly changing and recycling, it is generally most appropriate for citizen monitoring programs to measure all forms of phosphorus together. This one "umbrella" measurement is known as *total phosphorus*.

This manual describes a method that instructs the volunteer to collect a water sample, transfer it into a sample bottle that contains an acid preservative, and then ship it to a laboratory for total phosphorus analysis.

Alternatively, there are test kits on the market for total phosphorus analysis. To conduct the test, however, volunteers must be well-trained and possess special laboratory equipment. For these reasons, phosphorus test kits are not generally appropriate for volunteer monitoring programs.

In some instances, orthophosphate may be a parameter of interest since it is the form of phosphorus available for uptake by algae. Like total phosphorus, orthophosphate is best measured in a laboratory.

3.B Where to Sample

Analyzed together, the three parameters Secchi disc, chlorophyll *a*, and total phosphorus can provide information on the quantity of free-floating algae, the critical nutrient that feeds the population, and how the algae affect water transparency. Where the parameters are sampled on the water surface and in the water column is an important consideration when planning a program to monitor algal conditions.

A lake and its water quality are not uniform from shore to shore or from surface to bottom. Lake morphometry, exposure to winds, incoming streams, watershed development, and human activity can greatly influence the algal conditions found at any one location in the lake.

Thus, the planning committee or supervising staff is challenged to select sample locations that will best characterize the algal condition in accordance with the goals and objectives of the monitoring program. Increasing the number of sampling sites will reduce uncertainty, but it will come at increased cost.

Where to Sample on the Water Surface

The majority of citizen monitoring programs are designed to measure average algal conditions in the lake's *pelagic* (deep, open water) *zone.* For these programs, the number and location of sampling sites are most influenced by the size and shape of the lake basin.

In most cases, a site over the deepest section of the lake best represents average conditions. In natural lakes that are circular in shape, the deepest section is usually near the middle. In reservoirs, the deepest section is usually near the dam.

Many lakes, however, possess significant arms or bays. In this instance, it is often useful to sample the deepest section in each individual arm or bay. In many cases, monitors will find a significant difference between sites, especially if one arm of the lake is more populated.

Some monitoring programs, on the other hand, are designed to characterize the algal condition at its worst location. For these types of programs, certain known problem areas may be targeted for sampling. For example, a particular bay may be monitored because it "collects" algae and other materials because of prevailing winds.

More often, however, "worst area" sampling is designed to monitor how point or nonpoint sources of nutrient pollution affect water quality and algal growth. Examples of potential sources of nutrient pollution include farms, residential developments, and sewage outfalls. This monitoring can provide evidence that specific watershed management efforts are needed to manage the algal population.

The number and location of sampling sites can also be influenced by the basic goal of the program. A program managed primarily for public education, for example, may wish to include stations for various non -scientific reasons such as their proximity to residential neighborhoods or convenience of access. Such a program may even include additional stations in a lake so more volunteers can participate in monitoring.

Sample site selection should be consistent within a program in order to get results worthy of lake-to-lake comparison. For example, if the deepest part of the lake is chosen as the location for sampling, all the lakes in the program should then be sampled at the deepest site.

To select the location of a sampling site, the manager must possess some preliminary information about the lake including:

- a bathymetric (depth contour) map (or general knowledge of the location of maximum depth so that soundings can be taken in the field and a suitable sampling location identified);
- a watershed map with the lake's major inflows and outflows;
- a historical summary of water quality including the location of previous sampling sites and documentation of any lake problems (algal blooms, weed growth, fish kills);
- updates of any current activities in the watershed that may affect sampling results (point sources such as sewage plant or storm drain outfalls and nonpoint sources such as agricultural, urban, logging, and construction areas); and
- updates of any current lake activities that may affect sampling results, including dredging, water level drawdowns, and chemical applications.

All this information will influence the selection of the sampling site. It is also important for interpreting the results of data collection efforts.

In the field, the program manager and the volunteer should work together to identify and locate the proper sampling site location. Once identified, the site should be clearly marked on a lake map. The task of locating the site can be practiced by the volunteer under the supervision of the program manager.

For shoreline or near-shore stations, finding the site will probably not be a problem. Many programs, however, will require volunteers to sample over the deepest portion of the lake. This usually means the monitoring site will be somewhere in the middle of the waterbody. For volunteers to return consistently to the same sampling site location, they must use a method.

Two simple ways to find the site are by:

- locating the site by using landmarks visible on the shore; or
- setting a permanent marker buoy at the sampling location.

Shoreline Landmark Method

On land, volunteers know where they are located by finding familiar landmarks. The same process can be used on water, except that the landmarks are located on the shoreline. On an initial training trip, the volunteer and the program manager must designate an "official" site location.

Once securely anchored at the site, the volunteer should pick out two permanent landmarks on shore (a dwelling, tall tree, large rocks) that align one behind the other. This alignment forms an imaginary bearing line through the objects to the site.

Then, at about a 90 degree angle, two more aligning landmarks should be identified. These landmarks then form a second bearing line to the sampling site. Volunteers should mark these landmarks and bearing lines on their lake map for future reference. They should also practice finding the site location with the program manager.

To further verify that volunteers have found the proper sampling site, the program manager may also require that they perform a depth check using the anchor rope, a weighted calibrated sounding line, or an electric "fish-finder" apparatus that indicates bottom depth.

Marker Buoy Method

If the lake is small and protected from strong winds and waves, a marker buoy may be the simplest way to designate a sample site location. In many public lakes, however, it is illegal to set out buoys without proper permits. The rules and regulations regarding buoys should be checked before any placement.

There is a risk that a marker buoy will be moved by winds, waves, and /or lake users. Thus, volunteers should also be trained to verify that the buoy is in the proper location using the shoreline landmark method before starting the sampling procedure. This training will be useful if the buoy is lost or needs to be repositioned.

3.C Where to Sample in the Water Column

Free-floating algae grow and reproduce in the photic zone. This zone constitutes the upper portion of the water column where sunlight penetrates and stimulates photosynthesis in the algal cells. In programs designed to measure the algal condition of a lake, water samples are taken from the photic zone and analyzed in a laboratory for their chlorophyll *a* and total phosphorus content.

Where these samples are taken in the photic zone is another important decision that must be made by the planning committee. There are two basic choices for water sampling in the photic zone. Volunteers can collect:

- a point sample taken at a specific depth; or
- an integrated sample from a range of depths.

Point Sampling

Point sampling refers to the collection of a water sample from a specific depth in the water column. Also known as *grab sampling*, it is the method most often used in monitoring programs.

When measuring the algal condition parameters, a sample is usually taken at a selected depth between one-half and two meters. (Water samples are generally not collected directly at the surface because floating substances such as pollen and gasoline residue will contaminate them.)

If a depth of one-half meter is selected, volunteers can collect the sample by simply submerging the sample bottle to about elbow depth. For deeper point sampling, some type of water sampler instrument must be used.

A Kemmerer or Van Dorn water sampler is commonly used to collect water at a specific depth. These devices are cylindrical tubes with stoppers at each end. After the sampler has been lowered to the desired depth (marked on the lowering line), the volunteer slides a weight (called a *messenger*) down the line.

When the messenger reaches the sampler, it hits a trigger mechanism and the two stoppers snap shut, trapping the sample of water from that depth. The sampler is then hauled back into the boat and the sample water poured into a container.

The goals of the monitoring program and how the water quality data will be used will help the planning committee determine where a point sample should be collected. A depth of one meter is selected many times as a representative depth of photic zone conditions for chlorophyll *a* and total phosphorus analyses.

If a water sampler is used, other depths in the water column also can be easily sampled by the volunteer. Total phosphorus is an especially interesting parameter to monitor at different points in the water column, in addition to the upper layer photic zone.

As discussed in Chapter 2, phosphorus is released from bottom sediments under anaerobic conditions. If the lake is strongly stratified in the summer, and wind energy does not mix the water column, the bottom-released phosphorus cannot reach the photic zone and stimulate increased algal growth. In some lakes, however, summer stratification occasionally breaks down and the bottom phosphorus does reach the surface waters, causing sudden algal blooms.

This internal loading of phosphorus is often important when analyzing the algal condition of productive lakes. For this reason, the planning commit tee should consider having volunteers collect point samples from the bottom and middle of the water column for total phosphorus analysis, as well as in the photic zone.

Integrated Sampling

An integrated sample combines water from a range of depths in the water column. It is essentially a mixture of point samples designed to represent more of the photic zone than a single sample. The simplest way for volunteers to collect an integrated sample is to use a hose and bucket.

Basically, a measured length of hose is weighted on one end and then lowered into the lake. While the hose descends, it collects a vertical column of water. By plugging the surface end and then bringing the lowered end to the surface with a line, an intact column of water can then be emptied into a bucket and a sample drawn for laboratory analysis.

A basic drawback is that this method can not be easily standardized. Each volunteer will develop his/her own variation of this sample collection technique. Losing a portion of the sample while bringing up the hose may also be a problem for some volunteers. For these reasons, many monitoring programs rely on point sampling for measuring the algal conditions of lakes.

3.D Frequency of Sampling

There is usually a change in the quantity and species of algae occur ring in a lake throughout the year. Often algal density increases in the spring and early summer as water temperatures increase and nutrients become available in the well-lit upper layer as a result of spring overturn.

When summer arrives and the lake stratifies, the algae population may change as the supply of orthophosphate in the upper layer becomes depleted and/or microscopic animals (zooplankton) graze on the population. After the summer, fall overturn can once again bring fresh nutrients to the well-lit upper zone and stimulate increased algal growth.

A variety of other factors can also affect algal habitat and growth response, especially during the summer growing season. Storms can churn the lake and cause a temporary upwelling of nutrients from the lake bottom. Phosphorus-rich runoff can escape from residential or agricultural areas after rainstorms, drain into the lake, and stimulate growth. On the other hand, chemicals or herbicides that are toxic to algae may be released to the water and cause a (planned or unplanned) population crash.

The planning committee should base its decision on how often to sample on data quality criteria, costs, and other practical considerations.

Many citizen monitoring programs have found it appropriate to sample algal conditions on a two-week or bi-monthly cycle. In most cases, this time period has proven adequate to monitor changes in the algal parameters and, at the same time, fit into volunteers' participation schedules.

However, if conditions are known to change at more frequent intervals (if lake water flushes quickly through an inlet and outlet), the committee may determine that weekly sampling is more appropriate.

More frequent sampling also improves the odds of measuring a short-term event such as an algal bloom or a sudden pulse of phospho rus input because of storm runoff or a sewage plant bypass. Expense becomes a key factor when determining sampling frequency because each sampling round will increase program costs.

3.E Length of the Sampling Season

An ideal monitoring program runs year-round to collect the full amount of seasonal data on the lake. This regime would test the dedication of citizen volunteers to an extreme, however. A more practical sampling period for citizen monitoring is from spring overturn to the end of the summer growing season.

Spring overturn is important because it is when wind action circulates the entire volume of water. Importantly, citizens can sample the spring algal blooms that are sometimes observed as a result of increased nutrient availability and warming water temperatures.

The summer growing season corresponds with the main recreational season. It is during this time that increased algal growth is most objectionable because it can interfere with swimming, water-skiing, fishing, and other activities.

Fall overturn is another time when the water circulates and algal blooms typically occur. This season is not as important to the general public, however, because it comes at the end of the recreational season. Thus, fall algal blooms are not usually perceived as a problem. Volunteer interest also wanes as the weather turns cooler and more unpredictable. For these rea sons, it is often prudent to stop monitoring at the end of summer.

Section 3.F How to Sample

Presented in this section are suggested procedures for sampling Secchi disk depth, chlorophyll *a,* and total phosphorus concentration for a citizen monitoring program. Basically, these sampling activities are divided into four main segments.

- Confirming the sampling date and weather conditions and going through boating safety and sampling equipment checklists prior to launching the sampling boat (Tasks 1 through 3).
- Finding the sampling site and documenting observations about the water and weather conditions (Tasks 4 and 5).
- Taking a Secchi disk measurement and collecting water samples for chlorophyll *a* and total phosphorus analysis (Tasks 6 and 7).
- Returning to shore and preparing the chlorophyll *a* and total phosphorus samples for shipment to a laboratory (Tasks 8 and 9).

The program manager should provide volunteers with a sampling schedule and a sampling protocol sheet. In general, monitors should be instructed to conduct sampling between 10 a.m. and 3 p.m. Volunteers must understand, however, that there is flexibility in both the day and time, especially in consideration of weather conditions.

Volunteers' common sense and good judgment dictate when it is appropriate to sample. Both good and unacceptable weather conditions should be defined for volunteers during training sessions. Under no circumstances should volunteers be on the water during rain or electrical storms, high winds (white caps), or other unsafe conditions.

TASK 1

Confirm sampling day and weather conditions. *Elements of Task 1*

- Check the sampling date on the program sampling schedule.
- Check the current and forecasted weather and decide if the conditions allow for safe sampling. The volunteer should also be instructed to confirm this decision after personally inspecting lake conditions prior to launching the boat and beginning the sampling trip.

TASK 2

Go through the boating safety equipment checklist.

Before leaving shore, volunteers must confirm that all needed safety equipment is on board. Boating safety is a subject that volunteers need to take seriously because they will be moving around the boat, leaning over the edge, and working with equipment.

Volunteers should wear a life preserver (Type 1, 2 or 3 personal flotation device) at all times. Volunteers should educate themselves about safe boating laws and the rules of the road.

Elements of Task 2

- Confirm that the following boating safety equipment is on board the sampling boat.
- Personal flotation device for each person. Devices must be Coast Guard-approved, readily available, and the proper size
- First aid kit
- Other equipment that may be required by State and local boating laws. For example, boats may be required to carry fire extinguishers and sound-producing devices. Also, the boat must be registered according to State and local laws.

TASK 3

Go through sampling equipment and supply checklist.

Before leaving shore, volunteers must make sure that they have all the needed sampling equipment and supplies on board the boat. They must also confirm that other items are left on shore.

Elements of Task 3

- Confirm that the following sampling equipment and supplies are on board the sampling boat.
- Anchor (with a measured line if a depth check is required). Two anchors are helpful on windy days, one off the bow and the other off the stern.
- Secchi disk with a measured line and a clothespin
- Water sampler instrument (for integrated or point sampling)
- Water sample collection container
- Ice cooler (with a closable lid) with frozen ice packs
- Clipboard and pencils
- Map of lake with sampling site and landmarks marked
- Sampling protocol sheet
- Sampling form

Confirm that the following supplies are on shore.

- Phosphorus sample shipping bottle (with a small amount of acid to preserve the sample)

- New pair of vinyl gloves
- Chlorophyll *a* sample shipping bottle
- Shipping box with frozen ice packs

TASK 4

Position boat at the designated sample site.

Volunteers must locate the sample site on the water. Whether or not a marking buoy is used, the position should be verified using the shoreline landmark method.

Once the site is located, volunteers can anchor the boat. Repositioning the anchor once it is dropped should be discouraged, especially in shallow lakes, because it can stir up sediments from the lake bottom. Increasing sediment turbidity may alter data results. After anchoring, volunteers should allow the boat to stabilize. Then a depth check can be done.

TASK 5

Complete the observations portion of the sampling form.

Volunteers should record their observations about the lake and weather conditions on the sampling form. In addition, they should write down any unusual conditions that may affect the sampling results. A suggested format for a data form is presented on page 45.

Reporting visual conditions such as water color and appearance will aid in interpreting data results. For example, if the sampling trip was conducted after a storm, the water may temporarily be more be more brownish and turbed than usual.

This turbidity probably will lower the Secchi disk reading and elevate the total phosphorus concentration. Without the information concerning the rainstorm, an analyst might conclude that other factors could have caused a decrease in water quality.

Elements of Task 5

- Record the name of the lake and site, the date, the time of sampling, and the names of volunteers doing the sampling.
- Record water condition observations at the site including water color, suspended sediment and algae, aquatic plants, waterfowl activity, and odor.
- Record weather conditions on the form including the amount of cloud cover (when taking the Secchi disk reading), the approxi mate air temperature, the wind speed and direction, and water surface conditions. Indicate any unusual weather conditions that may have occurred in the past week including storms, high winds, and temperature extremes.
- Record any other factors or conditions that make the sam pling trip unusual or that may potentially influence sample results. For example, report any chemical, mechanical, or biologi cal control of algae or aquatic weeds that may have been done recently on the lake.

TASK 6

Measure the Secchi disk depth.

The Secchi disk is used to measure the depth that a person can see into the water (transparency). A Secchi disk reading is a personal measure ment; it involves only two pieces of equipment, the disc and the person's eyesight.

Because it so individualistic, the Secchi disc measurement may have low comparability between lakes and even between volunteers on the same lake. The key for consistent results is to train volunteers to follow standard sampling procedures for every measurement. It is preferable to have the same individual take the reading at a site throughout the entire sampling season.

The line attached to the Secchi disk must be marked according to the units and increments designated by the planning committee. Many programs use meters as the measurement unit and require volunteers to measure to the nearest one-tenth meter.

The line markings must be made using waterproof ink. Meter intervals on the line can be tagged with a piece of duct tape with the interval measurement indicated on the tag.

Elements of Task 6

- Check to make sure that the Secchi disk is securely attached to the measured line.
- Lean over the side of the boat and lower the Secchi disk into the water, keeping your back toward the sun to block glare.
- Continue to lower the disk until it just disappears from view. Lower the disk another one third of a meter and then slowly raise the disc until it just reappears. Continue to move the disk up and down until the exact vanishing/reappearing point is found.
- Attach a clothespin to the line at the point where the line enters the water. This is the point the measurement will be read.
- Slowly pull the disk out of the water and record the measure ment based on the location of the clothespin on the line.

This procedure can be repeated as a quality control check; an average of the two readings should be recorded on the sampling form.

TASK 7

Collect a point sample for chlorophyll *a* and total phosphorus.

Described below are two point sampling procedures. *Procedure A* describes how to hand-collect a sample approximately one-half meter below the surface. *Procedure B* describes how to collect a sample at a select depth using a sampler such as a Kemmerer Bottle.

Procedure A. Elements of hand sampling just below the surface

- Remove the cap from the sampling container, taking care not to touch the container mouth.
- Rinse the container with lake water by holding it by the bottom and plunging it mouth-first into the lake to about elbow depth. Your hand should always move in a forward motion so that water will not slide over it into the bottle. Fill the container, turn the mouth upwards, bring it above the surface, and empty the container.
- Rinse the cap at the same depth, holding the outside of the cap when plunging.
- Using the same motion, collect the sample of water in the con tainer. Tip out some of the water to leave some air space and cap the container.
- Store the container in the cooler.

Procedure B. Elements of point sampling using a water sampler

- Check to make sure that the water sampler is securely attached to the measured line (marked in meters like the Secchi disk line).
- Lower the sampler gently into the water to the desired depth marked on the line (rough treatment can trigger the closing mechanism prematurely).
- Slide the messenger down the line to close the stoppers.

- Gently haul the sampler to the surface, then release some of sample water into the container. Swirl it in the container to rinse and then pour it out. Rinse the cap in the same manner.
- Release sample water into the container until it is almost full, leaving some air space at the top. Cap the container.
- Store the container in the ice cooler away from the light.

TASK 8

Transferring sample water into shipping bottles.

Volunteers must bring the boat back to shore and unload the sampling equipment and supplies. Next, they must move indoors or find an outdoor location that is dry and shielded from the wind.

Volunteers then transfer the water from the sample container into the two bottles that will be shipped to the laboratory for analysis of chlorophyll *a* and total phosphorus concentrations.

During the training session, volunteers should be made aware how easy it is to contaminate the phosphorus sample unless precautions are taken. Volunteers should be instructed to leave the cap on the phosphorus shipping bottle until they are ready to pour the sample water into it.

Volunteers should wear clean vinyl gloves and should not smoke. They must always be aware that the phosphorus sample bottle contains an acid that preserves the sample during transport to the laboratory. This acid must be treated cautiously because it can burn skin or clothing if spilled or mishandled. Volunteers should also not breathe the vapors from the opened bottle.

Because of the potential for spills or mishaps, the planning committee should prepare an information sheet about the preservative acid. The sheet should include warnings and emergency care instructions should the acid accidentally come in contact with volunteers' skin or clothes. Volunteers should be told to keep the sheet nearby when working with this bottle.

Elements of Task 8

A. Phosphorus Sample Bottle

- Make sure the phosphorus sample bottle is labeled with:
- the parameter to be analyzed (total phosphorus).
- the date and the sample lake, location, and depth.
- any additional information such as an accession number for laboratory identification and the acid content.
- Put on a new pair of vinyl gloves.
- Confirm that there is acid present in the bottom of the bottle by visual inspection.
- Move the total phosphorus sample bottle into position and remove the cap, being careful not to spill the acid contents or breathe in the vapors.
- Gently shake the container with the sample water to re-suspend any settled material.
- Gently pour the sample water into the phosphorus bottle until the liquid reaches the fill line.

- Cap the sample bottle and place it into the shipment container with the frozen ice packs and close the lid so sunlight cannot reach it.

B. Chlorophyll *a* Sample Bottle

- Move the chlorophyll *a* sample bottle into position and remove cap.
- Gently shake the container with the sample water to re-suspend any settled material.
- Gently pour the sample water into the chlorophyll *a* bottle until the liquid reaches the fill line.
- Cap the chlorophyll *a* sample bottle and place it into the shipment container with the frizen ice packs and close the lid so sunlight cannot reach it.

TASK 9

Cleanup and shipment of samples and forms.

Volunteers must clean the sampling and laboratory equipment for the next sampling trip. The Secchi disk and water sampler should be rinsed off with fresh tap water and the sampling container rinsed with distilled water.

Volunteers must pack and forward the shipping container with the samples to the laboratory as soon as possible. In addition, the sampling form with the Secchi disk measurement and sampling observations must be sent to the coordinating agency.

3.G Notes on Equipment

A partial listing of companies that provide equipment and supplies for volunteer monitoring programs are listed in the appendix. Alternatively, some programs have volunteers construct some of their own equipment.

Secchi Disks

Some programs have volunteers make their own Secchi disks. A construction plan prepared by the Michigan Department of Natural Resource's Self-Help Water Quality Monitoring Program is illustrated here.

Water Samplers

Instead of purchasing commercial water samplers, some programs have volunteers construct their own.

References

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Diet for a Small Lake: A New Yorker's Guide to Lake Management. Albany.

Olem, H. and G. Flock, eds. August, 1990. *The Lake and Reservoir Restoration Guidance Manual.* 2nd ed. EPA 440/4-90-006. Prep. N. Am. Lake Manage. Soc. for U.S. Environ. Prot. Agency, Off. Water, Washington, DC.

Standard Methods for the Examination of Water and Wastewater. 16th ed. 1985. Am. Pub. Health Ass., Am. Water Works Ass., and Water Pollu. Control Fed. 1985. American Public Health Association. Washington, DC.

U.S. Environmental Protection Agency. August 1990. *Volunteer Water Monitoring: A Guide for State Managers* . EPA 440/4-90-010. Off. Water, Washington, DC.

Additional program material on volunteer monitoring of algae can be obtained from the following State programs:

Florida
Florida LAKEWATCH
79922 NW 71st Street
Gainsville, FL 32606

Illinois
Volunteer Lake Monitoring Program
Division of Water Pollution Control
Illinois Environmental Protection Agency
2200 Churchill Road
P.O. Box 19276
Springfield, IL 62794-9276

Maine
Volunteer Lake Monitoring Program
Division of Environmental Evaluation and Lake Studies
Maine Department of Environmental Protection
State House, Station 17
Augusta, ME 04333

Michigan
Self-Help Water Quality Monitoring Program
Department of Natural Resources
Land and Water Management Division
P.O. Box 30028
Lansing, MI 48909

Minnesota
Citizen Lake Monitoring Program
Division of Water Quality-Program Development Section
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155

New Hampshire
New Hampshire Lakes Lay Monitoring Program
University of New Hampshire
Petee Hall
Cooperative Extension
Durham, NH 03824

New Hampshire Volunteer Lake Assessment Program

Department of Environmental Services
6 Hazen Drive
Concord, NH 03301

New York
New York Citizens Statewide Lake Assessment Program
New YorkState Department of Environmental Conservation
Division of Water-Lake Services Section
50 Wolf Road, Room 301
Albany, NY 12233-3502

Rhode Island
Watershed Watch Program
Department of Natural Resource Science
210B Woodward Hall
University of Rhode Island
Kingston, RI 02881-0804

Tennessee
TVA Citizen Water Quality Monitoring Program
Tennessee Valley Authority
Water Quality Department
2S-270C Haney Building
311 Broad Street
Chattanooga, TN 37402-2801

Vermont
Vermont Lay Monitoring Program
Department of Environmental Conservation
Water Quality Division
103 S. Main Street
Waterbury, VT 05676

Washington
Washington's Citizen Lake Monitoring Project
Department of Ecology
7171 Clean Water Lane, Building 8 MS LH-14
Olympia, WA 98504

Wisconsin
Self-Help Lake Monitoring Program
Wisconsin Department of Natural Resources
Bureau of Water Resources Management
P.O. Box 7921
Madison, WI 53707-7921

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Chapter 4: Monitoring Aquatic Plants

4.A Aquatic Plant Condition Parameters

In many lakes across the country, an abundance of rooted aquatic plants impairs the use and enjoyment of recreational waters. A program that focuses on rooted aquatic plants as the lake condition to be monitored should train citizen volunteers to:

- map the distribution of rooted plants;
- determine the relative density of rooted plant types along a transect line running perpendicular from shore in select areas; and
- collect specimens for professional identification.

Mapping the Distribution of Rooted Plants

In healthy lakes, several different species of rooted aquatic plants usually occupy the littoral (shallow) zone. Submergent, rooted floating- leaved, free-floating, and emergent plants are all important for the overall ecology of a lake. Traveling around the shoreline with a lake map, volunteers can draw in the location of significant aquatic plant beds and note where growth has reached the surface. This effort will serve as an historical record for studying changes in vegetative location. In addition, these maps can be useful for planning the application of aquatic plant control methods, such as harvesting.

Determining the Relative Density of Rooted Plant Types

It is often useful to take a closer look at the types of rooted aquatic plants in the littoral zone. A healthy lake usually has many different kinds aquatic plants. Many lakes, however, have littoral zones that have been disturbed, fertilized, and/or invaded by more aggressive plant species. In these instances, the least tolerant species are often eliminated and one or two more-tolerant species begin to take over the zone. In fact, in the majority of lakes where aquatic plant overgrowths occur, it is the result of a population explosion of only one or two species.

Several exotic plant species (originally from other continents) are notorious for displacing native plants and dominating the littoral zone. They can become major nuisance problems primarily because no natural check and balance system controls their growth. A lack of predators and pathogenic organisms allows exotics to out-compete native species for growing space, light, and nutrients.

The relative density of different plants growing in the littoral zone can be examined by volunteers. The method described in this chapter has volunteers collect plants at specific intervals along a transect line. Addi tionally, the volunteers are directed to measure the length and depth of the littoral zone along the line.

Identification of Rooted Aquatic Plants

Eurasian watermilfoil (*Myriophyllum spicatum*) and water hyacinth (*Eichhornia crassipes*) are examples of exotic (non-native) species that can flourish and cause problems in waters of the

United States. One purpose of a citizen program focused on monitoring rooted aquatic plant conditions on lakes should be to inventory locations where there are significant amounts of plants.

The identification of plant species is important because the effectiveness of lake management techniques differ according to plant type. In many instances, the early detection (and elimination) of aggressive exotic species can save a lake from severe infestation problems later.

The Vermont Department of Environmental Conservation, for example, has established a Milfoil Watchers Program to train volunteers to identify Eurasian watermilfoil. Then, at least once or twice a summer, citizens survey lakes where the plant has not been seen. If watermilfoil is spotted, volunteers contact the department.

4.B Sampling Considerations

The location of sample collection and transect sites in a lake are defined on a lake-by-lake basis from an initial site visit by the program manager. Some lakes have extensive weed growth throughout the lake, others have small, well-defined problem areas.

In general, it is best to assign a team of two volunteers no more than four hours of sampling work. What can be accomplished in this period depends on the size of the lake, the length of the littoral zone, and the extent of the rooted plants.

In some lakes, the aquatic plant population is relatively stable through out the growing season. In other lakes, there is a definite pattern of succession. If the lake is small, volunteers may need to examine plant growth only once or twice a year (in spring and late summer). The program manager may wish to break a large lake with a significant weed problem into segments and send volunteers out every two weeks to sample different areas.

The density, diversity, and growth patterns of aquatic plants are unique to each lake. Therefore, many of the details concerning sample site loca tions and other program aspects must be worked out by the program man ager on a lake-by-lake basis.

4.C How to Sample

Presented in this section are procedures for mapping the distribu tion of rooted aquatic plants, collecting, and determining the relative density of plant types along a transect.

Basically, these sampling activities are divided into four main segments.

- Confirming the sampling date and weather conditions and going through boating safety and sampling equipment checklists prior to launching the sampling boat (Tasks 1 through 3).
- Touring the shoreline and mapping the location of aquatic plants at or near the surface (Task 4).
- Finding the sampling site, setting up a transect line, collecting plants along that line, and estimating plant densities (Task 5).
- Returning to shore and shipping the data forms and plant samples (Task 6).

The program manager should provide volunteers with a sampling schedule and a sampling protocol sheet. Volunteers' common sense and good judgment dictate when it is appropriate to sample. Both good and unacceptable weather conditions should be defined for volunteers during training sessions. Under no circumstances should volunteers be on the water during rain or electrical storms or high winds (white caps), or other unsafe conditions.

TASK 1

Confirm sampling day and weather conditions.

Elements of Task 1

- Check the sampling date on the program sampling schedule.
- Check the current and forecasted weather and decide if the conditions allow for safe sampling. The volunteer should also be instructed to confirm this decision after personally inspecting lake conditions prior to launching the boat and beginning the sampling trip.

TASK 2

Go through the boating safety equipment checklist.

Before leaving shore, volunteers must confirm that all the safety equipment is on board. Boating safety is a subject that volunteers need to take seriously because they will be moving around the boat, leaning over the edge, and working with equipment.

Volunteers should wear a life preserver (Type 1, 2 or 3 personal flotation) at all times. Volunteers should educate themselves about safe boating laws and the rules of the road.

Elements of Task 2

- Confirm that the following boating safety equipment are on board the sampling boat:
- A personal flotation device for each person that is Coast Guard-approved, readily available, and the proper size
- First aid kit
- Other equipment that may be required by State and local boating laws other unsafe conditions.

TASK 3

Go through equipment and supply checklist for sampling tasks.

Before leaving shore, volunteers must make sure that they have all the needed sampling equipment.

Elements of Task 3

- Confirm that the following sampling equipment is on board.
- Anchor
- Calibrated transect line (floating line marked off in meters) with anchor and buoy.
- Weighted calibrated sounding line for measuring water depth
- Weighted rake with throwing line
- Plastic bags for plant specimens labeled with the lake name, the date, and the site location (Transect #1, Site #1).
- Clipboard, pencils and waterproof marker
- Map of lake with sampling site(s) marked
- Protocol sheet

- Data recording sheets
- Confirm that the shipping box with frozen ice packs is on shore.

TASK 4

Map the location of aquatic plants at or near the surface.

For this task, volunteers must take a tour of the shoreline and observe areas of the lake where aquatic vegetation is on or near the surface. Using a clean copy of a lake map, volunteers draw a sketch showing the extent of rooted aquatic plant beds (see m ap on page 63).

TASK 5

Estimate plant type density and collect a sample for professional identification.

From shore, the volunteer will locate the sampling site designated by the program manager and establish a transect line perpendicu lar from shore. Following along this line at specified intervals, the volunteer will cast a weighted rake to the lake bottomand pull up aquatic vegetation.

This vegetation will be sorted, and the volunteer will make a qualitative estimate of the percentage and density of plant types. Specimens of each type will be bagged for shipment to a botanist for identification.

Elements of Task 5

- Find the designated sampling site and tie the end of the transect line securely to a tree or stake at the water's edge.
- Move the boat away from shore and stretch the transect line to the desired length.
- Attach the buoy and anchor so that the line remains floating, thus forming the transect.
- Measure and record the lake depth at the end of the transect using the weighted calibrated sounding line.
- Confirm that the throwing line is securely attached to the weighted rake (can be an ordinary garden rake).
- Facing the shore, pitch the weighted rake straight ahead (the 12 o'clock position) about six feet from the boat.
- Allow the rake to settle to the lake bottom and then pull the line so that the teeth of the rake drag along the floor of the lake.
- Bring the rake back into the boat and remove all the vegeta tion trapped on the teeth. Sort different plant types into separate piles.
- Examine the piles and estimate the percentage of each plant type found. Record on the sampling form. The total must add up to 100 percent.
- Repeat the procedure at the 3, 6 and 9 o'clock positions.
- After all four samplings are completed, examine the sorted piles and give each plant type a density rating. (See the density rating chart on the figure, *Example of an Aquatic Plant Sampling Form* on page 67.)
  If a plant type was found in all four casts and for each cast the teeth of the rake were full, mark 5. If the plant was found moderately on all four casts, mark 4. If the plant type was found in only three of the four casts, mark 3, and so on.
- Remove a few healthy specimens from each of the sorted piles of plant types, shake off excess water, and place them in a properly labeled collection bag.
- Move the boat along the transect line to the next sampling point and repeat these activities. (The number of sampling points should be determined by the program manager.)

- If practical, keep all collected plant fragments in the boat for proper disposal on land since many nuisance species reproduce from fragments.

TASK 6

Shipment of samples and forms

Volunteers pack and forward the shipping container with the plant type samples to the program botanist for identification. In addition, the data sheet with the density rating for each plant type and sampling observations must be sent to the coordinating agency for analysis. Volunteers should also request additional supplies or equipment as needed.

Elements of Task 6

- Confirm that the bags containing the plant type specimens are securely sealed and properly labeled.
- Place the bags and ice packs in the mailing box and seal the container.

- Ship the box as soon as possible.
- Confirm that all the sections of the sampling forms have been completed. Write down any additional observations of activities that may affect sampling results, such as harvesting, herbicide application, or increased recreation.
- Send the sampling information to the program coordinator.

References

Jessen, R. and R. Lound. 1962. An Evaluation of a Survey Technique for Submerged Aquatic Macrophytes. Game Investigational Rep. No. 6. MN Dept. Conserv, Div. of Game Fish.

Olem, H. and G. Flock, eds. August, 1990. *The Lake and Reservoir Restoration Guidance Manual.* 2nd ed. EPA 440/4-90-006. Prep. N. Am. Lake Manage. Soc. for U.S. Environ. Prot. Agency, Off. Water, Washington, DC.

State of Michigan Dept. of Natural Resources. December, 1987. *Common Aquatic Plants of Michigan*. Land Water Mgt. Div., Lansing, MI.

U.S. Environmental Protection Agency. August 1990. *Volunteer Water Monitoring: A Guide for State Managers* . EPA 440/4-90-010. Off. Water, Washington, DC.

Additional program material relating to volunteer monitoring of aquatic plants is available from these States:

New York
New York Citizens Statewide Lake Assessment Program
New York State Department of Environmental Conservation
Division of Water - Lake Services Section
50 Wolf Road, Room 301
Albany, NY 12233-3502

Vermont
Vermont Lay Monitoring Program

Department of Environmental Conservation
Water Quality Division
103 S. Main Street
Waterbury, VT 05676

Office of Water

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Chapter 5: Monitoring Dissolved Oxygen

5.A Dissolved Oxygen Parameters

The amount of dissolved oxygen in the water is an important indicator of overall lake health. When oxygen is reduced, organisms are stressed. When oxygen is absent, all oxygen-breathing life forms must either move to an oxygenated zone or die.

There are also many chemical reactions that occur depending on whether or not oxygen is in the water. For example, an essential plant nutri ent, phosphorus, can be released from bottom sediments when oxygen is reduced in the lower layer of a lake.

Dissolved oxygen conditions are best characterized by measuring the:

- dissolved oxygen profile (measurements from the surface to the bottom at set intervals); and
- temperature profile (at the same intervals).

Dissolved Oxygen Profile

When characterizing the oxygen condition in a lake, it is important to know how oxygen concentrations differ from the surface to the bottom. In lakes that have a problem with low dissolved oxygen, it is not unusual to measure high dissolved oxygen levels at the surface during the day because algae in the photic zone are photosynthesizing and producing oxygen. At night, these same algae respire and consume oxygen.

Near the bottom, however, there may be low or no oxygen because decomposers are absorbing it while breaking down the "rain" of organic matter (dead algae cells, zooplankton, fish) falling from above.

A profile of oxygen measurements taken from top to bottom may provide insight on the relative populations of oxygen-producing plants and bottom -dwelling decomposers.

Temperature Profile

Water temperature plays an important role in determining the amount of oxygen found in the lake. Oxygen is more soluble in cold than warm water. Most lakes over 20 feet deep stratify during the summer into a warm, lighted upper layer (epilimnion) and a cold, dark lower layer (hypolimnion). Thus, the cold lower layer can potentially hold more oxygen than the warmer upper layer.

Usually these layers do not mix; thus, the bottom layer is cut off from atmospheric oxygen and oxygen-producing plants. Consequently, bottom oxygen can become depleted if there is an active population of decomposers in the bottom sediments. For these reasons, it is important to define the thermal layers in a lake when characterizing dissolved oxygen conditions.

5.B Sampling Considerations

Temperature and oxygen profiles should be taken at a site directly over the deepest portion of the lake basin. If the lake has several distinct basins, the program manager may require volunteers to sample each at the deepest location.

Temperature and oxygen profile measurements should begin with spring overturn. At that time, both temperature and oxygen concentration are uniform from top to bottom in most lakes. Sampling should continue throughout the summer season. It may be even useful to extend the program to fall overturn.

To track the progress of oxygen depletion in the lower layer, sampling should be conducted every two weeks. In some cases, it may be useful to build some flexibility into the program and encourage volunteers to gather profile data after large, windy storms. This effort will document whether lake stratification breaks down under storm or high wind conditions.

Additionally, if there is a large crop of aquatic weeds or algae, the plan ning committee may wish to have volunteers sample the oxygen concen tration in the photic zone in the early morning to evaluate the impact of nighttime respiration.

There are two methods of measuring dissolved oxygen in a lake. Volunteers can use a dissolved oxygen field kit, or a submersible oxygen meter.

Field kits are available from many manufacturers. All kits basically require that volunteers take a water sample and analyze dissolved oxygen using a titrimetric procedure. The sample must be analyzed immediately after collection.

To get meaningful results, volunteers must observe strict sample handling protocol. Contact with the air, agitation, exposure to strong sunlight, and temperature and pressure changes will affect the oxygen content of a sample.

These factors, plus the fact that several dissolved oxygen measure ments are needed to make up a profile, makes the use of field kits generally unsuitable for volunteer programs that are monitoring the dissolved oxygen profile in lakes. If the goal of the program, however, is to simply sample oxygen in the photic zone and not create a full water column profile, a dissolved oxygen kit may be an attractive and less expensive alterna tive.

The most convenient method for taking both oxygen and temperature profiles, however, is to use a portable oxygen meter that incorporates a thermistor. The meter displays a dissolved oxygen readout based on the rate of diffusion of molecular oxygen across a membrane. The thermistor component of the instrument provides a temperature readout.

Each meter manufacturer provides detailed instructions on sampling protocol and how and when to calibrate the meter to obtain guaranteed precision and accuracy. Calibration should be done by experienced program personnel at the manufacturer-recommended intervals. This means the instrument will have to be transported between the volunteer and program officials between those intervals.

For convenience, citizen monitoring programs can purchase a meter with a permanent membrane to avoid having to calibrate it before each trip.

5.C How to Sample

Suggested procedures for measuring temperature and oxygen profiles of a lake are described in this section. Sampling activities can be divided into three sections:

- Confirming the sampling date and weather conditions and going through boating safety and sampling equipment checklists prior to launching the sampling boat (Tasks 1 through 3).
- Finding the sampling site and documenting observations about water and weather conditions (Tasks 4 and 5).
- Taking a temperature and oxygen profile, entering the readings on the sampling form, and then mailing the form to program officials (Tasks 6 - 8). To take a profile measurement, lower a thermistor and oxygen probe on a calibrated cable through the water column. At specified intervals, read and record the temperature and dissolved oxygen concentration.
- The program manager should provide a sampling schedule and a sampling protocol sheet to volunteers. In general, monitors should be in structed to conduct sampling between 10 a.m. and 3 p.m. Volunteers must understand, however, that there is flexibility in both the day and time, especially in consideration of weather conditions.
- Volunteers' common sense and good judgment should dictate when it is appropriate to sample. Both good and unacceptable weather conditions should be defined during training sessions. Under no circumstances should volunteers be on the water during rain or electrical storms, high winds (white caps), or other unsafe conditions.

TASK 1

Confirm sampling day and weather conditions.

Elements of Task 1

- Check the sampling date on the program sampling schedule.
- Check the current and forecasted weather and decide if the conditions allow for safe sampling. The volunteer should also be instructed to confirm this decision after personally inspecting lake conditions prior to launching the boat and beginning the sampling trip.

TASK 2

Go through the boating safety equipment checklist.

Before leaving shore, the volunteer must confirm that all the safety equipment is on board. Boating safety is a subject that volunteers need to take seriously because they will be moving around the boat, leaning over the edge, and working with equipment.

Volunteers should wear a life preserver (Type 1, 2, or 3 personal flotation device) at all times. Volunteers should

Elements of Task 2

- Confirm that the following boating safety equipment are on board the sampling boat
- A personal flotation device for each person that is Coast Guard-approved, readily available, and the proper size.
- First aid kit
- Other equipment that may be required by State and local boating laws

TASK 3

Go through equipment and supply checklist for sampling tasks.

Before leaving shore, volunteers must confirm that they have all the needed sampling equipment.

Elements of Task 3

- Confirm that the following sampling equipment and supplies are on board the boat.
- Anchor (with a measured line if a depth check is required). Two anchors are helpful on windy days.
- Weighted calibrated sounding line for measuring depth
- Clipboard and pencils
- Map of lake with sampling site and landmarks marked

- Sampling protocol sheet
- Sampling form
- Dissolved oxygen meter with thermistor

TASK 4

Position boat at the designated sample site.

The volunteer must locate the sample site on the water. Whether or not a marking buoy is used, the position should be verified using a shoreline landmark method (described in Chapter 3).

Once the site is located, the volunteer can anchor the boat. Reposition ing the anchor once it is dropped should be discouraged, especially in shallow lakes, because it can stir up sediments from the lake bottom. Increasing sediment turbidity may alter the data collected at the site.

After anchoring, volunteers should allow the boat to become stable.

Reporting visual conditions such as water color and appearance will aid in the interpretation of data results. For example, if the sampling trip was conducted after a storm, thermal stratification may have broken down and caused mixing of the layers.

TASK 5

Complete the observations portion of the sampling form.

Volunteers should record their observations about the lake and weather conditions on the sampling form. *Elements of Task 5*

- Record the lake and site name, the date, the time of sampling, and the names of volunteers doing the sampling.

- Record weather and water condition observations.
- Record any other factors or conditions that make the sam pling trip unusual or may potentially influence results. For example, report any chemical, mechanical, or biological control of algae or rooted aquatic plants.

TASK 6

Measure the depth of the site.

Using the weighted calibrated sounding line, volunteers should measure the depth of the site and record it on the sampling form. It is important to know the depth because the oxygen probe must not be allowed to come in contact with the lake bottom.

TASK 7

Measure the temperature and dissolved oxygen profile.

The thermistor and oxygen probe is lowered into the water at the specific intervals designated by the program manager. Volunteers will record readings on the data form.

Elements of Task 7

- Check to make sure that the oxygen probe is securely attached to the measured line.
- Lower the probe into the water just below the surface, let the probe acclimate according the manufacturer's instructions, take a temperature and oxygen reading, and record it on the data sheet.
- Lower the thermistor tvo the next deeper interval and repeat these steps.
- Continue to collect readings at each interval until the probe is approximately one to two meters above the bottom.

TASK 8

Ship forms.

This task requires volunteers to forward the data sheet with the temperature and oxygen profile data and the observation information to the coordinating agency.

References

Olem, H. and G. Flock, eds. August, 1990. *The Lake and Reservoir Restoration Guidance Manual.* 2nd ed. EPA 440/4-90-006. Prep. N. Am. Lake Manage. Soc. for U.S. Environ. Prot. Agency, Off. Water, Washington, DC.

Standard Methods for the Examination of Water and Wastewater. 16th ed. 1985. Am. Pub. Health Ass., Am. Water Works Ass., and Water Pollu. Control Fed. 1985. American Public Health Association. Washington, DC.

U.S. Environmental Protection Agency. August 1990. *Volunteer Water Monitoring: A Guide for State Managers* . EPA 440/4-90-010. Off. Water, Washington, DC.

Additional program material relating to the monitoring of dissolved oxygen and temperature is available from the following States:

New York
New York Citizens Statewide Lake Assessment Program
New York State Department of Environmental Conservation
Division of Water-Lake Services Section
50 Wolf Road, Room 301
Albany, NY 12233-3502

Tennessee
TVA Citizen Water Quality Monitoring Program
Tennessee Valley Authority
Water Quality Department
2S-270C Haney Building
311 Broad Street
Chattanooga, TN 37402-2801 79

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Chapter 6: Monitoring Other Lake Conditions

6.A Monitoring Sedimentation

Sedimentation problems occur when erosion is taking place in the watershed. Surface runoff washes sand and silt into the lake where it settles to the bottom and creates shallow areas that interfere with lake use and enjoyment. In addition, sediments often carry significant amounts of nutrients that can fertilize rooted aquatic plants and algae.

Citizens can characterize the build-up of sediments by measuring water depth and the depth of unconsolidated (soft bottom) sediments in key areas (mouths of tributary streams or near an eroding shoreline). In this manner, a historical record of sedimentation can be developed.

To measure sediment, set up a transect line and sample at specified intervals along it. A basic procedure involves the use of two dowels (probes) about one inch in diameter and long enough to stick above the surface at the deepest point of measurement. Securely attached to the bottom of one probe is a nine-inch plate (a pie pan works well). Both probes are calibrated in meters and tenths of meters.

Working along a transect line, volunteers can:

- locate the sample site along a transect;
- measure and record the depth of the water from the surface to the top of the sediments using the probe with the plate on the end;
- push the other probe into the sediments until first refusal (it becomes hard to push) and measure and record the depth. The difference between the two depths is the thickness of the unconsolidated sediments. The number of transects and the location of sites along

those transects will be decided by the planning committee. By participating in a sediment recording program, the volunteers will gain appreciation that erosion and sedimentation is an important lake management problem.

6.B Monitoring Suspended Sediment

Some of the silt and organic matter that enters a lake does not settle to the lake bottom. Instead it remains suspended in the water. These sus -pended solids decrease water transparency and can affect the suitability of the lake habitat for some species. In addition, solids often carry in significant amounts of nutrients that fertilize rooted aquatic plants and algae.

Total solids is a term used to describe all the matter suspended or dissolved in water.

Total suspended solids is that portion of the total solids that are retained on filter paper after a sample of water is passed through.

Citizens can monitor the suspended sediment condition by measuring two parameters:

- water transparency using a Secchi disk; and
- total suspended solids.

The Secchi disk is a instrument that measures water clarity. The reader is referred to Chapter 3 of this manual for a thorough explanation of its use in lake monitoring.

The concentration of total suspended solids in a water sample is analyzed in a laboratory. Procedures involve the use of a filtering appara tus, a special drying oven that can maintain a constant temperature between 103° and 105° F and a sensitive analytical balance capable of weighing material to 0.1 milligrams. In most cases, volunteers will take a grab sample just below the surface in an area designated by the planning committee. The sample must be kept cold and shipped to the laboratory as soon as possible after collection to minimize microbiological decomposition of solids. This monitoring is particularly useful for analyzing trends in suspended material after storm events. For this reason, the planning commit tee may wish to instruct volunteers to sample on a two-week schedule for baseline purposes and then to conduct additional sampling after storms.

6.C Monitoring Acidification

A citizen monitoring program that focuses on lake acidification usually examines:

- pH, a measure of lake acidity status; and
- alkalinity, a measure of the acid neutralizing capacity of a substance.

The *pH* is measured on a scale of 0 to 14. The lower the pH, the higher the concentration of hydrogen ions and the more acidic the solution. Acid rain typically has a pH of 4.0 to 4.5. In contrast, most lakes have a natural pH of about 6.0 to 9.0.

Alkalinity, or acid-neutralizing capacity, refers to the ability of a solution to resist changes in pH by neutralizing acid input. In most lakes, buffering is accomplished through a complex interaction of bicarbonates, carbonates, and hydroxides in the water. The higher the alkalinity, the greater the ability of the water to neutralize acids.

Lakes with low alkalinity are not well buffered. These lakes are often adversely affected by acid inputs. After a short time, their pH levels will drop to a point that eliminates acid-intolerant forms of aquatic life. Fish are particularly affected by low pH waters.

The planning committee can designate pH and alkalinity sampling to occur at the lake's center or at special areas of interest. The depth where samples are taken can vary with program objectives, but one meter is usually sufficient for a general characterization of a lake.

Sampling should occur from spring overturn until the end of the summer season. Both pH and alkalinity are affected by biological activity; there fore, the planning committee may direct volunteers to sample every two weeks. The time of the day that the sample is taken should be noted on the sampling form. The pH normally rises during active photosynthetic periods.

The pH of a lake sample can be easily determined by using a portable, battery-powered pH meter. In general, pH meters are accurate and easy to use. However, they do need to be calibrated at regular intervals accord ing to the manufacturer's instructions. Training on both meter use and calibration is important. A pH meter can also be used in the analysis of alkalinity.

As an alternative to a pH meter, volunteers can use a pH test kit. To conduct the test, volunteers add an indicator dye to a measured amount of water sample. The dye produces a color based upon the pH. Volunteers can then compare the color with a standard color of a known pH.

The pH test kits come in several varieties. Some can test for a wide pH range, others are designed to test narrow ranges. It is best to know the approximate pH of the lake to be sampled and choose the kit best suited to the planning committee's purpose. The program manager should plan to conduct regular quality control checks because when the dyes age, they sometimes give erroneous results.

The objectives of the volunteer monitoring program, economic considerations, and the data quality requirements of the users will guide the decision on whether to use a colorimetric test kit or a pH meter.

The other parameter used to characterize a lake's acidification condition is alkalinity. Volunteers can measure alkalinity in the field by using a test kit. The procedure involves monitoring the changes in pH of a water sample as an acid is dripped into it. Volunteers calculate alkalinity based on the amount of acid it took to reach an end point pH.

The end point pH for determining alkalinity varies according to the approximate actual alkalinity of the sample.

When titrating, the end point pH can be determined in two basic ways:

- by using a pH meter; or
- by mixing a standard indicator solution into the sample and watching for a color change that will occur when the desired end point pH is reached.

There are several kits on the market that can be used to measure alkalinity. Each kit has its own procedures that should be followed carefully.

As with pH, the objectives of the volunteer monitoring program and the data quality requirements of the program customers will guide the decision on which test kit to purchase.

The Gran analysis method is an alternative technique for charac terizing a lake's acidification condition. Commonly used in scien tific studies of acidic deposition, the method provides information, referred to as *acid neutralizing capacity* because it includes carbonate, bicarbonate, and hydroxide alkalinity plus the additional buff ering capacity of organic acids and other compounds.

6.D Monitoring Bacteria at Bathing Beaches

A wide variety of disease-causing organisms can be transmitted to humans at bathing beaches. Sources of pathogens include sewage, runoff from animal or wildfowl areas, and even swimmers themselves.

Because of the risk of waterborne disease, it is good public health practice to test beaches periodically during the swimming season. Public health officials usually monitor for the presence of one or more indicator organisms as part of a regular sampling program. The relative abundance of an indicator organism found in a water sample serves as a warning for the likely presence of other, more dangerous pathogens in the water.

The indicator organisms most often used to indicate sanitary conditions at bathing beaches are:

- fecal coliform bacteria; and
- enterococcus bacteria.

Coliforms belong to the enteric bacteria group, Enterobacteriaceae, which consists of various species found in the environment and in the intestinal tract of warm-blooded animals. Fecal coliforms are the part of the coliform group that are derived from the feces of warm-blooded animals. The fecal test differentiates between coliforms of fecal origin and those from other sources.

Enterococcus are a subset of the fecal coliform group. Like fecal coliforms, they, too, indicate fecal contamination by warm-blooded animals. They are useful because they are found only in certain animals. Examination of the ratio of fecal coliform to enterococcus can, there fore, indicate whether the bacterial pollution is from humans or animals.

Most public health officials recommend weekly testing of swimming beach areas. Sampling should occur at one or more sampling sites in water three to four feet deep. A sterilized sampling bottle should be prepared by the laboratory.

The number of sites needed will vary with the length and configuration of the beach. One site is generally adequate if the beach shoreline is 300 linear feet or less. If the shoreline is between 300 and 700 linear feet, a minimum of two sites is recommended. A beach shoreline greater than 700 feet requires three or more sample sites.

There are six steps in most basic procedures:

- Remove the cap from a sterile collection bottle without touching the inside of the cap or the inside of the bottle.
- Grip the bottle at the base and plunge it in a downward motion into the water to a depth of 12 to 18 inches.
- Using a forward sweeping motion (so water is not washed over the hand into the bottle), invert the bottle and bring it to the surface.
- Empty it slightly to leave approximately one inch of air at the top.
- Re-cap the container, then label and store it at a temperature between 39° and 45° F.

- Transport the bottle to the laboratory as soon as possible after sampling.

Sampling for bacteria at beaches should be conducted under the auspices of the local health department. Analysis should be done at a certified laboratory. If a problem is found, program officials should notify health authorities for follow-up testing and mitigation activities.

The sampling protocol for monitoring bacteria concentrations at natural bathing beaches will also vary according to program objectives and the requirements of data users who, in many instances, are officials of the local health department. Most health dep artments have strict criteria and procedures that must be followed when sampling for indicator organ isms like fecal coliform or enterococcus bacteria. The volunteer sampling protocol, therefore, must follow the protocol used by the health depart ment. References

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Chapter 7: Training Citizen Volunteers

7.A The Training Process

Training the volunteers to do their jobs properly is an essential component of a successful monitoring program. Significant amounts of time and resources should be budgeted specifically to plan, present, and evaluate volunteer training.

The payoff from effective volunteer training rises well above the initial costs. From the program manager's perspective, good training means less time and energy spent answering and re-answering basic procedural questions.

From the volunteers' perspective, effective training stimulates confi dence and increases the desire to do the job right. In addition, the data collected by well-trained volunteers tend to be of higher quality and thus more valuable to users.

Training is a dynamic process. It does not simply begin and end with a kickoff classroom session for new volunteers. For example, follow-up training must occur to resolve specific operating problems discovered in an on-going program.

Even experienced volunteers benefit from occasional continuing education sessions, which help everyone stay in touch with the program and foster the ideal of team effort.

The planning committee should plan volunteer training from three basic perspectives:

- training new volunteers;
- training experienced volunteers (about new equipment, improved methods, or simply to provide a refresher course on sampling protocol); and
- solving specific operating problems.

Each of the three training perspectives requires the presentation of unique material. The training processes involved in presenting this material, however, are similar.

Basically, the volunteer training process can be broken down into five phases.

Phase 1: Creating a Job Analysis

Phase 2: Planning the Training

Phase 3: Presenting the Training

Phase 4: Evaluating the Training

Phase 5: Conducting Ongoing Coaching, Motivation, and Feedback

Each of these phases are discussed in the following sections.

7.B Creating a Job Analysis

The job analysis phase is the hardest yet the most important part of training development. The job analysis is a list of all the tasks volunteers must accomplish when sampling a parameter. Its purpose is to ensure that sampling procedures are performed by volunteers consistently throughout all the program lakes.

When job tasks are performed with consistency:

- quality standards can be developed;
- time and cost requirements can be evaluated;
- performance evaluation criteria can be developed; and
- the data user can have greater confidence in the data results (especially when comparing the data from one lake with another).

There are four steps in creating a job analysis:

- developing a list of sampling tasks;
- determining the required quality level for each task;
- defining the job elements that comprise each task; and

- creating a sample protocol or job description handout for the volunteers.

The sampling protocols presented in the previous chapters can be used as a basic outline for creating job analyses. The planning committee can take the job tasks, quality levels, and elements described in the chapters and add the detail unique to the operation of their individual program.

The job description handout is an important product of this phase. An overall objective of this job description is to provide each program volunteer with clear instructions of what to do when performing each monitoring task.

A well-written handout can have several other uses, as well. For example, the job description:

- can be used as a volunteer recruitment tool. (Potential volunteers can preview the tasks involved before committing to the program);
- can serve as the basic outline for planning a training session; and
- can be used as a management tool for supervising and evaluating volunteer performance.

Once a job description is proposed, members of the planning committee (and a few volunteers) should test it in the field. The feedback will be useful in fine-tuning the job description document.

7.C Planning the Training

Once the job analysis is completed and a job description prepared, the planning committee can start designing the actual training session. The committee must decide if the training is to occur in a group setting or on a one-on-one basis.

Group training saves money and time, especially when there are many volunteers who must be trained simultaneously. This approach has its drawbacks because every lake has unique characteristics. Thus, there may be circumstances or problems that can be addressed only on an individual basis.

For example, training the volunteer to locate a sampling site is best done on that lake.
One-on-one training is more time consuming and expensive but allows program managers to instruct and demonstrate procedures under actual conditions experienced by the volunteer. For those programs operating under strict quality assurance/quality control guidelines, individual one-on-one training is essential.

In practice, it is often best to structure the training program so that there are group sessions as well as individual follow-up sessions for each lake. Given this scenario, the group presentation can be used to introduce program personnel and educate the volunteers about the following topics:

- purpose, goals, and objectives;
- basic lake ecology, preservation, and management;
- how the collected data will be used and by whom;
- the role of volunteers;
- lake condition being monitored;
- parameters to monitor the condition;
- procedures to measure the parameters;
- distribution and preparation of the sampling equipment; and
- how the results are reported to the data users and to the volunteers.

On-lake follow-up sessions will reinforce what was taught in the classroom and allow program officials to adapt any special variations of training protocol. Topics such as how to find a sampling site and how to prepare samples for shipment can be discussed and practiced at the actual locations.

In most instances, the job description document will serve as the foundation of the training session. Thus, the training session can be broken down into a series of mini lessons designed to teach the skills needed to perform each of the tasks in the job description. An example of how to plan a mini lesson is presented on the following pages.

Sample Mini Lesson:

Secchi Disk
The content and activities of the mini lesson need to be planned so that the task is covered thoroughly within the time allotted. The lessons should include volunteer participation wherever possible. Active participation usually stimulates questions and enhances the learning experience.

Training Topic: Measuring Algae

Mini Lesson: Taking a Secchi disk measurement

Objective: To train volunteers how to use a Secchi disk and record the reading on the data sheet.

Time Allotted: 30 minutes

Equipment: Secchi disks (to be distributed to volunteers)

Rope lines (to be attached by the volunteers)

Clothes pins

Data sheet Pencils

Topic A: Introduce the Secchi disk

- Distribute the equipment to the volunteers.
- Explain that the basic purpose of the Secchi disk is to measure water transparency.
- Discuss the historical significance of the Secchi disk mea surement.
- Explain standard characteristics of the disk.

Topic B: Note factors influencing water transparency readings

- Have the volunteers name factors that may influence Secchi disk readings (eyesight/glare or water reflection/cloud cover/algae in the water/sediment/waves).
- Discuss the factors that influence readings.

Topic C: Purpose of the Secchi disk measurement

- Discuss how the Secchi disk data collected by the volunteers will be used and by whom.
- Discuss the importance of data quality.

Topic D: How to take a Secchi disk measurement

- Demonstrate how a reading is taken.
- Discuss the range of Secchi disk depths likely to be encountered in the field.

Topic E: Attaching, marking, and flagging the line

- Demonstrate how the line is tied to the Secchi disk.
- Demonstrate how a Secchi disk line is measured and marked (in inches).
- Demonstrate how to attach and label duct tape flags to the line at six-inch intervals.
- Instruct the class to attach, measure, mark, and flag their Secchi disk lines.

Topic F: Learning the motions

- Demonstrate the task of making Secchi disk measurements (including placing the clothes pins on the line at the point the Secchi disk disappears and reappears).
- Instruct the class to practice attaching the clothes pins to the line and making a reading.

Topic G: Filling out the data sheet

- Demonstrate how to record the Secchi disk measurement on the data sheet.

Topic H: Quality control

- Discuss standard operating procedures (including the impor tance of taking the measurement on the shady and calm side of the boat, not wearing sunglasses, and so forth).

Topic I: Closing the lesson

- Review the Secchi disk measurement procedure and ask for questions.

7.D Presenting the Training

The time and effort spent on the first two phases of volunteer training pay off during the third phase, the presentation. Volunteers appreciate a well-organized and well-paced training session.

There are four steps that go into presenting an effective training session:

- preparation,
- presentation,
- demonstration, and
- review.

Preparation

There is nothing more important than good preparation. The lesson planning phase discussed in the previous section will provide the trainer with the basic agenda for the session. The trainer, however, will have the responsibility to adapt the lesson to the expectations, knowledge, and experience of the audience. An effective trainer, for example, will prepare separate sessions for new volunteers and experienced volun teers.

The person presenting the training must know the material and be organized. Lectures, activities, and discussions should be planned and kept to a timetable.

Similarly, demonstration materials, audio/visual equipment, and handouts must be accessible and easily incorporated into the presentation. The trainer must be able to anticipate and respond to problems and questions that may occur during an actual training session.

The trainer must always rehearse the session to work out any presentation bugs. Additionally, members of the planning committee should be given an opportunity to critique the performances of the trainers.

Presentation

Given all the planning and preparation work that goes into it, the actual presentation may be the easiest part of the whole training process. A relaxed presentation that fulfills the education objectives is the basic goal. While trainers will bring their own styles to the training session, there are basic public speaking techniques that should be used, which include:

- establishing rapport with the audience;
- enunciating clearly and distinctly;
- using effective body language;
- using eye contact; and
- encouraging questions and comments.

Demonstration

Whether in the classroom or in the field, volunteers must be allowed to demonstrate what they have learned. The trainer should observe volunteers closely and offer immediate feedback in terms of positive reinforcement or corrective assistance. This portion of the session is usually when the real learning takes place.

Review

During the review portion of the training session, the trainer summa rizes what was learned and the audience is given an opportunity to ask questions. The session should close with the reassurance that volunteers will continue to receive training through out their tenure with the monitoring program.

7.E Evaluating the Training

Has the training been successful? Have the learning objectives been met? The trainer and planning committee will never know unless the training is evaluated.

Training evaluation encompasses the entire training process and in cludes the volunteer's perspective as well as that of the planning committee.

Basically, training evaluation focuses on:

- training methods,
- training content, and
- training environment.

To gain immediate feedback about training, have volunteers fill out evaluation forms at the end of the session. Perhaps more effective, however, is to observe volunteers in action during the sampling season. If there are problems or if techniques are not performed according to desired sampling protocol, trainers may need to apply new methods in subsequent training sessions.

7.F Follow-up Coaching, Motivation, and Feedback

As stated previously, training is conducted throughout the life of the monitoring program. Follow-up coaching is an integral part of the training process.

Coaching usually occurs on a one-on-one basis and serves many pur poses. Specifically, it:

- maintains communication between the volunteer and program officials;
- allows the volunteer to ask questions and resolve problems;
- motivates the volunteer and conveys a sense of teamwork; and
- provides a format for implementing new or improved sampling techniques.

The key to follow-up coaching is personal contact. In many cases, however, it is enough to call volunteers periodically to find out how they feel the program is going and ask if they have questions. This personal touch, which increases volunteer satisfaction, should be maintained throughout the life of the program.

The companion manual to this document, *Volunteer Water Monitoring: A Guide for State Managers*, discusses several other ways to maintain volun teer interest. These techniques include:

- sending volunteers regular data reports;
- keeping volunteers informed about all uses of their data;
- preparing a regular newsletter;
- having program officials be easily accessible for questions and requests;
- providing volunteers with educational opportunities;
- keeping the local media informed of the goals and findings of the monitoring effort;
- recognizing the efforts of the volunteers through certificates, awards, or other means; and
- providing volunteers with opportunities to grow with the program through additional training, learning opportunities, and changing responsibilities.

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Chapter 8: Presenting Monitoring Results

8.A Overview of Data Presentations

One of the basic tenets of successful volunteer monitoring programs is that sampling data must be properly analyzed and presented. Volunteers need to see their sampling data interpreted and presented as findings if they are to maintain their interest in the program. Organizing agencies and other data users also need to see that the program is generating useful information.

Techniques for presenting volunteer data may vary depending on the technical background of the target audience. This chapter will focus on reporting monitoring results to those citizen volunteers who participate in the program; however, the methods that a re-outlined here should prove useful to other data users as well.

The Importance of Credible Data

Volunteer monitoring programs must ensure that data released to the public are absolutely accurate. Misinformation can occur when data are too hastily or sloppily collected, stored, analyzed, or presented. When this happens, the credibility and hence, the utility of the volunteer program is thrown into question.

To ensure that volunteer-collected data are credible and defensible, program managers must carefully plan and maintain a quality assurance program. Approved data collection methods must be established and followed; data must be stored and documented according to specific quality assurance protocols; incoming data must be constantly reviewed; and staff time should be committed in advance to conduct concise, clear, accurate analyses and presentations of volunteer-collected data. Further information on these quality assurance considerations is available in the EPA document, *Volunteer Water Monitoring: A Guide for State Managers* .

Presenting the Data

Some citizen monitoring programs issue annual reports at the end of the sampling season. Others rely on regularly-issued newsletters or bulletins. Whatever the format, it is always important to keep in mind the interest, background, and level of technical understanding of the target audience.

Three rules apply when presenting data to volunteers.

- The data presentation should not be overly technical or insultingly simple. Graphics are extremely helpful.
- The data presentation should convey information with a specific purpose in mind (e.g., to show a trend, to illustrate seasonal variations or variations with depth, or to identify problem sites).
- The data presentation must be timely and relevant to the lake condition. Volunteers and other data users will lose interest in the program if significant delays occur between the sampling season and the presentation of data results.

It is not enough to simply list the data when preparing a summary report for volunteers. Instead, the author of the report should use an appropriate combination of graphs, summary statistics, maps, and narra tive interpretation. Some common options for presenting the data are discussed below.

Graphs

Choosing a graphic format that will best transfer information about the monitoring data requires careful thought. Three basic types of graphs are often used to present volunteer monitoring information:

- bar graph,
- pie graph, and
- line graph.

The bar graph uses column bars of varying lengths to compare data. This graph places special emphasis on individual values in the data set rather than overall trends.

The pie graph compares parts to the whole. In a pie graph, each value in the data set is represented by a wedge in a circular pie. The pie as a whole equals 100 percent of the total values in the data set. The size of any individual wedge, therefore, corresponds to the percentage that the value represents to the total.

The line graph effectively shows changes (or trends) over a period of time or space. Unlike bar graphs, it does not place emphasis on the individual values in the data set.

Listed below are some basic rules when creating graphs.

- Prepare the graph with an informational purpose in mind.
- Limit the number of elements used in the graph. The number of wedges in a pie graph should be five or less. The bars in a bar graph should fit easily. Limit the number of overlaying lines in a line graph to three or fewer.
- Expand elements to fill the dimensions of the graph. Unless there is a specific reason to emphasize magnitude or scale, trends and patterns can be distorted if the graph is off -balance. Strive to balance the height and width so that information is represented accurately.
- Choose scales that quickly and easily illustrate values.
- Title the graph to describe clearly what it presents.
- Label the axes clearly and do not overcrowd points along axis lines.
- Use a legend (or key) when appropriate.
- Present information concerning sampling time or conditions when appropriate.

Summary Statistics

Summary statistics are useful for conveying information about a data set. These statistics should succinctly, yet efficiently, transfer facts about the measured variable.

Textbook statistics assume that if a parameter is measured a large number of times under a common universe of circumstances, the measurement values will be distributed at random around an average value. If the relative frequency of these values are plotted against value magnitude, the result will be the familiar Gaussian (normal or bell-shaped) curve. The specific shape of this curve is defined by two statistics, the mean (or average) of the data set values and the standard deviation.

The mean is a statistic that describes the central tendency of the data set. Standard deviation describes the variability or spread of the data around the mean. Traditionally, the mean and standard deviation are the statistics used to summarize a set of lake data.

In practical application, however, the mean and standard deviation are not always the appropriate summary statistics to use because lake data do not usually follow textbook patterns of normal distribution around an average value. Instead, the data are frequently skewed in one direction or the other.

This skewness occurs because there are many important factors that influence lake conditions, including the changing seasons, weather condi tions, and activity in the lake and watershed. As a result, the parameters used to describe lake conditions are constantly in a state of flux.

Thus, skewness can usually be expected, especially when measuring the parameters that characterize an algal condition (Secchi disk transpar ency, chlorophyll *a*, and total phosphorus concentration). Chlorophyll *a* concentration, for example, may go through several cycles each year. It may be low in the spring, high during a mid-summer algae bloom, and low again in the fall.

Robust Statistics

Whenever there is an irregular or uncertain pattern of data values for a lake parameter, robust summary statistics should be used. A robust statistic conveys information under a variety of conditions. It is not overly influenced by data values at the extremes of the data distribution.

Median and *interquartile range* are robust statistics that describe central tendency and spread around the median, respectively. Both these summary statistics are unaffected by extreme points. Consequently, they are usually more appropriate for summarizing lake data than the traditional mean and standard deviations.

Both the median and interquartile ranges are based on order statistics. They are derived by ordering data values from high to low. The median is simply the middle value of the data set. The interquartile range is the difference between the value at the 75 percent level and the value at the 25 percent level.

The Box Plot

The box plot is a convenient method of presenting lake data based on the robust order statistics. In one simple graphic, the box plot can provide information on:

- the median,
- data variability around the median,
- data skew,
- data range, and
- the size of the data set.

A box plot is constructed using the following steps:

1. Order the data from lowest to highest.
2. Plot the lowest and highest values on the graph as short horizontal lines. These are the extreme values of the data set and repre sent the data range.
3. Determine the 75 percent value and 25 percent value of the data set. These values define the interquartile range and are represented by the location of the top and bottom lines of the box.
4. The horizontal length of the lines that define the top and bottom lines of the box (the box width) can be used as a relative indica tion of the size of the data set. For example, the box

width that describes a lake data set of 20 values can be displayed twice as wide as a lake with a data set of 10 values. Alternatively, the width may be set as proportional to the square root of the sample size. Any proportional scheme can be used as long as it is consistently applied.
5. Close the box by drawing vertical lines that connect to the ends of the horizontal lines.
6. Plot the median as a dashed line in the box.

8.B Algae Results

The information in this section will be presented by using a data set from a fictitious lake appropriately named Volunteer Lake.

Volunteer Lake was sampled on the 1st and 15th of the month from May 15 to October 15. The lake depth at the sampling station was 30 feet. At one sampling site over the deepest part of the lake, volunteers:

- measured Secchi disk transparency,
- took a chlorophyll *a* sample at a depth of 3 feet, and
- took total phosphorus samples at depths of 3 feet and 26 feet.

Secchi Disk Transparency

Secchi disk transparency is a parameter that interests volunteers. Data are easily understandable and can be presented by a modified bar graph. The horizontal axis presents the sampling dates and the vertical axis represents the lake's water column.

Miniature Secchi disks extend down from the surface to the actual Secchi disk reading.

General trends in Secchi disk measurements can be noted in this data presentation, but the graphic emphasis is on the individual reading on each sampling date.

Chlorophyll a

Chlorophyll *a* is usually best presented in a traditional bar graph. By examining this data presentation, volunteers can observe when chloro phyll *a* concentrations were high and low during the sampling season.

The horizontal axis presents the sampling dates. The vertical axis is a scale of chlorophyll *a* values. Like the Secchi disk graph, general trends can be noted, but the graphic emphasis is on the chlorophyll *a* concentration on each sampling date.

Total Phosphorus

The total phosphorus graph displays the surface and bottom data together. By examining this double bar graph, volunteers can observe when phosphorus concentrations were high and low in each zone. In addition, they can compare surface and bottom concentrations on each sampling date.

The horizontal axis presents the sampling dates. The vertical axis is a scale of total phosphorus values. As with the other bar graphs, general trends in measurements can be noted, but the graphic emphasis is on phos phorus concentrations measured on each sampling date.

Data Interpretation

In addition to displaying graphs, box plots, and summary statistics, the report author must provide interpretation of what the data presentations mean. The interpretation process begins with a data analysis by an experienced limnologist. The report author then has the critical job of putting technical analysis into terms that can be understood by volunteers. Toward this end, data interpretation is often best presented in the context of an explanation of how the lake functions during a seasonal cycle.

Although time-consuming, a thoughtful explanation by the report author rewards volunteers with greater insight and understanding of their lake.

Examples of observations and reasonable conclusions based on the data from Volunteer Lake may include the following:

- Secchi disk readings were highest in May and October, and lowest in September.
- Chlorophyll *a* concentrations were relatively low from May through July. After July 15, concentrations increased, reach ing a maximum concentration on September 15.
- Phosphorus concentrations at a depth of 3 feet were generally moderate in May and October and relatively low in the summer. Phosphorus concentrations near the lake bottom were generally moderate in May, June, and October. Concentrations increased during the summer, reaching a maximum on September 1.
- The algal population can affect water clarity during the summer and early fall. This is evidenced by the fact that Secchi disk readings and chlorophyll *a* concentration followed opposite paths. When one was high, the other was low. Notably, the lowest Secchi disk reading occurred on the same date as the highest chlorophyll *a* concentration (September 15).
  The reduction of water transparency on June 15 may be due to algae, but it may also be due to increased water turbidity from a spring rain. A check of the field data sheet can often explain sudden variations in data magnitude.
- Algae take up and then remove phosphorus from the surface waters as they die and sink to the lake bottom. This is evidenced by lowered phosphorus concentrations during the summer.
- The lake probably stratifies into a warmer upper layer (epilimnion) and a colder lower layer (hypolimnion). Also, the lower layer probably is also anoxic in the summer. This theory is supported by the large concentration of phosphorus found in the lower layer during those months. The likely source of this phosphorus is lake bottom sediments that leach phosphorus to the overlying waters under anoxic conditions.
- In all likelihood, Volunteer Lake experiences a spring and fall overturn. This is evidenced by nearly equal shallow and deep total phosphorus concentrations on May 15 (spring overturn), October 1, and again on October 15 (fall overturn). The nearly equal concentrations indicate that the lake is mixing vertically and distributing phosphorus evenly throughout the water column.
- There may be a problem with fall algal blooms, which will reduce water clarity. Fall overturn may be stimulating increased growth when it brings phosphorus (released from the sediments during anoxic conditions) to the surface waters. Algae often reproduce rapidly when given this new pulse of nutrients.

Trophic State

Secchi disk transparency, chlorophyll *a*, and total phosphorus are often used to define the degree of eutrophication, or trophic status of a lake. The concept of trophic status is based on the fact that changes in nutrient levels (measured by total phosphorus) causes changes in algal biomass (measured by chlorophyll *a*) which in turn causes changes in lake clarity (measured by Secchi disk transparency).

A trophic state index is a convenient way to quantify this relationship. One popular index was developed by Dr. Robert Carlson of Kent State University. His index uses a log transformation of Secchi disk values as a measure of algal biomass on a scale from 0 - 110.

Each increase of ten units on the scale represents a doubling of algal biomass. Because chlorophyll *a* and total phosphorus are usually closely correlated to Secchi disk measurements, these parameters can also be assigned trophic state index values.

The Carlson trophic state index is useful for comparing lakes within a region and for assessing changes in trophic status over time. Thus it is often valuable to include an analysis of trophic state index values in summary reports of a volunteer monitoring program.

The program manager must be aware, however, that the Carlson trophic state index was developed for use with lakes that have few rooted aquatic plants and little non-algal turbidity. Use of the index with lakes that do not have these characteristics is not appropriate.

TSI = 60 - 14.41 ln Secchi disk (meters) TSI = 9.81 ln Chlorophyll *a* (µg/L) + 30.6
TSI = 14.42 ln Total phosphorus (µg/L) + 4.15

where:

TSI = Carlson trophic state index
ln = natural logarithm

The formulas for calculating the Carlson trophic state index values for Secchi disk, chlorophyll *a*, and total phosphorus are presented below. Also presented is a table that lists the trophic state values and the corre sponding measurements of the three parameters.

Ranges of trophic state index values are often grouped into trophic state classifications. The range between 40 and 50 is usually associated with mesotrophy (moderate productivity). Index values greater than 50 are associated with eutrophy (high productivity). Values less than 40 are associated with oligotrophy (low productivity).

Presented below are Carlson trophic state index values for Volun teer Lake. Summer averages (June 15 - September 1) are used in the calcula tions. As seen from the TSI values, Volunteer Lake can be classified somewhere near the border of mesotrophy and eutrophy.

Secchi Disk

Average Summer Secchi disk = 5.9 feet = 1.8 meters

TSI = 60 - 14.41 (ln Secchi disk (meters))

TSI = 60 - (14.41) (0.59)

TSI = 51.5

Total Phosphorus

Average Summer Surface Total Phosphorus = 19.6 µg/L

TSI = 14.42 (ln Total phosphorus (µg/L)) + 4.15

TSI = (14.42) (2.98) = 4.15

TSI = 47.1

Chlorophyll *a*Average Summer Chlorophyll *a* = 17.2 µg/L

TSI = (9.81) (ln Chlorophyll *a* (µg/L)) + 30.6

TSI = (9.81) (2.84) + 30.6

TSI = 58.5

8.C Aquatic Plant Results

Chapter 4 describes three activities that volunteers can use to monitor the rooted aquatic plant condition:

- mapping the distribution of plants at or near the surface;
- estimating percent composition and relative density of plant types at stations located along a transect line that runs perpendicular from shore; and
- collecting plant types for professional identification.
  Reporting the results of these activities can be relatively straightfor ward. The rough aquatic plant map drawn by volunteers can be cleaned -up and reproduced (see below).

  Estimates of the percent composition of the different plant types at each transect station are best displayed by using a pie graph. Relative density information can also be incorporated into the graph. Identified plants can be listed along with a sketch and a short description.

8.D Dissolved Oxygen Results

As in Section 8.B, this information will be presented using fictitous data set from Volunteer Lake.

Temperature and oxygen profiles were measured at one sampling site located over the deepest part of the lake on April 15 and July 15. Using a temperature/oxygen meter, volunteers recorded readings at five-foot intervals from the surface to the lake bottom. A data table of the results is presented below.

Results of the temperature and dissolved oxygen measurements (profiles) can be presented together on the same line graph (page 117). The horizontal axis displays a range of values that can be read both as dis solved oxygen units (mg/L) and temperature units (°C). The vertical axis represents the water column of the lake with the surface at the graph's top and the lake bottom at the graph's bottom.

References

Carlson, R.E. 1977. A Trophic State Index for Lakes. Limnol. Oceanogr. 22:363-369.

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State of Michigan Dept. of Natural Resources. December, 1987. *Common Aquatic Plants of Michigan*. Land Water Mgt. Div., Lansing, MI.

New York State Dept. of Environmental Conservation and Federation of Lake Associations, Inc. 1990. *Diet for a Small Lake: A New Yorker's Guide to Lake Management.* Albany.

Reckhow, K.H. and S.C. Chapra. 1983. *Engineering Approaches for Lake Management*. Vol 1 *Data Analysis of Empirical Methods* . Butterworth Publ. Woburn, MA.

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Appendix: Scientific Supply Houses

A partial list of chemical and scientific equipment companies that supply volun teer lake monitoring programs

Chestertown, MD 21620
Millipore Corporation
Technical Services
800-225-1380

Thomas Scientific
Main Office
609-467-2000
VWR Scientific
P.O. Box 2643
Irving, TX 75061
800-527-1576

Wildlife Supply Company
301 Cass Street
Saginaw, MI 48602
517-799-8100

YSI Incorporated
1725 Brannum Lane
Yellow Springs, Ohio 45387

Cost ranges for some typical monitoring equipment: Secchi disc $20-$40
Water Samplers $100 - $400
Dissolved Oxygen Meter $500-$1,000
Dissolved Oxygen Sampling Kit $40 - $60
pH Meter $300 - $500
pH Test Kit $40 - $60
Alkalinity Test Kit $20 - $50

Phosphate Test Kit $100 - $400

Fisher Scientific
711 Forbes Ave.
Pittsburgh, PA 152
9800-225-4040

HACH Company
P.O. Box 389
Loveland, CO 80539
800-525-5940

Hydrolab Corporation
P.O. Box 50116
Austin, TX 78763
512-255-804

LaMotte Chemical Products Inc.
P.O. Box 329