Temperature

Turbidity

Dissolved Oxygen

pH

Macro-invertebrates

Nitrates & Phosphates

An Angler's Guide to Water Quality Monitoring

v. 2

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TROUT UNLIMITED

Trout Unlimited Water Quality Monitoring Handbook

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I. CHAPTER 1 – INTRODUCTION TO WATER QUALITY MONITORING

1.1 Purpose

The primary goal of this handbook is to inform Trout Unlimited (TU) chapters, anglers, outdoor enthusiasts, and others of the importance of water quality monitoring, educate them on proper monitoring tools and techniques, and encourage them to monitor their local streams and rivers. This threefold approach will enable those interested to better understand the conditions necessary for healthy aquatic ecosystems, as well as allow them to actively participate in the conservation of the freshwater resources they enjoy and appreciate.

Unfortunately, government agencies, nonprofit organizations, and other groups tasked with monitoring our country's rivers, streams, and creeks simply do not have the resources to adequately do so. This handbook provides the information necessary for Trout Unlimited chapters, members, and other volunteers to fill these data gaps by monitoring the water quality of their local freshwater resources. Volunteer citizen science efforts have the potential to be catalysts for additional, more thorough monitoring initiatives or much needed restoration projects as they can uncover water quality issues that were previously unknown.

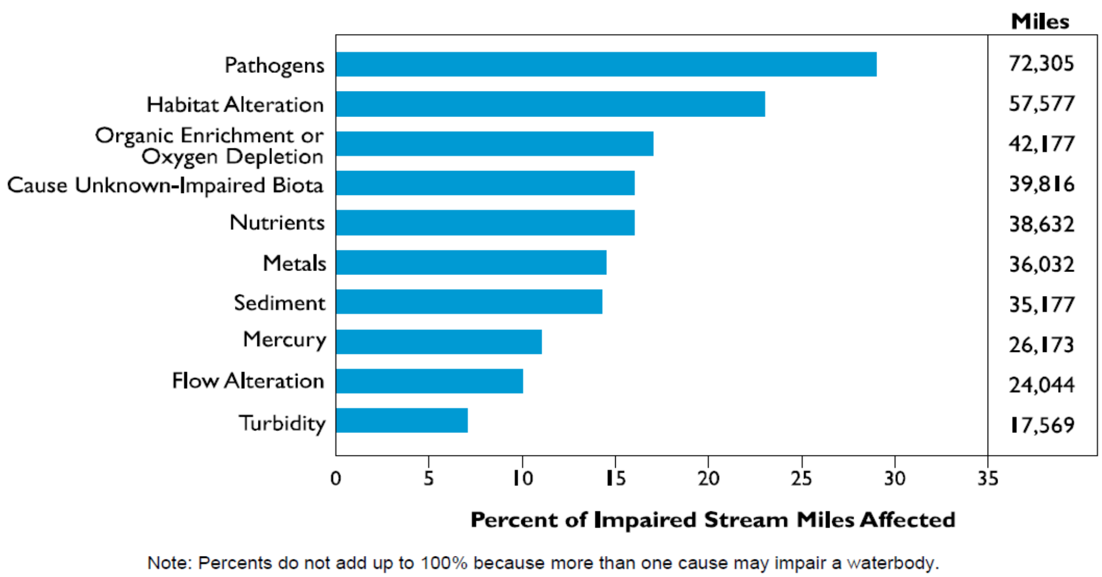

Figure 1. Top 10 causes of impairment in assessed rivers and streams. From 2004 EPA report to Congress (EPA 2009).

This handbook provides a brief introduction to water quality monitoring. The information contained herein can, and should, be supplemented by consulting the many existing water quality monitoring initiatives and programs across the nation – many of which are referenced in this manual. Partnerships with state agencies, nonprofit organizations, or nearby universities are also beneficial and can connect grassroots operations with knowledgeable professionals and high-quality equipment.

Volunteer water quality monitoring is the front line of environmental stewardship. Passionate anglers and outdoor enthusiasts far outnumber agency and nonprofit professionals. They also and share the desire and commitment to preserve valuable and beloved fisheries and freshwater resources. We believe that angler-based, citizen science water quality monitoring efforts will strengthen TU's mission of conserving coldwater fisheries and habitats, as well as ensure years of recreational opportunities for future generations. Any and all volunteer water quality monitoring efforts are greatly appreciated.

1.2 The Value of Water Quality Monitoring

Water is arguably Earth's most valuable natural resource. Every living organism on this planet—from humans to bacteria and everything in between—requires water for survival. Flowing waters—in the form of rivers, streams and smaller creeks—carry water, sediment, and organic materials from headwaters downstream and in the process connect the landscape to the stream while providing vital services to animal and human communities. Because of this inter-connectedness, our use of water resources can impact other living organisms, both directly and indirectly. Striking a balance between our freshwater needs and protecting the integrity of these resources and the ecosystems they support is of utmost importance.

Three Basic Questions for Basic Water Quality Monitoring

- ***Is there an issue with water quality?***
- ***What is the issue and what is causing it?***
- ***What can we do to resolve this issue?***

We rely on Earth's water resources for transportation, irrigation, municipal supply, industry, recreation, and a variety of other services. Many of these services are supplied by flowing waters, which are of particular importance because they supply both coastal and continental regions with fresh water. We aren't the only organisms dependent upon freshwater resources, as rivers, streams, and creeks host some of the planet's most diverse and dynamic ecosystems. In fact, 9.5% (~126,000) of Earth's described species are found in freshwaters, even though these resources cover only about 0.01% of Earth's surface (Balian et al., 2008). This disproportionate amount of supported biodiversity coupled with the provision of myriad essential, beneficial services means that we must make protecting these economically and intrinsically valuable resources a priority.

Unfortunately, flowing waters have seen subjected to extensive anthropogenic and environmental disturbances. When we utilize rivers and streams for transportation, municipal supply, irrigation, and even recreation, we sometimes alter certain characteristics of the water that can severely limit, or even eradicate, aquatic and riparian-dependent species. Complex aquatic ecosystems are often a reflection of specific habitat conditions and are extremely sensitive to environmental changes. This is where water quality monitoring becomes useful. Monitoring certain water quality parameters provides us with information that can be used to answer questions about aquatic habitat conditions and ecosystem integrity. This information can help us assess the quality of the habitat, make inferences about the health of the ecosystem, and determine whether any remedial or preventative actions need to be taken.

1.3 Selected Water Quality Parameters

Trout Unlimited's mission is to conserve, protect, and restore North America's coldwater fisheries and their watersheds. Our focus lies with trout and salmon (coldwater fish species) and the water quality parameters outlined in this handbook were chosen with these fish in mind.

This handbook provides information on water quality monitoring tools and techniques for the following parameters:

-Temperature
-Turbidity
-Dissolved Oxygen
-pH
-Macroinvertebrates
-Nitrates and Phosphates

These specific parameters were selected for a number of reasons. Firstly, each parameter has the ability to be a limiting factor for trout and salmon growth, survival, and reproduction. Secondly, each of these parameters can be measured using techniques and equipment that are simple, informative, and inexpensive. Lastly, these parameters can provide useful information regardless of location. Whether you're a TU member in Michigan, an angler in Tennessee, or an outdoor enthusiast in Oregon, monitoring these parameters can tell you a great deal about the state of your local freshwater resources and their ecosystems. With that in mind, let's dive into the nuts and bolts of water quality monitoring.

1.4 Choosing Which Parameters to Monitor

The most useful water quality assessments are those that monitor multiple parameters. Many of the parameters outlined in this handbook are interrelated in some way and a monitoring protocol that encompasses all of these parameters provides a more comprehensive assessment of overall water quality than one that only monitors a few. While all of the parameters described in this handbook can prove useful, it is always important to tailor monitoring protocols to specific stream conditions. Macroinvertebrates and pH are particularly good parameters to monitor for fast-flowing, headwater (upper watershed) streams. Fast-flowing headwater streams are susceptible to changes in water chemistry from geologic sources, past mining activity, acid rain, and other natural and/or human-related pollutants, and also provide ample habitat for macroinvertebrates.

Lower watershed streams are more likely to be downstream of pollution sources than headwater streams.

Temperature, turbidity, dissolved oxygen, nitrates and phosphates are good parameters to monitor for slow moving streams lower in the watershed. These types of streams typically have fewer rapids and riffles than their fast-moving counterparts and thus have lower concentrations of dissolved oxygen. Slow-moving, lower watershed streams are susceptible to high turbidity levels, elevated concentrations of nitrates and phosphates, and warm temperatures resulting from riparian land use change, urban runoff, and contributions of the multiple headwater streams. Monitoring temperature, turbidity, dissolved oxygen, and nitrates and phosphates in these types of streams may be more beneficial than monitoring macroinvertebrates or pH.

It may be helpful to examine the How's My Waterway website (http://watersgeo.epa.gov/mywaterway/), an Environmental Protection Agency database containing known water quality information for many U.S. streams. Searching this website will inform you whether any data already exist for a stream.

1.5 Accurate Data Collection

Water quality data must be accurately collected and recorded for it to be useful for conservation or management purposes. Without accurate data collection, monitoring may not adequately reflect trends in water quality or reflect the effectiveness of management actions. Thoroughly documented methods and accurate data collection will allow others to replicate your water quality monitoring efforts, validate the results, and allow for better comparisons of data collected over time.

Tips for accurately recording data:

1.) **Follow directions.** You'll find all of the information needed to correctly monitor different water quality parameters in the following chapters of this handbook. The information listed both in this handbook, and in the directions of whatever monitoring device you choose (kit, meter, etc.), is listed for the sole purpose of aiding you in collecting useful data. This includes checking, cleaning, and calibrating your equipment regularly.

2.) **Always use data sheets.** You will find links to these in this handbook. It is important that you utilize data sheets when monitoring water quality as they will help keep your data organized and contextualized. Fill in all applicable portions of a data sheet during monitoring (rather than later) to ensure that data are recorded correctly and nothing is forgotten.

3.) **Be consistent.** Your data will be better-organized, more complete, contextualized, and have more overall utility. If you record the time of day and weather on one monitoring outing, do the same thing for all of your other outings. The data sheet will have areas to record observations such as time of day, weather, stream conditions, location, and other factors that will help add context to your data and make it more useful and replicable for others. It is sometimes useful to record your observations in a small notebook. Recording the date, monitoring practices and results, conditions, and any other notable occurrence will provide you with an organized, chronological record of your observations that can be reviewed again if necessary.

4.) **Don't be afraid to record your observed data.** Record your data even if you think it may be unremarkable or wrong. People often get so caught up in what they expect their data to show that they become disappointed or discouraged when their results contradict their expectations. You should never feel any type of pressure to obtain a certain result. If you have reason to suspect that your results may be incorrect, make sure you're following directions properly, continue to monitor the same parameters at that location, and encourage others to do the same. Properly and thoroughly recorded data from correct, consistent monitoring methods is good data and will aid in your quest to identify and remedy water quality issues should they exist or arise.

If you think your water is clean but your monitoring results tell you otherwise, record what you get and repeat the sample to ensure accuracy.

Obtaining and recording data accurately, following directions, and being as thorough and consistent as possible will reward you with data that can be used to protect your local stream for the enjoyment of future generations.

1.6 Types of Water Quality Monitoring

This handbook aims to provide useful water quality monitoring information to an audience with a broad range of monitoring experiences. Whether you're a TU member with years of water quality monitoring experience looking to take the next step or have zero monitoring experience and are simply interested in becoming involved, our hope is that this handbook will allow you to play an active role in coldwater conservation appropriate to your experience and desires. To that end, we've organized water quality monitoring practices into two levels:

1.) <u>Level 1 Water Quality Monitoring</u>

Level 1 monitoring is intended to be a simple, inexpensive way to determine whether basic water quality parameters are limiting stream and fish conditions. It involves measurements and samples taken with kits, dip strips, thermometers, and meters (depending on parameter tested) at one point in time and is relatively inexpensive (< $300). These types of measurements can be taken in the field and will yield results within a matter of minutes, if not immediately.

2.) Level 2 Water Quality Monitoring

Level 2 monitoring is intended to be a more thorough, expensive type of monitoring that helps determine more precisely the nature of a water quality problem. This type of monitoring tends to be more situation-specific and is intended for predetermined water quality issues found at particular locations. This level of monitoring may be useful to those that already have some type of monitoring protocol in place and wish to develop long-term data sets (weeks, months, or years) in order to better distinguish causes of degradation from environmental variation. Water quality meters and data loggers may be used in some types of Level 2 monitoring; laboratory analysis may also be useful as well as partnering with local universities or environmental organizations when applicable.

3.) Choosing an Appropriate Level of Water Quality Monitoring

Level 1 monitoring is designed for streams with no existing water quality data or known issues and aims to answer the first basic question of water quality monitoring: "Is there an issue with water quality?" If existing water quality data and/or Level 1 monitoring reveals an issue with water quality that is limiting to coldwater fish species, Level 2 monitoring should be conducted to answer the second basic question of water quality monitoring: "What is the issue and what is causing it?"

If desired, Level 2 monitoring can replace Level 1 monitoring as the initial and primary monitoring protocol. Although Level 2 monitoring is more expensive and time consuming than Level 1 monitoring, it produces data that are more precise and may be a worthwhile financial investment if you plan on implementing a stream water quality program for an extended period of time (i.e. several years).

1.7 Variation in Water Quality Parameters

Many of the water quality parameters outlined in this handbook vary naturally by time of day, or due to changes in seasons or weather events. Adding contextual information to our data—such as time, date, location, and weather conditions—can help in understanding whether changes are due to natural variation or some form of degradation.

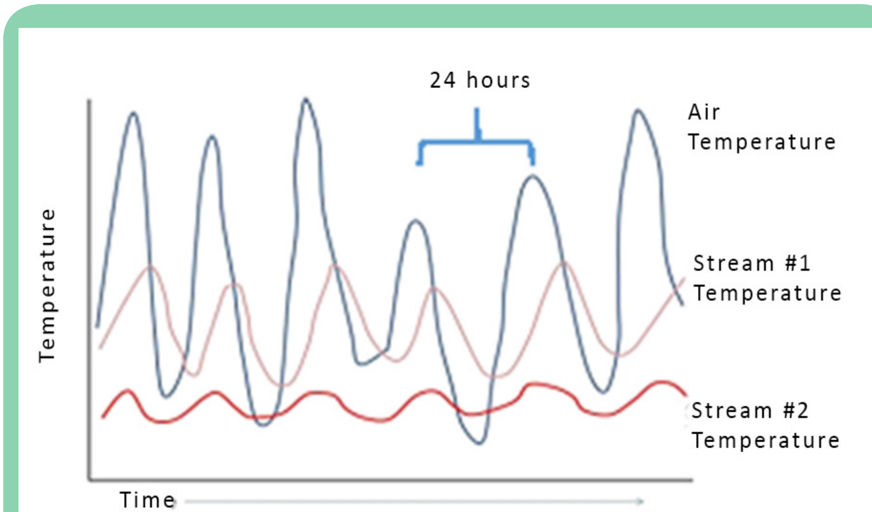

Figure 2. Relationship between air temperature, a surface-flow stream (#1), and a spring-fed stream (#2) over six days.

Weather events also have the ability to impact certain water quality parameters. Runoff from heavy precipitation events can increase turbidity and flush harmful chemicals and compounds, including nitrates and phosphates, from storm drains, streets, factories, and farms into nearby streams. Monitoring data taken up to a few days after a large precipitation event may reflect these flush events in the form of unusually high turbidity, nitrate and phosphate concentrations, and unusual pH values. If these values persist for several days following a precipitation event, the problem is likely not from a flush of storm runoff and should be addressed and investigated as soon as possible.

1.8 Preliminary Monitoring Activities

There are a few key steps that need to be taken prior to actual water quality monitoring activities, regardless of which parameter(s) you're monitoring or what level(s) of monitoring you're conducting. These steps should be completed before any monitoring practices are conducted and any data are recorded.

1.) Obtain the appropriate kit(s), digital multimeter with correct probe(s), and/or other equipment required to monitor selected water quality parameters.

2.) Acquire the All Parameter Data Sheet (Appendix A) for selected water quality parameters. Note: data sheets should be completed in the field as data are obtained.

All Parameter Data Sheet

Data Collector:____________________ **Site ID:**________
Stream Location:____________________

GPS Coordinates:____________________ **Location Description:**____________________
(County, Township, Road, Intersection, Other)

Sample # (if necessary)	**Date**	**Time**	**Water Temperature** (°F/°C)	**Turbidity** (cm / NTU)	**Dissolved Oxygen** (mg/L)	**pH**	**Nitrate/Phosphate** (ppm)	**Air Temperature** (°F/°C)	**Weather Conditions** (sunny, partly sunny, mostly cloudy, raining, or snowing)

Sample	**Weather of Past Two Days:**	**Current Observations/Comments:**
#1	__________	__________
#2	__________	__________
#3	__________	__________
#4	__________	__________
#5	__________	__________

3.) Upon arriving at the monitoring location, mark the bank corresponding to the area in the stream to be monitored with surveyor's tape, stake wire flags, or another type of non-harmful method that is easily recognized. Be sure and place it above the high water mark so that it is not swept away by high flow events. Photographs are also strongly encouraged. Whether you're monitoring daily, weekly, bi-weekly, monthly, or seasonally, it is important to conduct your measurements from the same location at the stream each time you monitor selected parameter(s). Note: acquire permission to monitor individual sites from the appropriate party when necessary.

Some Level 2 monitoring protocols for some parameters require frequent monitoring: daily, weekly, or bi-weekly, as opposed to monthly or seasonally. In these cases, monitoring regiments should be designed beforehand so that monitoring events are conducted at consistent time intervals and produce useful water quality information.

Note that if multiple locations on the same stream are monitored, all monitoring exercises should be performed on the same day so that any data disparities are due to differences in monitoring locations and not daily environmental variations. Because some parameters fluctuate throughout the day and time will naturally elapse as various locations are monitored, alter the order in which locations are visited. Monitor selected parameter(s) from upstream to downstream locations on one monitoring day and from downstream to upstream locations the next, or randomize locations each day.

II. CHAPTER 2 – TEMPERATURE

2.1 Background

Water temperature is an important parameter to monitor because it strongly influences the physiology of cold-blooded organisms, the composition of aquatic ecosystems, and is often a limiting factor for coldwater-dependent species such as trout and salmon. Water temperature also influences water chemistry, and, consequently, many of the water quality parameters outlined in this handbook. Temperature affects nutrient availability, oxygen solubility, and decomposition rates, which, in turn, alter the structure of aquatic ecosystems (Bain and Stevenson 1999). Water temperature is a keystone parameter of coldwater fish species conservation; if water temperatures aren't below a certain level, several other key parameters may also negatively affect the ability of coldwater fish species to survive and reproduce.

Temperature (°F)	Oxygen (mg/L)	Carbon Dioxide (mg/L)
32	14.2	1.1
59	9.8	0.6
86	7.5	0.4

Table 1. The amount of Oxygen and Carbon Dioxide that water can hold at different temperatures. Values are for near sea level.

Other resources for water temperature information:
Water Action Volunteers Temperature Factsheet
USGS Water Science School: Water Temperature
Michigan Trout Unlimited Water Temperature Background

2.2 Level 1 Monitoring: Point-in-time Measurements

Point-in-time measurements of water temperature are collected using thermometers. These types of measurements produce immediate results that can be recorded in the field along with contextual data such as date, time, weather, and location.

Directions for Level 1 Temperature Monitoring (Appendix B Conversion Chart):

1.) Obtain one or more of the following temperature recording instruments: hand-held thermometer, digital thermometer, or a digital multimeter with a temperature probe and acquire the All Parameter Data Sheet (Appendix A). Note: digital thermometers may need to be calibrated. Refer to device manual for calibration instructions.

2.) Upon arriving at the monitoring location, mark the stream bank so that the site can be easily relocated.

3.) Measure and record the air temperature before measuring water temperature. Once air temperature has been measured and recorded, insert the temperature-recording device (thermometer or YSI meter) roughly four inches below the water's surface in a centralized, flowing portion of the stream. Wait approximately 2 minutes until the reading has stabilized before recording the result. If using a thermometer, try to take the reading with the tip of the thermometer still submerged. You can fill a clear plastic cup with water and raise it to eye level to record your temperature, but don't let too much time elapse before taking your measurement.

Instructional videos and equipment:
Temperature Monitoring Instructional Video
Alcohol Thermometer
YSI EcoSense Line many models measure temperature along with other parameters outlined in this handbook

2.3 Level 2 Monitoring: Long-term Trend Monitoring

Long-term temperature trend monitoring is conducted using water temperature data loggers (such as Onset Computer HOBO Water Temp Pro v2) submerged in the body of water for a certain period of time. These types of measurements provide trend data on water temperature variations over time.

Directions for Level 2 Temperature Monitoring:

1.) Acquire Onset Computer HOBO Water Temp Pro v2 water temperature data logger or similar device and set logging interval. The logging interval can be set by connecting the logger to a computer prior to submerging it in a stream. Set the logging interval to record temperature data at the interval you wish it to be recorded (half-hourly, hourly, daily, etc.). An hourly logging interval is common and provides useful data.

2.) Upon arriving at the monitoring location, mark the stream bank so that the site can be easily relocated.

3.) Place the data logger in the protective PVC canister (see link below), then place the canister in a position that ensures it will be submerged throughout the duration of the monitoring protocol. The logger placement position should also be in an area that is free flowing, well mixed, and free of sedimentation (riffles and runs are preferred to pools). Loggers should also be easily accessible in all seasons so that data can be retrieved when needed.

4.) Logger checks can and should be performed throughout the course of the monitoring period to ensure the logger is working properly and not damaged, download the data, and check the accuracy of the data logger temperature measurements with a thermometer. Once the temperature and visual check are completed, remove the data logger from the water and download the data. Once the data are downloaded, redeploy it in the same location and note your observations on the data sheet (e.g. logger buried in sediment, logger in good condition, etc.). Monitor the data logger 1 to 4 times throughout each year of data collection.

For more information regarding Level 2 water temperature monitoring with data loggers (PVC housing, set-up, retrieval, etc.), consult TU's Stream Temperature Monitoring Handbook or the Michigan Trout Unlimited Temperature Volunteer Manual.

Recommended data logger:
Onset Computer HOBO Water Temperature Pro v2 Data Logger

2.4 Preferred Water Temperatures for Coldwater Fish Species

SPECIES	PREFERRED TEMPERATURE (F)	UPPER INCIPIENT LETHAL TEMPERATURE (F)
Rainbow Trout	60	77
Brown Trout	60	77
Brook Trout	59	77
Chinook	57	73
Coho	58	71
Pink Salmon	55	--

Table 2. Preferred and Upper Incipient Lethal Temperatures (UILT) for coldwater fish species. (Hasnain et al. 2010).

Note: both preferred temperatures and upper incipient lethal temperatures may vary regionally among coldwater fish species. Consult with local agencies for the most accurate data for your region.

2.5 Potential Factors Impacting Water Temperature

Streams can experience variations in water temperature with changes in seasons, time of day, weather events such as storms or drought, as well as a variety of land uses and other human influences. Changes in land use along streams can lead to warmer temperatures and changes in many other water quality parameters. Removal of overhanging trees to clear land for agriculture, hot runoff from impervious urban surfaces, and industries that return hot, diverted water to cold rivers (thermal pollution) are all common, human-induced causes of increasing water temperatures.

Figure 3. Turbidity plume from tributary carrying high volumes of suspended sediment after a rainfall event.

III. CHAPTER 3 – TURBIDITY

3.1 Background

Turbidity is the measure of the extent to which light penetration in water is reduced from suspended solids (Armantrout 1998; Barrett et al. 1992). The United States Geological Survey defines turbidity as "the measure of relative clarity of a liquid" (USGS Water Science School 2014). A water resource's turbidity is unique from many parameters in that it is readily visible with the naked eye. A stream that appears dark, murky, or muddy, and disallows large portions of sunlight penetration due to high amounts of suspended solids is considered turbid. Sedimentation, the main cause of turbidity, is the largest water pollutant in the United States.

Turbid streams are not healthy habitats for many aquatic organisms, including coldwater fish species. Suspended solids that filter sunlight out are bad for trout and other aquatic organisms that rely on sight to find food; living in turbid aquatic environments is like living in a perpetual sandstorm. Fish obtain oxygen by filtering water through their gills, a task made harder in turbid waters. Harmful compounds and microorganisms easily bond to the suspended solids that increase turbidity, adding to the already lengthy list of negative impacts of sedimentation. (Appendix B)

Trout trying to breathe in turbid waters is similar to a human trying to breathe without a mask in a sandstorm.

Resources for water turbidity information:
Water Action Volunteers: Turbidity
USGS Water Science School: Turbidity
Minnesota Pollution Control Agency: The Secchi Tube
Nephelometric Turbidity Units Explained (NTU's).

3.2 Level 1 Monitoring: Secchi Tubes and Secchi Disks

Level 1 Turbidity Monitoring is conducted using Secchi disks and Secchi tubes and produces immediate results.

1.) Acquire a Secchi tube, Secchi disk, or similar device for turbidity measurement and the All Parameter Data Sheet (Appendix A). A transparency tube may be used if a Secchi tube is unavailable.

2.) Upon arriving at the monitoring location, mark the stream bank so that the site can be easily relocated.

3.) If using a Secchi disk, wade into the stream and lower the Secchi disk into a flowing, central, deep portion of the water. Be sure and stand downstream from the Secchi disk so that any sediment you disturb while wading or standing does not affect your results. Continue to lower the Secchi disk into the water until it is no longer visible. Record the depth of the water at which the Secchi disk first becomes invisible. It may be useful to attach a small weight to the bottom of the Secchi disk so that it sinks more easily and is less affected by the current. If the stream you are testing is shallow and the disk reaches the bottom before becoming invisible, transparency tubes may be a better option.

Conduct Secchi disk measurements in deeper portions of the stream so that the disk doesn't reach the bottom before becoming invisible.

4.) If using a Secchi tube, collect the sample from a flowing portion of water using a bucket. Be sure to collect a water sample that does not have sediment from the stream bottom. If you do, toss out sample and collect a new one. Scoop your bucket down and into the current flow so that you get a sample from the middle of the water column and not the stream surface or bottom.

Figure 4. Secchi tube

a. If wading: face upstream and collect sample upstream from where you are wading being careful not to collect a water sample containing sediment that you have disturbed by wading.

b. If on the shore: attach your bucket to a pole and scoop below the surface in the upstream direction of the flow.

c. If on a bridge: lower your bucket into the flow below to collect your sample.

5.) Pour the sample into the Secchi tube until filled.

6.) Stand out of the direct sunlight (remove sunglasses), hold Secchi tube vertically, and look straight down into the tube. Lower the Secchi disc into the tube by using the attached string.

7.) By slowly lowering and raising the disc with the string, record the point at which the disc disappears from view in centimeters as marked on the side of the tube. If the disc is visible at the bottom of the tube, then the transparency reading is ">60 cm" or ">120 cm" depending on length of the tube and it is unlikely that turbidity is a limiting factor for coldwater fish.

Consult Water Action Volunteers: Transparency Factsheet and USEPA: Water Monitoring and Assessment, Secchi Disks and Secchi Tubes for more information and detailed instructions on Secchi disk and Secchi tube turbidity monitoring.

Secchi disks and tubes:
Novatech Secchi Disk
LaMotte Secchi Disk
Forestry Suppliers Secchi Tube
Water Monitoring Equipment: Secchi Tubes

3.3 Level 2 Monitoring: Long-term and Multiple-site Monitoring

Unlike Level 1 turbidity monitoring, there is no set protocol for Level 2 turbidity monitoring. Level 2 turbidity monitoring can assume many different forms depending upon determined situations at individual rivers, streams, or creeks.

Suggestions for Level 2 Turbidity Monitoring:

1.) Conduct Level 1 Turbidity Monitoring at several different locations along the same stream. If there is an issue with turbidity, this method could help you discover the location(s) at which turbidity becomes a limiting factor for coldwater fish species, what factor(s) is causing the influx of sediment, and how to solve the problem.

Monitoring turbidity immediately after storms may reveal sources of stream sedimentation.

2.) In situ (on-site) turbidity sensors are expensive and likely not very practical for volunteer monitoring, however, they do provide extremely accurate, laboratory-grade data for long-term turbidity trends. You can request a quote for a YSI turbidity sensor here: YSI Turbidity Sensor.

3.4 Limiting Turbidity Threshold for Coldwater Fish Species

There is no available data on turbidity thresholds for specific coldwater fish species. Streams with high turbidity levels also likely have warmer temperatures, less dissolved oxygen, and more chemical and biological pollution than clear bodies of water, all of which could be stressors for coldwater fish species. Consult local and state agencies (Department of Natural Resources, Fish and Wildlife Services, etc.) for information regarding turbidity thresholds.

3.5 Potential Factors Impacting Turbidity

Sedimentation is one of the most widespread forms of water pollution in the United States and is caused by a wide range of natural and human influences. Significant rainfall events, snowmelt, and natural erosion from wind and water are all natural causes that lead to sedimentation and turbidity. However, when storm events occur on degraded landscapes, erosion and sedimentation can be accelerated beyond natural levels. Human-induced turbidity can last for longer periods and therefore has greater potential to stress coldwater fish species. Land use changes that remove forest cover in exchange for agricultural lands are huge contributors to stream turbidity. Without root systems from vegetative cover to anchor soil and slow wind, a substantial amount of topsoil can readily wash into U.S. waterways each year. Unsustainable agriculture, riparian developments, impervious urban surfaces, and human alteration of flow paths (e.g. channelization) all play large roles in sedimentation and resulting high turbidity levels.

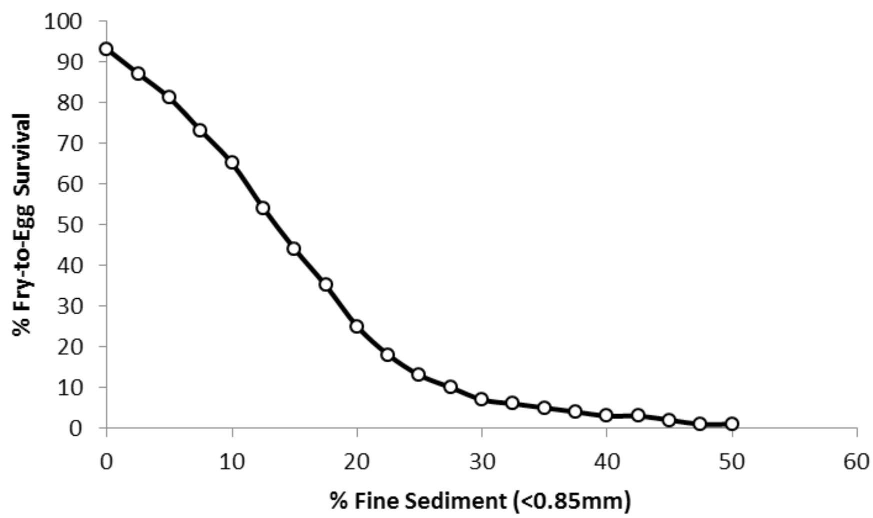

Figure 5. Effect of fine sediments in spawning gravels on coho salmon egg-to-fry survival (Jensen et al. 2009).

Streams with high turbidity are prone to other coldwater fish species limitations such as high temperatures (darker colors absorb and hold more heat), low dissolved oxygen (low sunlight inhibits photosynthesis in aquatic plants), and high biological and chemical pollution (suspended solids act as vehicles for harmful compounds and organisms). Decreasing turbidity can be as simple as encouraging farmers and landowners to preserve riparian zones and informing contractors and farmers about best management practices to decrease erosion

IV. CHAPTER 4 – DISSOLVED OXYGEN (DO)

4.1 Background

The amount of oxygen dissolved in a stream is crucial for the health of aquatic organisms. If oxygen concentrations drop below certain levels, the entire aquatic ecosystem can become stressed and, in extreme cases, due to altered bio-chemical processes, stream metabolism, and hypoxia.

Water bodies can receive much of their oxygen from the atmosphere via wind and wave action. Because streams are flowing bodies of water with rapids and riffles, they typically have high concentrations of dissolved oxygen and aren't as susceptible to eutrophication as stagnant, non-moving bodies of water like lakes and ponds. Water temperature also plays a strong role in dissolved oxygen concentrations; dissolved oxygen solubility and temperature are negatively correlated. The warmer the water temperature, the less dissolved oxygen it can hold and vise versa. The cold water temperatures required by coldwater fish species are therefore able to hold adequate amounts of dissolved oxygen for coldwater fish species survival and reproduction. Dissolved oxygen is also correlated with several other parameters outlined in this handbook and is useful in determining the overall water quality.

Colder water temperatures have higher oxygen solubility whereas water with warmer temperatures can hold less dissolved oxygen.

Resources for dissolved oxygen information:
Water Action Volunteers: Dissolved Oxygen
USGS Water Science School: Dissolved Oxygen
USEPA: Dissolved Oxygen and Biochemical Oxygen Demand
Water Action Volunteers: Dissolved Oxygen Background

4.2 Level 1 Monitoring: Water Quality Kits

Level 1 monitoring techniques for dissolved oxygen are conducted using various water quality monitoring kits, many of which contain materials for testing multiple parameters. Trout Unlimited recommends test kits made by LaMotte or Hach as they are very informative, useful, relatively inexpensive, and provide immediate results.

1.) Acquire a LaMotte or Hach water testing kit (or similar) with dissolved oxygen monitoring capabilities and the All Parameter Data Sheet (Appendix A).

2.) Upon arriving at the monitoring location, mark the stream bank so that the site can be easily relocated.

3.) Using the bottle and stopper supplied in the LaMotte or Hach (or similar) kit, collect a water sample from the flowing portion of the stream. Face upstream and lower the bottle roughly one foot into the oncoming current. Manipulate the bottle under water so that all air bubbles escape and cap it with the stopper before removing it from the water. Once the bottle is stopped and out of the water, look for air bubbles within the bottle. If bubbles are present, pour out the sample and collect another following the same steps. Once you have collected an appropriate sample containing no air bubbles, head to the bank and begin the dissolved oxygen test immediately.

4.) Conduct monitoring exercises at the same time of day each time as dissolved oxygen concentrations fluctuate throughout the day due to changes in ambient temperature.

5.) Refer to the instruction manuals for dissolved oxygen testing in the LaMotte or Hach (or similar) kits (whichever you are using). You can find the step-by-step instructions for both kits here: LaMotte and Hach Dissolved Oxygen Test Methods

Online Manuals for both kits:
LaMotte DO Kit, model 5860-01
Hach DO Kit, model 146900

Kits for purchase:
LaMotte Individual Test Kit for Dissolved Oxygen, model 5860-01
Hach Dissolve Oxygen Kit, model 146900

4.3 Level 2 Monitoring: Long-term and Meter Monitoring

If Level 1 dissolved oxygen monitoring with LaMotte or Hach kits reveal low levels of dissolved oxygen, it may be smart to continue to investigate with more sophisticated, precise monitoring equipment; YSI Ecosense digital multimeters with dissolved oxygen probes are moderately priced, easy to use, and produce precise data. Frequent dissolved oxygen monitoring with a YSI meter over the course of several months (May-September) could aid in determining the extent of the dissolved oxygen issue: one or two unusually low dissolved oxygen readings versus a well-established, consistent lack of dissolved oxygen over the course of several months. Testing multiple locations along the same stream could also be useful in determining if low dissolved oxygen is an issue throughout the stream's course, or if it becomes an issue at a certain point or location.

1.) Obtain a YSI Ecosense digital multimeter (or similar high-end water quality meter) with a dissolved oxygen probe and the All Parameter Data Sheet (Appendix A). Calibrate the meter according to the device's instruction manual before heading out to monitor water quality.

2.) Develop and follow a monitoring regiment without skipping planned monitoring events.

3.) Upon arriving at the monitoring location(s), mark the stream bank so that the site(s) are easily relocated.

4.) Wade into the stream and insert the dissolved oxygen probe of your digital multimeter (YSI or similar) into the middle of the water column in a flowing portion of the stream. Allow the reading to stabilize (approximately 30 seconds) before recording dissolved oxygen values.

Whether you are monitoring one location throughout the summer, monitoring multiple points along a stream, or both, be sure and collect measurements the exact same way each time. Any disparities in data (by location, time, or both) should be from environmental differences in dissolved oxygen levels and not differences in monitoring techniques.

Note that if you monitor multiple locations on the same stream, you should perform all of the monitoring exercises on the same day so that any disparities in dissolved oxygen are due to differences in monitoring locations and not daily environmental variations. Because DO fluctuates throughout the day and time will naturally elapse as you monitor DO at various locations, alternate which locations you visit first. Monitor DO from upstream to downstream locations on one monitoring day and from downstream to upstream locations the next.

Find the equipment here:
[YSI DO 200A Dissolved Oxygen Meter]
[YSI ProODO Optical Dissolved Oxygen Meter]
[YSI EcoSense ODO200 Optical Dissolved Oxygen Meter]

4.4 Limiting Dissolved Oxygen Levels for Coldwater Fish Species

Once dissolved oxygen levels drop below 8 ppm (equivalent to 8 mg/l), coldwater fish species begin to experience decreased growth, activity, fitness, and survival rates (British Columbia Ministry of the Environment). The established acute lethal limit of dissolved oxygen for adult salmonids is 3 ppm and 6 ppm for embryos/juveniles (USEPA 1986). Adult coldwater fish species are more tolerant of low dissolved oxygen levels than embryos and juveniles, needing just 8 ppm to thrive compared to 11 ppm (juveniles) (USEPA 1986; Carter 2005). In general, dissolved oxygen concentrations below 8 ppm are lower than preferred for coldwater fish species and concentrations below 6 ppm are limiting and should be addressed immediately. As always, there will be slight variations in limiting dissolved oxygen concentrations between regions and fish species. Consult with local and state agencies when determining important dissolved oxygen thresholds.

Resources on limiting DO levels:
Carter 2005: Steelhead Trout, Coho Salmon, and Chinook Salmon Biology and Function by Life Stage
Fondriest: Fundamentals of Environmental Measurements, Dissolved Oxygen

4.5 Potential Factors Impacting Dissolved Oxygen Concentrations

Dissolved oxygen concentrations are closely linked to other water quality characteristics. Low dissolved oxygen concentrations in streams can often be traced back to warm water temperatures (see USGS Dissolved Oxygen concentration and Temperature graph),), high turbidity levels, and excess nutrients (eutrophication and excessive plant growth and decay), where their combined effects negatively impact the ability of coldwater fishes to survive and reproduce.

V. CHAPTER 5 – pH

5.1 Background

Monitoring water pH can be a great indicator of increasing pollution or some other environmental problem, especially if there is no readily visible change in the water resource. pH is the measurement of the concentration of available hydrogen and hydroxyl ions in a body of water and is measured on a scale of 1 to 14 with 7 being neutral, values less than 7 being acidic (lots of free hydrogen ions), and values greater than 7 being basic (lots of free hydroxyl ions).

It is important to note that pH is measured on a logarithmic scale, meaning that water with a pH of 4 is 10 times more acidic than water with a pH of 5, and 100 times more acidic than water with a pH of 6.

pH is important for coldwater fish species and all aquatic organisms because the amount of readily available ions in the water determines biological availability and solubility. In other words, pH determines the amount of chemicals that can be dissolved in water and available for aquatic organisms to use. Some of these chemicals are good (nutrients: carbon, nitrogen, and phosphorus) and some are detrimental to fish health (heavy metals: lead, copper, etc.), therefore, it is important that a balance is found (close to neutral 7) that allows aquatic organisms to use nutrients and keeps heavy metals dissolving into the water. If pH is too high or too low, aquatic organisms will be unable to survive.

Resources for pH information:
[USGS Water Science School: pH]
[Fondriest: Fundamentals of Environmental Measurements, pH]

5.2 Level 1 Monitoring: Litmus Paper

pH is one of the easiest water parameters to monitor. Level 1 pH monitoring involves dipping a piece of litmus paper (a pH indicator) into stream and then comparing its color to a color chart corresponding to different pH values. This type of monitoring produces immediate results that can be used to determine whether or not more thorough Level 2 testing is necessary.

1.) Obtain litmus paper (sold in strips and rolls from a variety of sources) and the All Parameter Data Sheet (Appendix A).

2.) Upon arriving at the monitoring location, mark the stream bank so that the site can be easily relocated.

3.) Enter the stream with a small strip of litmus paper. Partially submerge the litmus paper into a flowing portion of water and remove it after a few seconds.

4.) Compare the submerged portion of the litmus paper (which should have changed colors) to the color chart (included with the purchase of litmus paper) and record the corresponding pH value.

Because litmus paper pH monitoring is so inexpensive (relative to other types of water quality monitoring) and easy to do, feel free to repeat the above steps with multiple pieces of litmus paper to add rigor to your data and record the average reading. Note: do not purchase red or blue litmus paper. These are for determining if a single solution is a base or an acid, not both. Make sure the litmus paper you purchase will measure pH on a scale of 1-14.

Litmus paper here:
Amazon: Litmus Paper
Edmund Scientifics: pH paper

5.3 Level 2 Monitoring: Long-term Meter Monitoring

If results from Level 1 pH monitoring with litmus paper reveal a potential water quality impairment due to abundant free hydrogen or hydroxyl ions (pH of below 6.0 or above 9.0), Level 2 monitoring using digital multimeters with pH probes may be appropriate (YSI makes several digital multimeters with pH monitoring capabilities). Digital multimeters record pH values to a tenth of a point whereas litmus paper records pH values on a half-point scale. Long-term pH monitoring (May-September) and/or pH monitoring at multiple stream locations may provide useful information as to seasonal pH trends and determining if dangerous pH levels exist throughout the water resource or only at certain location(s).

1.) Acquire a digital multimeter with a pH probe (YSI or similar) and the All Parameter Data Sheet (Appendix A). Remember to calibrate your pH meter according to the instructions in your meter's manual before you head to the field.

2.) Develop a monitoring regiment and follow it without skipping planned monitoring events.

3.) Upon arriving at the monitoring location, mark the stream bank so that the site(s) can be easily relocated.

4.) Wade into the stream and submerge the digital multimeter's pH probe into the middle of the water column of the flowing portion of the stream. Allow the reading to stabilize (approximately 30 seconds) before recording pH values. Conduct pH monitoring efforts in the same way each time so that differences in pH values are from environmental variations and not monitoring techniques.

Note that if you monitor multiple locations on the same stream, you should perform all of the monitoring exercises on the same day so that any disparities in pH are due to differences in monitoring locations and not daily environmental variations. Because pH fluctuates throughout the day and time will naturally elapse as you monitor pH at various locations, alternate which locations you visit first. Monitor pH from upstream to downstream locations on one monitoring day and from downstream to upstream locations the next, or randomize all locations during each monitoring exercise.

pH meters:
YSI pH Pen, YSI pH10A
YSI Handheld pH meter, YSI pH100A
US Water Systems Handheld pH meter, pH-200 HM Digital Pro Grade Handheld pH Meter

5.4 Limiting pH Levels for Coldwater Fish Species

Most fish species prefer pH levels between 6.5 and 9.0 (Wurts and Durborow 1992) and are negatively impacted when levels fall below 5.0 or rise above 9.6. When pH levels fall below 6.0 (high amounts of available hydrogen ions), fish become vulnerable to fungal infections and heavy metals; fish begin to die at levels below 4.0 (Radke 2013). As always, check with local agencies for the most accurate information regarding regional species' pH preferences and tolerances.

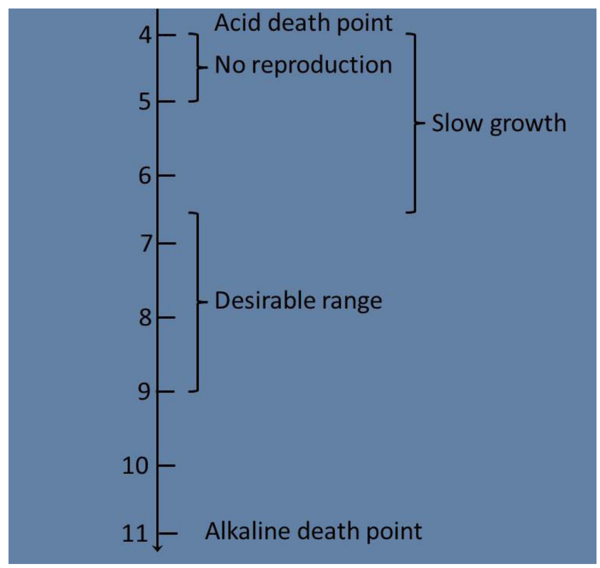

Figure 6. Effects of pH on fish.

5.5 Potential Factors Impacting pH Values

Water acidity and alkalinity are influenced by underlying geologic composition, nearby soils, precipitation events, and mining activities (to name a few). As streams cut paths through or dissolve different types of rock, dissolved ions may alter water chemistry and change pH. Ions, metals, and other compounds in nearby soil may also impact water pH. Precipitation that has previously been in contact with the atmosphere, high amounts of CO2, and other elements can be highly acidic and influences the pH of recipient streams and rivers of water that it falls or flows into. Acid mine drainage caused by surface mining activities drastically alters water pH and is harmful to sensitive aquatic organisms throughout entire watersheds. Natural and human processes alike have the ability to alter water pH and limit coldwater fish species' ability to survive and reproduce.

VI. CHAPTER 6 – MACROINVERTEBRATES

6.1 Background

Macroinvertebrates are aquatic insects, mollusks, clams, worms, and other species that live along or within stream substrates. They are excellent monitoring subjects because they are found all over the world, are relatively immobile (unable to escape pollution and other deleterious water parameters), spend most or all of their lives in the water, and exhibit various tolerances to poor water quality. Biotic indices of macroinvertebrate richness (number of different species or taxa) are important indicators for coldwater streams because they provide key insight into water quality and the overall health of stream ecosystems.

Some species groups, such as stoneflies, are very sensitive to pollutants and tend to disappear in disturbed areas while species such as midges and blackfly larvae, are highly tolerant of pollutants.

6.2 Level 1 Monitoring: Biotic Index

The Biotic Index in this section is a macroinvertebrate assessment borrowed from a protocol designed by the Water Action Volunteers organization in Wisconsin, USA. You can find all steps, information, data sheets, and the instructional videos here: WAV Biotic Index.

1.) Obtain the necessary equipment for assessing macroinvertebrates: D-frame kick net, two white basins or buckets (white background aids in seeing macroinvertebrates), plastic spoons, white ice cube trays, macroinvertebrate identification key, writing utensil, and biotic index data form. Other materials may be useful such as a magnifying glass, tweezers, plastic cups, hip boots (waders) or other water shoes, and latex or plastic gloves.

For streams with rocky bottoms, sample at two separate riffle areas and at one other habitat. For streams with no riffles and soft bottoms, sample at submerged logs, snags, or undercut banks.

2.) Calculating a stream's Biotic Index involves taking samples from different locations. Choose three locations within a 300 ft stream section that support different types of organisms. The goal is to collect as many different kinds of macroinvertebrates from 2 to 3 different habitats to ensure a comprehensive, accurate sample. Several different habitat types may exist in the same stretch of water: riffles (rocky bottom, very diverse), undercut banks (rocky, soft bottoms, moderately diverse), snag areas and tree roots (rocky, soft bottoms, lower diversity), and leaf packs (rocky, soft bottoms, least diverse). For streams with multiple habitats to choose from, start with the most diverse habitat types (i.e. riffles and undercut banks).

3.) Before taking samples, make sure that the D-frame net doesn't have any debris on it from previous sampling exercises. Fill white basins/buckets so that about one inch of clean stream water covers the bottom. Once you begin sampling, if your water sample in the first basin/bucket is too muddy, pour it through your net into the second basin/bucket and add some clean water if necessary. Turn your net inside out and dislodge any remaining macroinvertebrates into the basins.

4.) You will collect three total Biotic Index samples within a 300 ft stretch of stream. A complete Biotic Index sample consists of subsamples collected from different habitats (focusing on the most diverse habitats first) in the stream.

Figure 7. Sampling invertebrates with a D-frame net. Photo: Schrems West Michigan TU.

5.) For riffle sampling:

a. Collect one sample in the upstream portion and one in the downstream portion. Together, both samples comprise one of the three Biotic Index samples.

b. Enter the downstream portion of riffle. Place the flat side of the D-frame kick net on the stream bottom facing upstream and move so that you are standing in front (upstream) of the net opening.

c. Proceed to disturb the streambed by shuffling your feet around and kicking the stream bottom to dislodge macroinvertebrates and let the current carry them into the net. If the stream is shallow enough, scrub river rocks with your hands to dislodge any macroinvertebrates. Do this for two minutes.

d. Carry the net to the shore and empty it into one of the basins. Turn the net inside-out and remove any remaining macroinvertebrates with your hands and place them in the basin.

e. Repeat steps b through d for the upstream portion of the riffle. Combine the contents of the second sample with the first in the basin.

f. Thoroughly inspect all pieces of debris to ensure that all macroinvertebrates are found.

g. You now have a Biotic Index sample. Combine this sample with the other samples taken from other habitats.

h. Once you have collected three Biotic Index samples, identify the macroinvertebrates using the identification key and determine water quality by calculating the Biotic Index using the Biotic Index data form.

6.) For undercut bank sampling:

a. Undercut banks are habitats with carved out areas just below the surface of the water. The overhanging bank is habitat to many macroinvertebrates.

b. Facing the bank, move the D-frame kick net in a bottom-to-surface motion, jabbing at the bank vegetation to dislodge macroinvertebrates. 20 jabs comprise a biotic index sample.

c. Carry the net to shore and dump the contents in a basin. Turn the net inside-out and remove any remaining debris or macroinvertebrates and place them in the basin.

d. Thoroughly inspect all pieces of debris to ensure that all macroinvertebrates are found.

e. You now have a Biotic Index sample. Combine this sample with other samples taken from other habitats.

f. Once you have collected three Biotic Index samples, identify the macroinvertebrates using the identification key and determine water quality by calculating the Biotic Index using the Biotic Index data form.

7.) For snag, tree root, and submerged log sampling:

a. Snag areas are accumulations of debris caught behind logs, stumps, or boulders in the water.

b. Select a three-foot by three-foot area (for uniform comparisons) around the snag, submerged roots, logs, or other debris.

c. Scrape the surface of tree roots, logs, or other debris with the D-frame kick net. The surfaces can also be disturbed with a stick or your hands and feet. You can pull off some of the bark to get at organisms hiding underneath. 20 jabs comprise one sample.

d. Carry the net to shore and dump the contents in a basin/bucket. Turn the net inside-out and remove any remaining debris or macroinvertebrates and place them in the basin.

e. Thoroughly inspect all pieces of debris to ensure that all macroinvertebrates are found.

f. You now have a Biotic Index sample. Combine this sample with other samples taken from other habitats.

g. Once you have collected three biotic index samples, identify the macroinvertebrates using the identification key and determine water quality by calculating the Biotic Index using the Biotic Index data form.

8.) For leaf pack sampling:

a. Look for old leaf packs that are several months old. Old leaf packs are dark brown, slimy, and slightly decomposed.

b. Position the D-frame kick net downstream of the leaf pack and use your hands to gently move it into the net.

c. Carry the net to shore and remove the leaves one by one to inspect them for macroinvertebrates. Place all discovered organisms in the basin.

d. Thoroughly inspect all debris, leaves, and the net for any remaining macroinvertebrates and place them in the basin.

e. You now have a Biotic Index sample. Combine this sample with the other samples taken from other habitats.

f. Once you have collected three Biotic Index samples, identify the macroinvertebrates using the identification key and determine water quality by calculating the Biotic Index using the Biotic Index data form.

9.) Once the Biotic Index has been calculated using the Biotic Index data form, safely return all macroinvertebrates to the stream and rinse the basins and D-net so that they are clean for future sampling activities.

Stream Health	Excellent	Good	Fair	Poor
Biotic Index	> 3.5	2.6 to 3.5	2.1 to 2.5	1.0 to 2.0

Table 3. Biotic Index Water Quality Grades

Resources for this section:
WAV: Biotic Index fact sheet and Methods
WAV: Biotic Index data form
WAV: Macroinvertebrate Identification Key
Macroinvertebrate Monitoring Instructional Videos

D-frame Kick Net:
Heavy Duty D-Frame Water Quality Net
D-Frame Dip Net

6.3 Level 2 Monitoring

Once a Level 1 Biotic Index has been performed, there isn't much more that a volunteer citizen science initiative can do as far as macroinvertebrates are concerned. Thorough, complex macroinvertebrate analyses often require laboratory work and expert knowledge. If Biotic Index results indicate poor water quality that may be limiting to coldwater fish species, we recommend monitoring other parameters

(Level 1 or Level 2) or partnering with local universities, environmental organizations, or governmental agencies to determine if a more thorough assessment in partnership with a professional lab is necessary.

6.4 Potential Factors Impacting Macroinvertebrate Abundance

Like coldwater fish species, macroinvertebrates are impacted by various water quality parameters including temperature, turbidity, dissolved oxygen, pH, and nitrates and phosphates. Many of these parameters are influenced by human activities including but not limited to land use changes, thermal pollution, urban and agricultural runoff, chemical pollution, and mining activities.

VII. CHAPTER 7 – NITRATES AND PHOSPHATES

7.1 Background

Nitrogen and phosphorous are crucial nutrients for aquatic plants and fish, but they can cause problems when in abundance. Excess nutrients in water, a condition known as nutrient pollution or eutrophication, can lead to a low oxygen levels that suffocate aquatic life (hypoxia). Although eutrophication can naturally occur as lakes age over time it is often associated with excess nutrient loading, especially in streams.

When nutrient pollution occurs, dissolved oxygen levels increase substantially as photosynthesis rates accelerate due to increased algal growth from increased nutrient availability. However, once algae and aquatic plants begin to die oxygen-consuming bacteria decompose them. This can cause anoxic conditions and hypoxia because photosynthesis only occurs during the day but decomposition occurs night and day.

Eutrophication is much more common in standing bodies of water than flowing water, however, coldwater fish species are extremely sensitive to low levels of dissolved oxygen that nutrient pollution can exacerbate. Slow moving rivers can be susceptible to eutrophication as well as streams flowing out of stationary bodies of water. Dams also slow historically fast flowing rivers and allow nutrient rich sediment to build up, sometimes causing eutrophication.

Resources for nitrate and phosphate information:
IUPUI Center for Earth and Environmental Science: Water Quality
Chislock et al. 2013: Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems

7.2 Level 1 Monitoring: Water Quality Kits

Similar to dissolved oxygen monitoring, nitrate and phosphate concentrations can be measured simply and effectively using water quality kits (LaMotte or similar). These kits are relatively inexpensive, easy to use, and provide immediate results that can be recorded in the field.

1.) Acquire a LaMotte (or similar) nitrate and phosphate test kit and the All Parameter Data Sheet (Appendix A).

2.) Upon arriving at the monitoring location, mark the stream bank so that the site can be relocated.

3.) Refer to individual kit instructions for step-by-step directions on collecting a sample, adding the appropriate reagent, and properly interpreting your observations.

a. If testing for nitrogen with the LaMotte Nitrate Nitrogen Tablet Test Kit 3354-01, refer explicitly to these instructions.

b. If testing for phosphorous with the Hach Phosphorus Test Kit PO-19, refer explicitly to these instructions (download manual link).

4.) Record results on data sheet.

Figure 8. Hach phosphorous test kit.

7.3 Level 2 Monitoring: Long-term Meter Monitoring

If Level 1 results of nitrates or phosphates indicate that nutrient pollution exists, Level 2 monitoring may be appropriate. Long-term (May-September) monitoring protocols with digital multimeters with nitrate and/or phosphate probes (YSI or similar) can provide more insight into the excess nutrient problems discovered during Level 1 monitoring. Monitoring at multiple locations along the same stream may also be useful in determining if and where nitrates or phosphates become a limiting for coldwater fish species.

1.) Obtain a YSI Professional Plus handheld water meter that tests a variety of water quality parameters, including nitrates, or a Hanna Handheld Phosphate Checker water test meter (designed for aquariums) or similar meters and the All Parameter Data Sheet (Appendix A).

2.) Develop a monitoring regiment and follow it without skipping planned monitoring events.

3.) Upon arriving at the monitoring location(s), mark the stream bank so that the site(s) can be easily relocated.

4.) If testing for nitrates: submerge the nitrate probe of your digital multimeter into the middle of the water column in a flowing portion of the stream. Wait for the reading to stabilize (approximately 30 seconds) and record the results on the data sheet.

5.) If testing for phosphates:

a. Collect a water sample from the middle of the water column of flowing portion of the stream using the vial included with the phosphate checker.

b. Calibrate the phosphate checker with recently collected sample. Once calibrated, add the reagent to the sample vial and shake to dissolve. Once dissolved, reinsert the vial into the checker and press and hold the button on the front. Record the result (3-minute wait) on the data report sheet.

c. Hanna Instruments Phosphate Checker instructional video

7.4 Limiting Nitrate/Phosphate Levels for Coldwater Fish Species

Nitrate nitrogen levels exceeding 100 ppm (or 100 mg/L) have negative impacts on some trout species such as stunted growth (curved spines), sideways swimming, and increased swimming speeds; nitrate

Figure 9. Buffer zones between fields and streams can help absorb nutrients (nitrogen and phosphorus). Photo: J. Hastings.

nitrogen concentrations less than 100 ppm do not appear to inhibit trout growth (The Freshwater Institute). Nutrient toxicity for fish varies by species and region, and you may find the USEPA's Ecoregional Criteria Documents for Excess Nutrients useful, specifically the Summary Table for the Nutrient Criteria Documents. As always, check with local and state agencies for the most accurate nutrient toxicity data for your region.

7.5 Potential Factors Impacting Nitrate and Phosphate Concentrations

Excess nitrogen and phosphorous find their way into streams through a variety of pathways. Runoff from agricultural activities is one of the largest sources of nutrient pollution. Large-scale agricultural operations use large amounts of fertilizer each year, some of which inevitably makes its way into bodies of water, accelerating plant growth, and contributing to eutrophication.

Urban runoff contributes nitrates and phosphates to streams in the form of storm water runoff, sewage and septic wastes, and lawn and garden fertilizers. Excess nutrients can exacerbate existing water quality issues like warm temperatures, turbidity, and low dissolved oxygen concentrations.

VIII. CHAPTER 8 – RESULTS, SUGGESTIONS, & ADDITIONAL RESOURCES

8.1 What to do with your Results

The purpose of conducting water quality monitoring exercises is to gain a better understanding of the water quality in your local rivers, streams, and creeks in order to protect coldwater fish species and their habitats. Data obtained from water quality monitoring can tell us whether or not the stream in question provides a healthy environment for coldwater fish species or limits them in some way. These same procedures can be used to determine the effectiveness of management or restoration activities and refine our ability to better protect these fish.

Although water quality monitoring is a key first step to protecting coldwater fish species, what you do with the results of your monitoring is equally important. If the results from Level 1 and/or Level 2 monitoring indicate that a limiting water quality issue exists, the appropriate authorities need to be notified so that steps can be taken towards improving water quality. Each state has a department dedicated to protecting natural resources and the environment (Department of Natural Resources, Department of Environmental Protection, Department of Environmental Quality, etc.). The Environmental Protection Agency and U.S. Fish and Wildlife Service also have offices in each state. Contacting these agencies is a good place to start. These organizations exist to protect and conserve the environment and the mammals, plants, fish, and birds that depend on healthy and appropriate environmental conditions for survival. Notify them if your results suggest poor water quality; they may be interested in conducting some water quality monitoring of their own or even joining you in the field the next time you go. Local universities may also be worth notifying. Universities often have expensive water testing equipment, laboratory access, knowledgeable faculty, eager students, and have credibility with state environmental agencies, all of which could be useful in solving water quality problems.

Find your state's agencies here:
USEPA State Health and Environmental Agencies
Fish and Wildlife Services

8.2 Multi-Parameter Monitoring Equipment

The most useful water quality assessments are those that monitor multiple parameters. Trout Unlimited recommends monitoring as many of the parameters outlined in this handbook as possible in order to gain a comprehensive understanding of local water quality. Fortunately, there are several kits that you can purchase that are capable of monitoring multiple parameters. Since all monitoring practices outlined in above sections require some degree of financial commitment, it may be more economically practical to purchase a kit that tests multiple parameters instead of purchasing one or a few separate kits for individual parameters. Monitoring multiple water quality parameters will provide a well-rounded glimpse of overall water quality and will be more time- and financially efficient for both Level 1 and Level 2 monitoring protocols.

Useful multi-parameter kits and meters:
LaMotte Water Quality Educator and Monitoring Outfit 5870
Parameters: pH, Nitrate-Nitrogen, Phosphate, Dissolved Oxygen, Alkalinity (related to pH), Turbidity, and Temperature

LaMotte Shallow Water Testing Outfit 5854-02
Parameters: Temperature, pH, Turbidity, and Dissolved Oxygen

LaMotte Earth Force Standard Water Monitoring Kit 5848

Parameters: Dissolved Oxygen, Nitrate, pH, Phosphate, Turbidity, Temperature, Biochemical Oxygen Demand, and Coliform Bacteria

LaMotte Earth Force Low Cost Water Monitoring Kit 3-5886

Parameters: pH, Dissolved Oxygen, Temperature, Turbidity, Nitrate, Phosphate, Biochemical Oxygen Demand, and Coliform Bacteria

For a complete list of multi-parameter LaMotte water monitoring kits, click here.

8.3 Acknowledgements

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8.4 Additional Web Resources

There is no shortage of useful resources containing information on water quality parameters, the significance of these parameters to coldwater fish species and other aquatic organisms, existing monitoring initiatives, and general water quality and aquatic health knowledge. Consult these resources to supplement your knowledge of water quality monitoring and results, and to better understand your local freshwater resources.

Water Action Volunteers
Water Action Volunteers Biotic Index Background
Water Action Volunteers Biotic Index Fact Sheet
Water Action Volunteers Dissolved Oxygen Background
Water Action Volunteers Dissolved Oxygen Fact Sheet
Water Action Volunteers Temperature Fact Sheet
Golden State Flycasters Conservation
Michigan Trout Unlimited Education
Michigan Trout Unlimited River Stewards
Central Wisconsin Trout Unlimited River Keepers
Fondriest Environmental: Water Quality
Fondriest Environmental: Dissolved Oxygen
Fondriest Environmental: pH of Water
National Water Quality Monitoring Council
How's My Waterway
Crooked River Project
Government of British Columbia Ministry of the Environment: Ambient Water Quality for Dissolved Oxygen
Hach Company's H2O University: Important Water Quality Factors
Hach Dissolved Oxygen Test Kit Instruction Manual
Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign. World Weather 2010 Project. Summary of the Hydrologic Cycle

Hoopman Riverview Science. Water Monitoring: Turbidity
IUPUI Center for Earth and Environmental Science Water Quality
LaMotte Dissolved Oxygen Kit Instruction Manual
Queen's Printer for Ontario. 2004. Ministry of Natural Resources: Ontario Fish Water Temperature Preferences. Kab Lake Lodge
Red River Basin Water Quality Monitoring Volunteer Manual
Turbidity in Lakes: Nephelometric Turbidity Units
United States Department of Agriculture National Sedimentation Laboratory
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United States Environmental Protection Agency Summary Table for the Nutrient Criteria Documents
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United States Geological Survey Water Science School Dissolved Oxygen
United States Geological Survey Water Science School pH
United States Geological Survey Water Science School Temperature
United States Geological Survey: Water Quality

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8.6 Appendix A

All Parameter Data Sheet

Data Collector: ______________________ **Site ID:** __________ **Stream Location:** ______________________

GPS Coordinates: ______________________ **Location Description:** ______________________________

(County, Township, Road, Intersection, Other)

Sample # (if necessary)	**Date**	**Time**	**Water Temperature** (°F/°C)	**Turbidity** (cm / NTU)	**Dissolved Oxygen** (mg/L)	**pH**	**Nitrate/Phosphate** (ppm)	**Air Temperature** (°F/°C)	**Weather Conditions** (sunny, partly sunny, mostly cloudy, raining, or snowing)
			/				/	/	
			/				/	/	
			/				/	/	
			/				/	/	
			/				/	/	
			/				/	/	

Sample	**Weather of Past Two Days:**	**Current Observations/Comments:**
#1	______________________	______________________
#2	______________________	______________________
#3	______________________	______________________
#4	______________________	______________________
#5	______________________	______________________

8.7 Appendix B - Useful Conversion Charts

Temperature Conversion Chart

Fahrenheit	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Celsius	0	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.6	6.1	6.7	7.2	7.8	8.3	8.9	9.4	10

Fahrenheit	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
Celsius	10.6	11.1	11.7	12.2	12.8	13.3	13.9	14.4	15.0	15.6	16.1	16.7	17.2	17.8	18.3	18.9	19.4	20.0	20.6

Fahrenheit	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
Celsius	21.1	21.7	22.2	22.8	23.3	23.9	24.4	25.0	25.6	26.1	26.7	27.2	27.8	28.3	28.9	29.4	30.0	30.6	31.1	31.7

Transparency Conversion Chart

Centimeters	Inches	Approximate NTU Value
<6.4	<2.5	>240
6.4 to 7.0	2.5 to 2.75	240
7.1 to 8.2	2.76 to 3.25	185
8.3 to 9.5	3.26 to 3.75	150
9.6 to 10.8	3.76 to 4.25	120
10.9 to 12.0	4.26 to 4.75	100
12.1 to 14.0	4.76 to 5.5	90
14.1 to 16.5	5.6 to 6.5	65
16.6 to 19.1	6.6 to 7.5	50
19.2 to 21.6	7.6 to 8.5	40
21.7 to 24.1	8.6 to 9.5	35
24.2 to 26.7	9.6 to 10.5	30
26.8 to 29.2	10.6 to 11.5	27
29.3 to 31.8	11.6 to 12.5	24
31.9 to 34.3	12.6 to 13.5	21
34.4 to 36.8	13.6 to 14.5	19
36.9 to 39.4	14.6 to 15.5	17
39.5 to 41.9	15.6 to 16.5	15
42.0 to 44.5	16.6 to 17.5	14
44.6 to 47.0	17.6 to 18.5	13
47.1 to 49.5	18.6 to 19.5	12
49.6 to 52.1	19.6 to 20.5	11
52.2 to 54.6	20.6 to 21.5	10
>54.7	>21.6	<10

Courtesy of Hoopman Riverview Science