Lake Superior Educators’ Handbook

Scientific Exploration of Lake Superior & Connecting Waters
Aboard the Research Vessel (R/V) *Agassiz"

By
Western U.P. Center for Science, Math & Environmental Education and
Dept. of Civil & Environmental Engineering at Michigan Technological University.

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Introducing the Agassiz Research Vessel (R/V)

Welcome to the Research Vessel (R/V) Agassiz. The Agassiz is a well equipped floating laboratory-classroom used to study the aquatic environment of Lake Superior and connecting waters. Lake Superior contains 50% of all the water in the five Great Lakes, and is the largest body of water by surface area in the world! The Great Lakes contain 95% of the United State’s freshwater.

Michigan Technological University operates the Agassiz for research and education. This manual introduces you to the vessel logistics and provides background on sampling and the biological, physical, and chemical parameters of water. It is written to assist teachers and group leaders in understanding the logistics of the scientific cruise aboard the vessel.

The Agassiz is a custom-built, 36-foot, aluminum-hulled vessel. It is used by university classes, faculty and graduate students conducting Great Lakes research. Some of our most enthusiastic participants are middle and high school students and teachers who extend their classrooms to include the waters of Lake Superior and the Keweenaw Waterway.

An Opportunity to Study Lake Superior and Connecting Waters

Here in Michigan’s Upper Peninsula, our students live beside the largest freshwater lake in the world! To many of them, this vast body of water will serve only as a backdrop for their lives...a place to live, work and play. However, these students also have the good fortune of living near a university which is active in the exploration of that lake. Class excursions aboard the Agassiz are now available to regional middle and high school students, providing an opportunity for a hands-on, guided experience in scientific water quality investigation. An afternoon aboard the Agassiz can help to maintain student interest in science and math and open the door to exciting career opportunities.

The R/V Agassiz offers great flexibility in the design of educational experiences, working with teachers to deliver age-appropriate content that complements classroom curricula. Typically, a cruise is 2-4 hours, with 4 hours needed to visit Lake Superior. Teachers may select their cruise destination, choosing between the waters of Portage Lake, Torch Lake, Keweenaw Waterway and Lake Superior. Lake water quality can vary both seasonally and with location. Cruises may be tailored to a teacher’s request and the curricula. Content varies depending on cruise length and season. The captain is also willing to demonstrate electronic navigation and other equipment, upon request. Examples of topics investigated on educational cruises are listed below.

Biological Limnology

Plankton nets are used to sample phytoplankton and zooplankton. Samples are brought back to the lab (or taken to the classroom) for viewing. A PONAR sediment dredge is used to collect samples of the invertebrate animals which inhabit the bottom sediments. Samples are processed to separate the animals from the sediment and the collection is inspected. On board discussion focuses on differences in the diversity of aquatic life in different habitats and the role of invertebrate animals as indicators of ecosystem health.
Physical Limnology
Depth, water clarity, turbidity, water color, temperature may be measured and bottom sediments collected with a PONAR dredge. The sand-silt-clay content of sediment samples from various depths are compared. Discussion focuses on the role of particle size, density, and their interaction with wave energy in determining the types of organisms which can inhabit various environments.

Chemical Limnology
Depth profiles of dissolved oxygen and water temperature are developed at several sites using a HydroLab sonde. Vertical structure in oxygen and temperature is explored as a basis for understanding the significance of the thermal stratification process. On board discussion focuses on the interplay of physics (temperature), chemistry (oxygen), and biology (oxygen consumption) in determining the oxygen resources of lakes. Acidity (pH), alkalinity, and conductivity may also be measured.

Safety
The Agassiz has been inspected by the U.S. Coast Guard and certified as a small passenger vessel. Agassiz captains are licensed by the Coast Guard as U.S. Merchant Marine Officers. The Agassiz is equipped with a full complement of safety (life jackets, fire suppression system, lifeboat), navigation (electronic charting, GPS, radar) and communications (cell phone, marine radios, EPIRB) gear.

Capacity
The Agassiz can carry a teacher and up to 16 students, in addition to the captain, an MTU scientist, and a deck hand. Larger classes can be accommodated by splitting the cruise into two segments and scheduling companion visits to local sites of environmental interest, e.g. a wetland or wastewater treatment plant.

Seasonal Availability
The Agassiz sails from ice-out in May through October. September cruises provide an exciting start to the school year, offering hands-on experiences supporting classroom discussions. May and June cruises help integrate principles developed over the year in the classroom.

Cost
The cost for a four-hour scientific cruise for school classes varies with the availability of grants, rising cost of fuel, availability of a Michigan Tech faculty scientist or graduate student to accompany the cruise, and other factors. Contact Joan Chadde (see below) for current cost information. All water quality sampling equipment is provided.

Reservations
To learn more about scientific educational cruises for K-12 classes, youth or the community, contact Joan Chadde, K-12 Education Program Coordinator at Michigan Tech. Chadde has an M.S. in Water Resources and extensive experience leading environmental explorations for elementary, middle, and high school students. MTU faculty and graduate students are available to lead cruises, sharing their expertise and introducing students to the fascinating world of Great Lakes water quality and research.

To Arrange a Scientific Cruise Aboard the Agassiz, please contact:
Joan Chadde, K-12 Education Program Coordinator, Center for Science & Environmental Outreach
115 Great Lakes Research Center - Michigan Technological University, 1400 Townsend Dr., Houghton, MI 49931
Tel: 906-487-3341   Email: jchadde@mtu.edu
Agassiz Web Page: http://techalive.mtu.edu/resources/agassiz/index.htm
Instructions for the Teacher

1. **Confirm the time and place to meet the vessel.**
   Plan to arrive at the dock about 10 minutes before departure. If you have to cancel your reservation or if your group will be late, notify the Western U.P. Center at 906-487-3341 as soon as possible.

2. **Submit “float plan,” i.e. a list of participants 2 days in advance of departure** (Maximum 18 people)
   Please email or fax your list of participants (called a ‘float plan’) to Joan Chadde (jchadde@mtu.edu) who will provide it to the Chief Scientist the day before your scientific cruise. The Chief Scientist and Captain need to know the exact number and names of students and adults prior to departure. A maximum of 18 passengers is allowed on the Agassiz, in addition to the Captain and Chief Scientist.

3. **Be prepared for any weather conditions.**
   The vessel will go out regardless of weather and temperature, unless conditions are severe or there is lightning.

4. **Wear/bring appropriate clothing**
   Check the weather forecast the day before. Remind students that it can be 10-20°C cooler and windier on the water, so encourage them to bring a jacket, rain gear, and hat. Participants deemed not appropriately dressed for conditions will be asked to stay on shore. Participants should wear close-toed shoes onboard, preferably rubber-soled, as a wet deck is very slippery. If sensitive to the sun, students should wear a long sleeve shirt, long pants, and bring the proper sunscreen. (NOTE: long pants and closed toed shoes are also required in the lab).

   Students should bring extra clothes (jacket, rain gear, hat) and a water bottle in a backpack which can be stored below deck. Student cell phones should not be taken on-board and adult use of cell phones is limited to emergencies. Unless out for a full day, there will be no opportunity for eating. Snacks may be permitted on longer excursions. No gum chewing is allowed on the vessel.

5. **Determine special needs of the group.**
   If there are any disabled (physical or developmental) members of the group, or any special needs, please let the Center know as soon as possible so appropriate arrangements can be made. For those needing medication for motion sickness, advise them to take their medication at the proper amount of time BEFORE going on-board the vessel. Check if anyone in the group has a need for special medication or is allergic to insects such as bees and wasps. Advise them to have any needed medication with them.

6. **Safety procedures aboard the vessel.**
   At the start of each cruise, the Captain will provide safety instructions to all passengers. Be sure that everyone in the group is aware of the importance of safety aboard the vessel and listens carefully. Anyone under twelve years of age will be required to wear a life jacket at all times. Just before your cruise begins, the crew will instruct you on where you’ll need to stand during certain parts of the trip. Stay clear of the ropes.
7. **Supervision and discipline.**
   The Chief Scientist will facilitate the education program. **Class teachers and chaperones are expected to supervise and discipline students during the cruise—this is not the responsibility of instructors, captains, or crew.**

8. **Using Pre-Trip Activities**
   Pre-trip activities are included that will enhance students’ interest and understanding of lakes and water quality monitoring. We encourage teachers to use these activities to introduce students’ to the Great Lakes and to spark their interest in our freshwater resources. Many of the activities can also be used as post-trip activities.

9. **Using Post-Trip Activities**
   Teachers are encouraged to conduct post-trip activities in their classrooms after a scientific cruise. The knowledge gained in understanding our freshwater resources can be put to use through individual, classroom, and community activities.
Understanding Lakes

Scientific cruises are designed to address “Are the Great Lakes Healthy?” and "What is the water quality?" You will participate in several monitoring activities aboard the research vessel that are designed to help answer these questions. Water quality is defined in terms of physical, chemical, and biological parameters with respect to a certain use. For example, acceptable water quality for warm water fishes would not be optimal for coldwater fishes, and standards for drinking water differ from those for boating and recreation. No single factor alone indicates good water quality, and the quality varies with factors such as season and location. Long-term water quality measurements from well-defined locations are needed to tell if conditions are changing or remaining the same.

**Biological Properties of Water**

Biological properties of water that may be sampled aboard the Agassiz include:

- Phytoplankton
- Zooplankton
- Benthos

Plankton nets are used to sample for plankton, the smaller mesh size samples the phytoplankton and the larger mesh size samples for the zooplankton. A PONAR dredge samples for benthic organisms.

Like other ecosystems, lakes host a complex combination of plants (producers), animals (consumers), and decomposers, which are interrelated through food chains and food webs. Introduction of exotic or nonindigenous species can upset the balance of existing food chains. The productivity of a body of water is dependent upon variables such as the available nutrients, light, and temperature.

Aquatic plants and animals are generally divided into three groups:

1. **Plankton** – plant and animal organisms that drift with the currents
   - a. phytoplankton - plants
   - b. zooplankton - animals
2. **Nekton** - larger size organisms that can swim freely
3. **Benthos** - organisms which live in the sediment or on the bottom of a water body, i.e. bloodworms (larval stage of a midge *Chironomus sp.*), phantom midges, and *Diporeia sp.*

These organisms have a spatial distribution that is defined by regions adjacent to the shore (littoral), open waters (limnetic or pelagic), and the bottom (benthos).

**Physical Properties of Water**

Physical properties of water that may be measured aboard the Agassiz include:

- water transparency or clarity
- color
- turbidity
- temperature

Suspended particles in water influence water color and clarity. Particles can settle to the bottom and contribute to a buildup of sediment. Instruments and equipment used to quantify these properties include the Secchi disk, turbidity tubes, and thermometers.

Water is a unique chemical compound that exists naturally on earth in the gaseous (water vapor), liquid, and solid (ice) states. Water has a maximum density at 4°C, boils at 100°C, and freezes at 0°C.
Chemical Properties of Water

Chemical properties of water that may be measured aboard the Agassiz include:
- dissolved oxygen
- pH
- conductivity
- alkalinity
- phosphorus
- nitrogen

Water chemistry is influenced by many factors such as the geology of a region, photosynthesis and respiration, pollutant load, pressure, temperature, and time of day. Water behaves as a solvent in which a substance (solute) dissolves. The resulting solution may contain individual ions (particles with charges) or molecules. Gases, solids, and other liquids are capable of dissolving in water but some of these substances do not dissolve. The solubility of a solid in water generally increases with temperature while the solubility of a gas decreases with temperature. Concentrations of a chemical in water are generally expressed in terms of milligrams per liter (mg/L), parts per million (ppm), and percent saturation for gases. Heavy metals and organic compounds require specialized laboratory equipment for their measurement and are not sampled on a standard cruise.

Comparing Water Quality

One of the best ways to understand water quality is to compare two areas that differ in their water quality. If time allows, you will sample and compare Lake Superior with another water body (Torch Lake, Portage Waterway, Dollar Bay). Lake Superior is the largest body of fresh water in the world by surface area (31,700 square miles), making it the largest Great Lake. The flushing time of the Lake is 199 years. The average depth of Lake Superior is 483 feet with a maximum depth of 1332 feet making it the deepest Great Lake. Overall water quality can be evaluated by considering the trophic status or biological productivity. Eutrophication, or aging of lakes, progresses through various trophic states (oligotrophic --> mesotrophic --> eutrophic). As lakes age, their nutrient levels, organic matter content, and turbidity increase, while the dissolved oxygen levels and water transparency decrease. The trophic state indicates the biological productivity of a water body.

The open waters of Lake Superior are oligotrophic. Oligotrophic lakes are characterized by low nutrient levels, low biomass, high oxygen concentrations, and high transparency. These lakes are usually deep. Eutrophic lakes are highly productive with high nutrient levels, high biomass, low oxygen concentration in the bottom waters, and low transparency. The large volume of organic matter accumulated in bottom sediments depletes oxygen as it decomposes. Mesotrophic lakes are between the other two trophic states in their characteristics. Of the 730 inland lakes that the Michigan Department of Environmental Quality has assessed, 33% of Michigan lakes were eutrophic, 51% were mesotrophic, and 16% were oligotrophic (MDEQ, 2000).
Great Lakes Food Web

The general flow of biomass in Lake Superior is through trophic levels that include producers: phytoplankton (algae) and aquatic plants (macrophytes), and consumers: zooplankton, forage fishes, predator fishes, and fish-eating humans and other animals. The Lake Superior food web is composed of two distinct but overlapping parts: the pelagic food web associated with offshore open water (pelagic) and the bottom (benthic) food web. Both webs are dependent upon the phytoplankton in the surface waters. (See the food web shown on the next page).

Members of the pelagic food web include small invertebrates such as cladocerans and copepods. The benthic food web is fueled by the algae, fish, and detritus (dead and decomposing organic matter) that fall from the upper part of the water column (photic zone). Two large macrobenthic animals, the opossum shrimp (*Mysis relicta*) and an amphipod or "sideswimmer" (*Diporeia sp.*) are important species for the food web. Alewife, lake herring, and rainbow smelt represent prey species for the lake trout in offshore regions. The benthic food web fish include lake whitefish, sturgeon, and sculpin.

Besides humans, consumers of Great Lakes fish include birds such as herons, osprey, bald eagles, loons, cormorants, and mergansers. Minks and river otters also consume fish. The web comes full circle with the detritus and decomposers completing the cycle.

Exotic Species

Exotic or nonindigenous species are plants and animals that are found beyond their original range. They may be beneficial to an ecosystem, but they can also disrupt the ecological balance of an area. Harmful aquatic nuisance species include the *zebra mussel*, *quagga mussel*, *ruffe*, *round goby*, *spiny water flea*, *sea lamprey*, *Eurasian watermilfoil*, and *purple loosestrife*. When released into habitats where there are no natural controls such as pathogens, parasites, and predators, these species can grow rapidly.

Over one third of the 130 exotic species in the basin have been introduced since the opening of the St. Lawrence Seaway for shipping 30 years ago. Ballast water from ships is the most common transporter of these species. Other means of transport for exotic species are the water used for the bait industry, food processing, exotic pet trade, and the aquarium trade. Boat transfers from one body of water to another and landscape practices are other ways of transporting aquatic nuisance species. Inland lakes as well as the Great Lakes have seen invasions of exotic species.

A website for exotic species is found at the Michigan Sea Grant website. For more information about the Great Lakes, see the U.S. Environmental Protection Agency Lakewide Management Plan.
The Lake Trout Food Web in the Upper Great Lakes

Phytoplankton

Detritus

Note: The death of any organism results in a contribution to the detritus pool. For simplicity, only an arrow showing the contribution from phytoplankton is illustrated here.

Terms
Pelagic - zone of open water characterized by an absence of contact with either the lake bottom or shore. Organisms in the pelagic zone must be adapted to swimming or floatation.
Forage fish - fish eaten by other fish
Benthic - bottom-dwelling
Benthos - the collection of benthic organisms
Detritus - dead organic matter (dead plants and animals)
Plankton - floating or weakly swimming organisms, includes both algae (phytoplankton) and animals (zooplankton).

Source: Dr. Marty Auer, Department of Civil and Environmental Engineering, Michigan Technological University
Scientific Educational Cruises Aboard the *Agassiz* Research Vessel

**Arriving “On Station”**

As the vessel begins to slow, you’ll hear the captain announce that we’ve arrived “on station.” This means we are at the area where we’ll be collecting samples. It is important to know exactly the location of the vessel so we can compare water quality information from station to station.

The captain uses a GPS or global positioning system to assist in finding our exact location. The GPS works with orbiting satellites to determine the latitude and longitude of the vessel. Latitude and longitude are terms given to invisible lines overlain on the globe. **Latitude** is measured in degrees north or south of the equator and **longitude** is measure in degrees east and west of the prime meridian, an imaginary line running from the North Pole to the South Pole through Greenwich, England.

**Water Sampling**

Students will be involved as much as possible in water sampling, so listen carefully to the Chief Scientist. Below is a list of some water quality measurements we may collect to help us learn about the health of the lake.

**Water Quality**

**Water transparency** helps to determine the amount of light reaching plants in the water. Sunlight provides direct energy to water plants. We measure transparency with a **Secchi disk**. When lowered into the water with a marked rope, we are able to measure at what depth the disk disappears. This helps us to determine the transparency of the water.

**Water color** is another important aspect of water quality. Color can tell us a lot about what’s in the water. Deep blue may mean there are low amounts of organic matter or plankton, while green water might indicate lots of plant life. Water color can also indicate water depth. Open seas are blue to green, inshore water and inland lakes are often yellow-green and water in rivers and harbors tends to be brown and brown-green.

**Turbidity** is another factor related to transparency. It is a measure of the materials suspended in the water. These materials give water its **cloudiness**, and can be anything from organic material such as plankton and sewage, to inorganic material like silt and clay. We use a turbidity meter to help us determine how cloudy the water is. This meter uses a source of light and a **photocell**. Shining light through a water sample scatters it. The photocell measures this light, telling us how cloudy the water is. The cloudier the water, the more solids are suspended in it. Turbidity may also increase water temperature, impacting its overall quality.
The temperature of water can tell us many things about its quality. It is important to know that generally, water temperatures vary according to depth. During the summer, warmer water is usually found near the surface with the colder water near the bottom. You can often feel the difference in temperatures just by touching the Van Dorn bottles. You’ll made precise temperature measurements by reading the thermometers inside the Van Dorn bottles.

We measure the electrical conductivity in a water sample to help determine water quality. Generally, the higher the electrical conductivity of a sample, the greater the concentration of potential pollutants. To measure this, we’ll use an instrument called a conductivity meter.

Measurement of pH is a way to tell if the water is acidic, basic, or neutral. Pure water is neutral but certain materials in the water can make it acidic or basic. For example, lemon juice mixed in water makes lemonade which is acidic. We measure pH with and instrument called a pH meter. The pH scale is a series of numbers ranging from 0 to 14 with 7 being neutral. Certain plants and animals may be harmed by pH levels that are either well above or well below 7.

**Bottom Sampling**

Because material on the bottom of lakes and rivers can tell us a lot about water quality, it is important for us to bring some of this sediment up for analysis. To do this, we’ll utilize the PONAR grab sampler. The PONAR will collect the bottom sediments and the bottom-dwelling organisms called “benthos.” The sediment is dropped into a steel tray and is then washed away to reveal the benthic organisms which inhabit the lake bottom. The benthic organisms may be inspected under a microscope.

**Plankton Sampling**

We will pull a plankton net through the water to collect samples of some of the smallest plants and animals in the water. These organisms are called plankton. We can look at these samples under a microscope to identify them. The phytoplankton are the “plants” which photosynthesize, and the “animals” are called zooplankton. Zooplankton eat the phytoplankton.

**Being a Scientist**

The tests you perform and the tools you’ll use aboard the Agassiz are similar to what scientists around the world use to measure the health of lakes and oceans.

A scientist asks questions, collects and analyzes data, and shares this information with others. Your cruise will provide you with an exciting snapshot of how the Great Lakes are studied by scientists at Michigan Technological University, and universities around the five Great Lakes.

Now that you’ve been on a research vessel, you probably have A LOT of questions. Email any questions to Dr. Martin Auer in the Department of Civil & Environmental Engineering at Michigan Tech (mtauer@mtu.edu). There are a lot of college majors and careers related to studying the Great Lakes.
Pre-Trip Activities
Teachers are encouraged to provide students with an introduction to the Great Lakes and the purpose of the vessel trip, in order to spark their interest. Several activities are included in this handbook. Understanding Lake Data, a 20-page booklet, is available free of charge to teachers or available online.

Post-Trip Activities
Following a vessel trip, teachers are encouraged to conduct post-trip activities. The knowledge gained in understanding our freshwater resources can be put to use in a variety of ways through individual, classroom, and community activities. The Center can assist teachers in finding the activities and we welcome any activities or extensions that you would like to contribute.

Sampling Equipment Aboard the Agassiz
Let’s take a look at some of the equipment we’ll be using to gather scientific data about the lake. The quality of water is affected by many things, and to help us understand some of those, we need to get samples of water from different depths using a Van Dorn Sampler. If we don’t need the actual water sample, a HydroLab is used to measure oxygen, temperature, and depth by lowering a probe down into the water. A Secchi disk is used to measure water clarity. A conductivity meter measures ions in the water using a probe and a spectrophotometer measures what is in water using wavelengths of light.

Many organisms live in this water. Most are too small to see individually. To study what lives here, we need to have a way to collect samples of this microscopic life. Using the plankton net, we are able to collect a variety of tiny plants and animals that we can view under a microscope.

To find out what is at the bottom of the lake, we will use a crane to drop the PONAR dredge to scoop up sediment from the bottom. Once that’s done, you’ll use the hose to wash mud and sand away to reveal the living things which live in the sediments on the lake bottom. Knowing what lives there will tell us about water quality.

Water Sampling Equipment Aboard the Agassiz (See Figure I)
- Microscopes (dissecting/compound)
- Secchi disk
- Van Dorn Water Sampler
- Conductivity meter
- Phytoplankton & zooplankton nets
- PONAR dredge (& wash tubs)
- Portable spectrophotometer
- HydroLab
Fig. 1. Sampling equipment aboard the *Agassiz* research vessel.

- **PONAR dredge**
- **Plankton Net**
- **Van Dorn Water Sampler**
- **HydroLab** measures Oxygen, Temperature and Depth
- **Conductivity Meter**
- **Secchi Disk**
Pre-Trip Activities

Demonstrate a 3-D Watershed Model

Overview
Using a simple floor model of a watershed, students will identify the parts of a watershed.

Materials:
sheet of plastic, shower curtain or tablecloth
various objects or wadded newspaper to put under to create a drainage basin.
4 rain cups filled with water
watershed labels

Procedure
Make a model of a watershed on your classroom floor (or outdoors) by laying a sheet of plastic or a tarp over newspaper wads to create a U-shaped ridgeline (exact shape is not essential). If available, the model can be placed into a child’s swimming pool or large, shallow plastic container.

Have the class gather around, as you demonstrate the movement of water and parts of a watershed using your model. Spray blue-colored water (or use the rain cups) to demonstrate rainfall and runoff on the watershed model. The water will flow downhill, with several small streams coming together to form a main channel that eventually empties into a lake (if necessary, elevate the headwater end of the model). Ask students to predict what will happen when water is sprayed onto the top of a ridge. [Some water will run off one side of the ridge into one stream, and some will run off the other side of the ridge into another stream]. The ridge between the two streams is called the drainage divide—it is the highest point of land between two bodies of water. Water falling on the other side of the drainage divide will run off into a different watershed.

Distribute the overhead transparency watershed labels amongst the students. Taking turns, ask students to place the labels in the appropriate places on the watershed model:

• Watershed/drainage divide = higher elevation (ridge) between two watersheds
• Floodplain = an area next to a stream channel that is periodically covered by flood overflows.
• Headwaters = the source or beginning of a river
• Main channel = the largest channel into which smaller streams flow
• Mouth = outflow of stream or river entering a lake or ocean
• Tributary = small stream entering main channel
• Meander = curve in river
• Stream bank = the sides of the channel
• Direction of flow = water flows down gradient from headwaters to mouth
• Sub-watershed = land area surrounding a tributary
• Upstream = towards the source of a stream or river
• Downstream = towards the mouth of a stream or river

To clean up, fold the tablecloth/shower curtain and drain water into a sink or outdoors. Wipe down.
How Tiny is a Part Per Million?

Activity Summary
Students discover that many contaminants cannot be seen, smelled, or tasted, so water chemistry analysis has to be done to ensure the safety of drinking water. Students perform a serial dilution to observe that even an extremely small concentration of a contaminant can still pose a threat to human health. Students answer the following essential questions: What units are used to measure water pollution? How do I know if my water is safe to drink?

Materials

per class
- Maximum Contaminant Levels in Drinking Water (transparency master)
- Serial Dilution (answer key)
- red food coloring

per small group
- Serial Dilution (student activity)
- 4 oz. cup labeled “well” water
- 4 oz. cup labeled “rinse” water
- 1 clear, plastic Chemplate® or white ice cube tray
- white sheet of paper to place under Chemplates
- 2 water droppers
- calculator
- paper towels

Procedure

Display the Maximum Contaminant Levels in Drinking Water overhead transparency. A ‘contaminant’ is any substance in the air, water, or land, including microorganisms, chemicals, metals, etc., that may be harmful to human health. The Maximum Contaminant Level (MCL) is the maximum amount of a contaminant allowed in drinking water that is legally enforceable in the United States. MCLs are set as close as possible to the level below which there is no known or expected risk to health and removal is feasible using the best available treatment technology taking cost into consideration.

What is a part per million? Write ppt, ppb, ppm, ppth on the board and explain these abbreviations. Which amount is largest? [ppth] Smallest? [ppt]
- ppt = part per trillion (smallest)
- ppb = part per billion
- ppm = part per million
- ppth = part per thousand (largest)

Ask students to look at the Maximum Contaminant Level table on the overhead transparency and ask: Which of these regulated contaminants have you heard of before? Where do these contaminants come
from? Note that even very small amounts of these contaminants can harm human health. Special expensive equipment is used to measure the presence of these contaminants.

**Understanding parts per million: How little is ‘little’?**

*What are some examples of one part per million? Brainstorm ways to comprehend a ppm.*

One part per million is equivalent to:

- One second in 12 days of your life.
- One penny in $10,000.
- One pinch of salt in 10 tons of potato chips.
- One inch in 16 miles.

Arrange students in small groups. Distribute the materials and the *Serial Dilution* student activity pages. Put a few drops of 10% food coloring in each group’s Cup 1. Have the students follow the directions on their student activity pages.

After all serial dilutions have been made discuss the calculation of the concentration of food coloring in each cup. *When could you no longer see the food coloring/contaminant? [Cup 6-8.] Why might there have been differences between groups? [Larger-sized drops of food coloring or smaller sized drops of water, or other errors in procedure.] Has the contaminant gone away if we can no longer see it? [No, because of the law of conservation of mass which states that matter can change form, but cannot be created or destroyed..] Can the students think of a way to confirm the presence of food coloring in the cups where it cannot be seen? [Allow the water to evaporate and a precipitate will be left in the bottom of the cup.]*

Go over the data table. *Where is there one part food coloring per thousand drops of water? [Cup 3.] Where is there one part of food coloring per million parts of water? [Cup 6.] How many more dilutions would it take to reach a concentration of 1 ppb? [Three more □ Cup 9.] These tiny amounts represent enough of a contaminant to be harmful.*

Have each group play the role of the Environmental Protection Agency. Assign each group one contaminant from the table of *MCLs in Drinking Water*. Tell students that 1.0 ppm of their assigned contaminant has been found in the school’s drinking water. Using the information in the table, determine whether one ppm level of that contaminant poses a human health risk. Be prepared to share your assessment with the class.
## Maximum Contaminant Levels (MCLs) in Drinking Water

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL Parts per million (ppm)</th>
<th>Potential Health Effects</th>
<th>Possible Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>0.01</td>
<td>Skin damage, problems with circulatory system; may increase risk of getting cancer</td>
<td>Erosion of natural deposits; runoff from orchards, and glass and electronics production wastes.</td>
</tr>
<tr>
<td>Asbestos (fiber&gt;10 micrometers)</td>
<td>7 MFL (million fibers per liter)</td>
<td>Lung disease and cancer after lifetime exposure</td>
<td>Used in many building materials, including cement pipes in water supply systems.</td>
</tr>
<tr>
<td>Benzene (petroleum product)</td>
<td>.005</td>
<td>Anemia (low iron in blood); increase risk of cancer</td>
<td>Fumes and exhaust from gasoline and manufacturing chemicals; industrial discharge and spills; petroleum-refining industry; gas storage tanks; landfills</td>
</tr>
<tr>
<td>Copper</td>
<td>1.3</td>
<td>Liver and kidney damage</td>
<td>Mine wastes; corrosion of household pipes; erosion of natural deposits</td>
</tr>
<tr>
<td>Dioxin</td>
<td>Zero or 0.00000003</td>
<td>Reproductive difficulty; increased risk of cancer</td>
<td>Emission from waste incineration; discharge from chemical and paper-making factories</td>
</tr>
<tr>
<td>Lead</td>
<td>.015</td>
<td>Delays in physical and mental development in infants and children; kidney problems, high blood pressure</td>
<td>Corrosion of household pipes, erosion of natural deposits</td>
</tr>
<tr>
<td>Mercury (methylmercury is more toxic than elemental mercury)</td>
<td>.002</td>
<td>Kidney damage Respiratory failure (methylmercury causes impaired neurological development)</td>
<td>Discharge from refineries and factories; runoff from landfills and croplands; atmospheric deposition from power plants; erosion of natural deposits</td>
</tr>
<tr>
<td>Nitrate &amp; Nitrite</td>
<td>Nitrate ≤ 10 Nitrite ≤ 1.0</td>
<td>Shortness of breath; blue baby syndrome and possible death in infants</td>
<td>Runoff from fertilizer use; leaching from septic tanks; sewage; erosion from natural deposits</td>
</tr>
<tr>
<td>PCB (Polychlorinated Biphenyls)</td>
<td>Zero or .0005</td>
<td>Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer.</td>
<td>Runoff from landfills; discharge of waste chemicals; used as a fire retardant.</td>
</tr>
</tbody>
</table>
**Serial Dilution**

**Directions:** You will perform a serial dilution using food coloring to illustrate concentration levels of parts per million (ppm) and parts per billion (ppb).

**Materials**

*per group*
- Chemplate® or ice cube trays or small cups numbered 1-9
- 2 droppers (use one dropper for the well water and one dropper to “transfer” drops)
- 4 oz. cup labeled “well” water
- 4 oz. cup labeled “rinse” water
- White paper to place under Chemplate®

1. The teacher will place a few drops of food coloring (10% solution) into Cup 1. Observe the color. The color and concentration have been recorded for you in your data table.

2. Using your “transfer” dropper, remove one drop from Cup 1, and place into Cup 2. Using your well water dropper, add 9 drops of clean water and mix thoroughly. Observe the color and record in your data table.

3. Using your “transfer” dropper, remove one drop from Cup 2, and place into Cup 3. Using your well water dropper, add 9 drops of clean water. Mix thoroughly. Observe the color and record in your data table.

4. Repeat the procedure for Cups 4-9.

5. Determine the concentrations for each cup and record in your data table.

<table>
<thead>
<tr>
<th>Cup</th>
<th>Color</th>
<th>Concentration</th>
<th>Describe Concentration in Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dark red</td>
<td>1/10</td>
<td>There is one part food coloring to 9 parts water.</td>
</tr>
<tr>
<td>2</td>
<td>Pretty dark red</td>
<td>1/10 x 1/10 = 1/100</td>
<td>There is one part food coloring in 99 parts of water.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Answer these questions.**

6. In which cup did the color disappear? Cup _________

7. What is the concentration of the solution in this cup?

8. Has the food coloring gone away, since we can no longer see it? Explain your answer.
### Serial Dilution Student Page – ANSWER KEY

<table>
<thead>
<tr>
<th>Cup</th>
<th>Color</th>
<th>Concentration</th>
<th>Describe Concentration in Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Very dark red</td>
<td>1.0</td>
<td>100% food coloring</td>
</tr>
<tr>
<td>1</td>
<td>Dark red</td>
<td>1/10 = 0.1</td>
<td>There is one part food coloring to 9 parts water.</td>
</tr>
<tr>
<td>2</td>
<td>Pretty dark red</td>
<td>1/10 × 1/10 = 1/100 = 0.01</td>
<td>There is one part food coloring in 99 parts water, or one part per hundred.</td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>1/1000 = 0.001</td>
<td>There is one part food coloring in 999 parts water, or one part per thousand.</td>
</tr>
<tr>
<td>4</td>
<td>Light red</td>
<td>1/10000 = 0.0001</td>
<td>There is one part food coloring in 9999 parts water, or one part per 10,000.</td>
</tr>
<tr>
<td>5</td>
<td>Very pale red</td>
<td>1/1000000 = 0.000001</td>
<td>There is one part food coloring in 99999 parts water, or one part per 100,000.</td>
</tr>
<tr>
<td>6</td>
<td>Can’t see any red</td>
<td>1/100000000 = 0.0000001</td>
<td>There is one part food coloring in 999999 parts water, or one part per 10 million.</td>
</tr>
<tr>
<td>7</td>
<td>Can’t see any red</td>
<td>1/1000000000 = 0.00000001</td>
<td>There is one part food coloring in 9999999 parts water, or one part per 100 million.</td>
</tr>
<tr>
<td>8</td>
<td>Can’t see any red</td>
<td>1/1000000000 = 0.000000001</td>
<td>There is one part food coloring in 99999999 parts water, or one part per billion.</td>
</tr>
</tbody>
</table>

**Answer these questions.**

1. In which cup did the color disappear? **Cup 6**
2. What is the concentration of the solution in this cup? **1 ppm**
3. Has the food coloring gone away, if we can no longer see it? Explain your answer. **No, the food coloring is in such a small quantity that it is not observable.**
The Story of Freddie the Fish

Activity Summary
Through the tale of an intrepid fish named Freddie, students discover the environmental requirements for maintaining healthy fish habitat. They also learn some ways in which humans have impacted aquatic habitats, and ways that we can keep lakes and streams healthy.

Objective
Students will be able to describe fish habitat requirements, types and sources of pollution, and how it can affect the health of fish populations and water quality.

Materials
Weighted fish lure (with hooks removed)
Clear gallon jar or small fish tank with gravel on bottom
8 small cups to hold pollutants:
- Sediment: soil
- Fertilizer: green drink mix
- Road Salt
- Oil spill: molasses or syrup
- Air Pollution: red food-coloring + water in spray bottle
- Manure: raisins
- Weed Killer: pink drink mix
- Litter: cut up paper
- Industrial site: coffee sludge

Introduce Freddie the Fish
“This is Freddie. He is a healthy fish. What does Freddie need to have a healthy home to live in? “
- Cool water (holds more oxygen) {pour in water}
- Gravel and/or rocky stream floor to lay eggs (reproduction needs) {add gravel}
- Shrubs and trees along the stream (to provide shade and keep water cool, with lots of oxygen, and provide food from falling leaves

“Freddie is happy with his home, this stream where he lives in. Freddie has everything he needs right here. The water is nice and cool, and that is good because cool water holds more oxygen, so Freddie can breathe more easily. The trees and shrubs that line the shore of Freddie’s stream shade the stream and keep the water from getting to warm. Freddie has food from leaves that fall off the shrubs and trees, so Freddie always has something to eat. While Freddie likes this stream, he’s a little bored with it, and would like to have an adventure. Do you think he should leave this stretch of stream and see what’s out there in the big world?”

Freddie’s Adventure
So Freddie leaves the shady, cool waters and heads downstream on his adventure. After a while, Freddie notices that the sun is shining and it’s no longer so cool and dark in the water. He looks out of the water and notices that all the trees have been cut down. Hmm, thinks Freddie, the water is looking brown.
**Canister #1:** Sediment from stream bank erosion after trees are removed. Sprinkle some sediment over the water and allow it to slowly settle over Freddie. “How does it feel to get sediment into your gills, oops, and into your eyes, Freddie?” Explain how fish breathe and how grit hurts fish gills. Also explain how sediment can cover the rocky floor of a stream, where fish lay their eggs. “Should Freddie go home?” NO!

**Canister #2:** Livestock Manure (Raisins) “Freddie pokes his snout out of the water and sees some BIG black and white animals coming down to visit the water, and they are stirring up the sediment in the stream. Oh my, they are also leaving some presents.” Sprinkle a few raisins into the water and let them dramatically sink in the water, leaving brown trails. Let the kids observe and draw their own conclusions on what the cow presents really are. “Freddie doesn’t like the taste or smell of these presents. Should Freddie go home?” NO!

**Canister #3:** “Grass Fertilizer” Freddie notices a golf ball floating (add a plastic golf ball). “Hmm... what is this nasty green stuff running off the golf course? Bleck! Too much fertilizer! How do you feel Freddie?” Explain that people should not use too much fertilizer on their lawns, or apply it before a heavy rain. (Tell older students that fertilizer contains nutrients like nitrogen, phosphorous and potassium. They accelerate the growth of aquatic plants, which may not seem like a big deal. But when the plants die and decay the decaying process uses most of the oxygen in the water, leaving very little for creatures like Freddie.) Go through the same routine with the “Weed-killer.”

**Canister #4:** Road Salt “Freddie notices that the river has taken on a salty taste.” [Add salt into the water.] Explain that road salt is good for traffic safety in the winter; but bad for wildlife in general, including trees along the roadside, which may die from too much salt; and bad for groundwater as well. “Kids have you ever had salt get into an open cut? Ouch! How do you think Freddie feels? Look, Freddie is swimming faster in an attempt to get away from the salt, but the saltiness seems to be everywhere in the water. Freddie may be missing the cool, shady pool back upstream. Should Freddie go home? NO!”

**Canister #5:** Litter “Continuing on, Freddie passes a picnic site... some campers left their rubbish behind: dirty plastic dishes, and empty bottle of charcoal lighter fluid and a used disposable diaper. We would never do this, would we? Freddie must feel disgusted with this mess, wouldn’t you? He tries to push the litter out of the water. Lets remember to keep litter in its proper place and dispose of used diapers in a trashcan! Yuck! Should Freddie go home? NO!” Freddie swims on.

**Canister #6:** Air Pollution in the rain (acid rain) “Freddie hears the distant rumbling of some thunder. Are you afraid of thunder? Well, Freddie is brave, he’s not afraid of a little thunder.” [Spray in rain.] “Oh dear, Freddie is noticing that something is wrong with the rain water. You might expect rainwater to be very clean, but this is not always the case. Pollution that gets into the air can be dissolved in the rain water and end up in Freddie’s river.” “Should Freddie continue his journey, or should Freddie go home? Things are getting rough on Freddie, but then he’s a tough kind of guy who is still up for adventure.”
**Canister #7: Contaminated Industrial Site**
Place the leaking industrial waste canister into the water. “Freddie passes a leaky, rusty, old barrel full of unknown chemical goo. Workers from an abandoned factory dumped it here, after all, out-of-sight, out-of-mind. But now the barrel is leaking. As Freddie swims by he sniffs at the barrel...OH! Bad choice Freddie. That barrel was filled with toxic pollutants. He better get out of here as fast as he can!”

**Canister #8: Oil Spill**
“An oil truck overturned on the road and spilled some oil into the stream. Did you know that just one cup of oil can poison a tank of water twice the size of this classroom? Freddie gets his gills clogged with oil and he starts having trouble breathing.” Gasp a little and hold your throat. “Life is getting pretty tough for Freddie. Poor Freddie has come through so much. Even though Freddie is a tough fish, this is more than Freddie can withstand. He takes his last gasp.”

**Summary & Learning Assessment**
Pull Freddie out of the water. Explain “Freddie was just acting, he’ll be alright. But Freddie is trying to make a point here. What do you think Freddie is trying to teach us?”
All living things need a clean, healthy environment to thrive. Fish need a suitable place to live. If their homes become polluted, fish will have trouble. A stream that becomes polluted, and then flows into Lake Superior, can affect all of Lake Superior. If we want to have healthy fish populations and a healthy Lake Superior, we must act wisely.”

“What could have been done to keep Freddie’s stream a healthy place to live?”
- Leave trees along the stream, instead to cutting all the way down to the river’s edge.
- Don’t allow livestock to graze along streams. Pump water out of the stream and put it in a large trough for the livestock to drink, away from the stream.
- Follow label directions on fertilizers and pesticides. Do NOT use too much!
- Do not use excess road salt.
- Don’t be a litterbug. Participate in beach clean ups to remove litter.
- Acid rain comes from air pollution. It can hurt trees, plants and and kill fish and other aquatic organisms in lakes and streams.
- Support efforts to clean up industrial sites.
- Drive carefully. If accidents happen, have a plan to keep oil or gas out of lakes and streams.

**Is This Water Safe for Fish & Frogs?**

**Overview**
Students are introduced to the concept of pH and water quality. They determine the pH of common household items using litmus paper; and decide if fish could thrive, survive, or die?

**Objective**
Students will be able to explain how measuring pH can indicate the suitability of water quality for fish.

**Materials**
- pH Paper
- Cups or chempate trays
- Data sheets
- Solutions: Baking Soda, Lemon Juice, Dilute lemon juice, Tap Water, Cola, Coffee, Orange Juice, Dishwashing soap solution
Introduction

How can you tell if a fish or frog would survive and be healthy in the water of a lake or river? Does looking at the water alone tell you if it is polluted with something that could hurt a fish? Yes, but how water looks is not good enough because some pollutants are as clear as water, so we need something more. Would you taste the water to see if it is polluted? NO! Never taste a liquid if you are not sure what is in it. Would smell be a good indicator? YES!

Are there any other simple tests that we can use to tell if there is pollution in water? We can test the pH of the water using pH paper. “We can rank all materials by identifying its pH. The pH scale runs from 0 to 14. (Draw 0-14 scale on board, and label 0-7 as “acid” and 7-14 as “basic”) If pH is 0-7, then the liquid is an acid like vinegar. The closer the liquid is to “0” the stronger the acid. Would a fish or frog want to live in vinegar? NO! If the pH measures 7-14, then it is a base like bleach or detergent. Would a fish or frog want to live in soapy water or bleach? NO! The closer the number is to 14, the more basic (or polluted) the water is. Fish and frogs want to live in water that is neither acidic or basic....that pH number is 7!! Or close to “7” like between 6-8 pH.

“It is important to know something about the pH of water because it is an important indicator of whether an environment is healthy and unpolluted for organisms that live in the water. Just like your body temperature is an indicator of your health, pH of water can tell us something about the healthiness of water for many species that live in the water...like fish.”

<table>
<thead>
<tr>
<th>Organism</th>
<th>Optimal pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria:</td>
<td>1.5-13.5</td>
</tr>
<tr>
<td>Plants:</td>
<td>6.5-12.0</td>
</tr>
<tr>
<td>Carp, sucker, catfish:</td>
<td>6.0-9.0</td>
</tr>
<tr>
<td>Bass, crappies:</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>Trout, aquatic macroinvertebrates:</td>
<td>6.5-7.5</td>
</tr>
<tr>
<td>(most mayfly nymphs, stonefly nymphs, and caddisfly larvae)</td>
<td></td>
</tr>
</tbody>
</table>

Fish and frogs are healthiest in water that has a pH number of 7!! Scientists who have studied fish have found that they can live in water that ranges from a pH of 6 to a pH of 8, but they are healthiest and can reproduce in water with a pH = 7.” If the water’s pH drops to 6 or rises to 8, fish are not able to have babies successfully, and other fish do not grow as quickly. The fish will survive but not thrive. If the pH of water drops below 5, fish may die. Likewise, if the pH of water is greater than 8 fish could also die.

Watch closely how to use the pH paper. First you hold the pH paper strip with tweezers. Next, dip it into the liquid halfway. Then pull out the pH paper and match the color at the end you put into the liquid, with the color chart provided.

Determine the pH of some household liquids.

Students work in pairs during this exercise. Pass out data sheets. There are seven liquids you could find in most homes in the U.S. Your job is to identify the pH of each liquid and determine if the sample could be a safe water for fish and frogs. Record the pH of each liquid in the data chart. Then decide if a fish could thrive, survive, or die. We will discuss the results after everyone finishes.”
Discussion of Results

Go through each liquid:

- Tap Water should provide a healthy environment for Freddie.
- Coffee: Depending on what pH students come up with, Freddie will either thrive or survive. They should get a 4 or 5 on the pH scale.
- Strong Lemon Juice: pH = 2, Freddie dies
- Weak Lemon Juice Solution: pH = 4, Freddie still dies
- Baking soda solution: pH = 8 – 9, Freddie may survive or die, depending on how much soda is in water.
- Cola: pH = 2-3, Freddie dies
- Orange Juice: pH = 5, Freddie will probably only survive
- Sun Light Solution: pH = 10-12, depending on strength of the solution. Freddie and friends will die. This is a great time to talk about why we don’t want soap to get into Freddie’s water.

So just by testing pH we can tell something more about the health of water for fish and frogs.

A Healthy Home for Freddie and His Friends

Pass out blank page and have students draw a large “U” to represent the cross-section of a stream channel. Have students complete the drawing to create a healthy stream habitat for fish.

Discuss students’ drawings. Healthy stream habitats have:
- Gravel/stony stream bottom,
- Trees and shrubs along the stream banks, overhanging the channel and providing shade,
- Insects on bottom of the stream channel, attached to rocks, buried in sediments, and on the water surface, for fish to feast on. Draw a happy Freddie

Learning Assessment:
- List 3 things that make a healthy home for fish and frogs?
- List 3 things you can do to keep streams and lakes healthy.

In conclusion:
- Humans who live in the Lake Superior watershed can have a positive or negative impact on the health Lake Superior.
- Polluting streams results in pollution flowing into Lake Superior.
- If you want to have a clean environment to live in, if you want a clean Lake Superior, and if you want to help Freddie and his friends have healthy homes, then we need to take care of the environment where we live.
Post Trip Activities

Layering Water

Activity Overview
Now that students have observed the change in temperature and dissolved oxygen with depth, they will create a model to show how warm water can layer atop colder water.

Materials
Aquarium or clear 9 oz. plastic cups or glass jar
4 oz. hot tapwater
4 oz. cold water with ice cubes
Food coloring (red and blue)

Procedure
Can you create layered water? Pour warm water, colored red, into a cup (more water if using an aquarium). Slowly pour in the cold water, colored blue, along the side of the aquarium or cup, so that it doesn’t mix with the warmer water. This is what happens in the summer when the sun warms the top layer of water, while the denser, colder water is beneath.

Investigate A Great Lakes Issue

Activity Overview
Students select a topic and follow the scientific method. They prepare a research paper or PowerPoint presentation to present to the class.

Procedure
Students should follow these steps:

a) State the problem as a question. For example, “Is mercury impacting Great Lakes fish?”
b) Present data that answer the question, including the source of the data.
c) Present three (or more) different points of view on the issue: government agency, university, industry/business, citizens’ organization, etc.
d) Present the opinions of people from your community by interviewing at least three different types of people: students, parents, relatives, teachers, etc.
e) Describe your personal opinion.
f) Propose a solution to the problem. For example, “I think the best way to solve this problem is to ....” Identify who or what would be affected in a positive or negative way by your proposed solution.
g) Consult a minimum of four sources, such as a government agency, university, industry/business, and citizens’ organization. Correctly list your references.
Some possible research topics are:
- Area of Concern (AOC) Restoration/Sediments
- Invasive Species
- Nonpoint Source
- Emerging Contaminants
- Sustainable Low Impact Development
- Storm water management and combined storm water overflows.
- Contaminants in Great Lakes fish & bioaccumulation in the food chain.

### Investigate A Great Lakes Issue – Rubric

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Excellent (4 points)</th>
<th>Good (3 points)</th>
<th>Fair (2 points)</th>
<th>Poor (1 points)</th>
<th>Not Addressed (0 points)</th>
<th>Points Earned</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) State the problem as a question</td>
<td>Problem is clearly stated as a question.</td>
<td></td>
<td>Problem is not clearly stated.</td>
<td></td>
<td>No question stated.</td>
<td></td>
</tr>
<tr>
<td>b) Present data that answers the question</td>
<td>Data clearly presented from 2 sources and references for each provided.</td>
<td>Data clearly presented from one source and reference provided.</td>
<td>Data presented but no reference (source) stated.</td>
<td>Data not clearly presented.</td>
<td>No data.</td>
<td></td>
</tr>
<tr>
<td>c) Presents different perspectives on the issue: government, scientist, industry, business, citizens’ organization, etc.</td>
<td>Three or more perspectives presented.</td>
<td>Two perspectives presented.</td>
<td>One perspective presented.</td>
<td>Different perspectives not clearly identified.</td>
<td>No perspectives presented.</td>
<td></td>
</tr>
<tr>
<td>e) Recommend a solution to the problem. Include discussion of pro’s and con’s of your solution.</td>
<td>A creative, well-thought-out, and well-explained solution is presented.</td>
<td>A reasonable solution is presented, with limited discussion of pros and cons.</td>
<td>Solution is minimal or doesn’t match the problem.</td>
<td>Not clearly addressed.</td>
<td>Not addressed.</td>
<td></td>
</tr>
<tr>
<td>f) Consults at least three sources that are correctly listed in reference section.</td>
<td>Four or more sources consulted and listed in reference section.</td>
<td>3 sources consulted and listed in reference section.</td>
<td>2 sources consulted; no reference section.</td>
<td>1 source consulted; no reference section.</td>
<td>No sources.</td>
<td></td>
</tr>
</tbody>
</table>
**Toxic Tag: A Game of Life & Death**  
(Bioaccumulation of Contaminants in the Great Lakes Food Chain)

Tell students that they will become a part of the food chain on a mission to gather their necessary food in order to stay alive. Separate students into three groups: half become zooplankton, a third are small fish (minnows), and the rest are fish-eating birds (loon, for example). Show students the phytoplankton food squares. Those marked with an X are toxic, which the students will learn when the game ends.

Show students the boundaries of the playing area: 25 x 20 meters. Remind students that they are to not to go outside the playing area to avoid predation. Scatter the phytoplankton squares inside the playing area.

Tell zooplankton that they have 60 seconds to gather as many phytoplankton as they can and place them into their “stomach” (a small plastic bag in which they will store their food). Next send in the minnows, each carrying bags. Minnows have 60 seconds to try to catch the zooplankton by tagging them and then taking their food. If a zooplankton is caught, it must give all of its food to the small fish and leave the playing field. Lastly, the loons have 60 seconds to gather their food by tagging minnows and taking their entire stomachs.

Gather everyone together to examine the results. Have survivors count the number of food squares they have. The zooplankton must have at least three food pieces to survive. Minnows must have eight pieces and loons, twelve pieces to survive. Who does not survive? Next, count the number of toxic food particles they have and compare to the number on the overhead transparency *Toxic Tag* that shows the chart of consequences due to consuming contaminated prey. What happens when animals cannot reproduce? What happens if an entire population declines?
Contaminant Concentrations in Organisms In the Food Chain

Water ............................................ .000003 ppm
Phytoplankton ................................. .025 ppm
Zooplankton ................................. .123 ppm
Small Fish ..................................... 1.04 ppm
Large Fish ..................................... 4.83 ppm
Egg of Fish-eating Bird ................. 124.00 ppm

Toxic Tag Game Results

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number of Toxins in Stomach</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zooplankton</td>
<td>&lt; 3</td>
<td>Survives</td>
</tr>
<tr>
<td></td>
<td>3-4</td>
<td>Survives but cannot reproduce</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>Dies</td>
</tr>
<tr>
<td>Minnow/Small Fish</td>
<td>&lt; 4</td>
<td>Survives</td>
</tr>
<tr>
<td></td>
<td>4-6</td>
<td>Survives but cannot reproduce</td>
</tr>
<tr>
<td></td>
<td>&gt;6</td>
<td>Dies</td>
</tr>
<tr>
<td>Loon</td>
<td>&lt; 5</td>
<td>Survives</td>
</tr>
<tr>
<td></td>
<td>5-8</td>
<td>Survives but cannot reproduce</td>
</tr>
<tr>
<td></td>
<td>&gt;8</td>
<td>Dies</td>
</tr>
</tbody>
</table>
APPENDIX

Map of Lake Superior

Great Lakes Watershed and Political Boundaries

Data Sources:
- Great Lakes Commission
- Statistics Canada

August 27, 2004
Melissa L. Bieler
OSU Center for Science and Environmental Outreach
Michigan Technological University
### Table of Great Lakes Physical Features & Population

(From [http://www.epa.gov/cgi-bin/epaprintonly.cgi](http://www.epa.gov/cgi-bin/epaprintonly.cgi))

<table>
<thead>
<tr>
<th>Feature</th>
<th>Superior</th>
<th>Michigan</th>
<th>Huron</th>
<th>Erie</th>
<th>Ontario</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(feet)</td>
<td>600</td>
<td>577</td>
<td>577</td>
<td>569</td>
<td>243</td>
<td></td>
</tr>
<tr>
<td>(meters)</td>
<td>183</td>
<td>176</td>
<td>176</td>
<td>173</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(miles)</td>
<td>350</td>
<td>307</td>
<td>206</td>
<td>241</td>
<td>193</td>
<td></td>
</tr>
<tr>
<td>(kilometers)</td>
<td>563</td>
<td>494</td>
<td>332</td>
<td>388</td>
<td>311</td>
<td></td>
</tr>
<tr>
<td>Breadth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(miles)</td>
<td>160</td>
<td>118</td>
<td>183</td>
<td>57</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>(kilometers)</td>
<td>257</td>
<td>190</td>
<td>245</td>
<td>92</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Average Depth(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(feet)</td>
<td>483</td>
<td>279</td>
<td>195</td>
<td>62</td>
<td>283</td>
<td></td>
</tr>
<tr>
<td>(meters)</td>
<td>147</td>
<td>85</td>
<td>59</td>
<td>19</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Maximum Depth(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(feet)</td>
<td>1332</td>
<td>925</td>
<td>570</td>
<td>210</td>
<td>802</td>
<td></td>
</tr>
<tr>
<td>(meters)</td>
<td>406</td>
<td>282</td>
<td>229</td>
<td>64</td>
<td>244</td>
<td></td>
</tr>
<tr>
<td>Volume(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cu. miles)</td>
<td>2,900</td>
<td>1,180</td>
<td>850</td>
<td>116</td>
<td>393</td>
<td>5,439</td>
</tr>
<tr>
<td>(km(^3))</td>
<td>12,100</td>
<td>4,920</td>
<td>3,540</td>
<td>484</td>
<td>1,640</td>
<td>22,684</td>
</tr>
<tr>
<td>Water Surface Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(sq. miles)</td>
<td>31,700</td>
<td>22,300</td>
<td>23,000</td>
<td>9,910</td>
<td>7,340</td>
<td>94,250</td>
</tr>
<tr>
<td>(km(^2))</td>
<td>82,100</td>
<td>57,800</td>
<td>59,600</td>
<td>25,700</td>
<td>18,960</td>
<td>244,160</td>
</tr>
<tr>
<td>Land Drainage Area(^b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(sq. miles)</td>
<td>49,300</td>
<td>45,600</td>
<td>51,700</td>
<td>30,140</td>
<td>24,720</td>
<td>201,460</td>
</tr>
<tr>
<td>(km(^2))</td>
<td>127,700</td>
<td>118,000</td>
<td>134,100</td>
<td>78,000</td>
<td>64,030</td>
<td>521,830</td>
</tr>
<tr>
<td>Total Area(^b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(sq. miles)</td>
<td>81,000</td>
<td>67,900</td>
<td>74,700</td>
<td>40,050</td>
<td>32,060</td>
<td>295,710</td>
</tr>
<tr>
<td>(km(^2))</td>
<td>209,800</td>
<td>175,800</td>
<td>193,700</td>
<td>103,700</td>
<td>82,990</td>
<td>765,990</td>
</tr>
<tr>
<td>Shoreline Length(^c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(miles)</td>
<td>2,726</td>
<td>1,638</td>
<td>3,827</td>
<td>871</td>
<td>712</td>
<td>10,210^(^d)</td>
</tr>
<tr>
<td>(kilometers)</td>
<td>4,385</td>
<td>2,633</td>
<td>6,157</td>
<td>1,402</td>
<td>1,146</td>
<td>17,014^(^d)</td>
</tr>
<tr>
<td>Retention Time (^)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(years)</td>
<td>191</td>
<td>99</td>
<td>22</td>
<td>2.6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. (1990)</td>
<td>425,548</td>
<td>10,057,026</td>
<td>1,502,687</td>
<td>10,017,530</td>
<td>2,704,284</td>
<td>24,707,075</td>
</tr>
<tr>
<td>Canada (1991)</td>
<td>181,573</td>
<td>0</td>
<td>1,191,467</td>
<td>1,664,639</td>
<td>5,446,611</td>
<td>8,484,290</td>
</tr>
<tr>
<td>TOTALS</td>
<td>607,121</td>
<td>10,057,026</td>
<td>2,694,154</td>
<td>11,682,169</td>
<td>8,150,895</td>
<td>33,191,365</td>
</tr>
<tr>
<td>Outlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Mary’s River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straits of Mackinac</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Clair River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niagara R./Welland Canal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Lawrence River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Notes:

\(^a\) Measured at Low Water Datum.

\(^b\) Land Drainage Area for Lake Huron includes St. Marys River.

Lake Erie includes the St. Clair-Detroit system.

Lake Ontario includes the Niagara River.

\(^c\) Including islands.

\(^d\) These totals are greater than the sum of the shoreline length for the lakes because they include the connecting channels (excluding the St. Lawrence River).
Pre/Post Test for Students

1. Check either Oligotrophic or Eutrophic for each characteristic listed in table below.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Oligotrophic Waters</th>
<th>Eutrophic Waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Plankton Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Turbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy Bottom Sediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shallow water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lots of nutrients present in water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muddy Bottom Sediments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Plankton Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secchi Disk can still be seen in more than 2 meters of water.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Write each word in a separate circle and draw arrows to show a Lake Trout food web in the Upper Great Lakes.

Word Bank

- Trout
- Alewife & Smelt
- Zooplankton
- Sea Lamprey
- Human
- Diporeia (Benthos)
- Sculpin
- Detritus
- Phytoplankton
3. In the life cycle of a midge fly, the bloodworm is the:  (circle)
   A. pupa    B. egg    C. larva    D. adult

4. Fill in the correct order of the midge fly’s life cycle, by
   placing the letters from #3 above into the appropriate arrows
   (to the left).

5. Graph the depth profile of temperature using the sampling
   data given. Be sure to label the axis.

<table>
<thead>
<tr>
<th>Depth (ft) (from water surface)</th>
<th>Temp (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td>5</td>
<td>56</td>
</tr>
<tr>
<td>10</td>
<td>56</td>
</tr>
<tr>
<td>15</td>
<td>55</td>
</tr>
<tr>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>25</td>
<td>53</td>
</tr>
<tr>
<td>30</td>
<td>47</td>
</tr>
<tr>
<td>35</td>
<td>44</td>
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<td>40</td>
<td>42</td>
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<tr>
<td>45</td>
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<td>50</td>
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<td>55</td>
<td>37</td>
</tr>
<tr>
<td>60</td>
<td>37</td>
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<tr>
<td>65</td>
<td>36</td>
</tr>
<tr>
<td>70</td>
<td>36</td>
</tr>
<tr>
<td>75</td>
<td>35</td>
</tr>
</tbody>
</table>

6. Place the correct letter of the definition next to the word it defines.
A. A measure of the ability of water to carry electricity
B. Cloudiness of water.
C. Material at the bottom of a lake or carried by rivers and streams.
D. Organisms that are not native (originally from) an area.
E. All the different food chains that make up an organisms ecosystems.

_________ Sediment
_________ Food Web
_________ Turbidity
_________ Exotic Species
_________ Conductivity

7. List three indicators of “good” water quality in a lake. Think about the sampling that you did aboard the Agassiz.
   i. 
   ii. 
   iii. 

8. What are three things you can do to protect the water quality of the Great Lakes?
   i. 
   ii. 
   iii. 

Michigan Tech R/V Agassiz ~ School Reservation Form

**Group Information**
Group Leader: ___________________________  School: ______________________________________
Street, City, State, Zip: _________________________________________________________________
Email: __________________________ Telephone: _______________  Today’s Date: ______________
Total Number of Students: ___________  Subject: ___________________  Grade: ___________
School Start time:  School End Time: ___________________________

**Agassiz Trip Request**
Dates (list 3 possible dates/times):  1st choice: ____  2nd choice: _____  3rd choice: _____
Total Time/Cost:         ______ Full-Day (8 hours) = $880           ______  Half-Day (4 hours) = $440
No. of students per cruise: ___  Preferred cruise length per student group: 1 hour  2 hour  3 hour  4 hour
Do you want a 1- hour lab after the Agassiz trip with MTU faculty ($60):   yes       no
Preferred Agassiz Trip Leader:       ______ Faculty scientist         _____ Graduate Student

**What is the educational goal of your Agassiz Trip:** __________________________________________

Mark All Topics of Interest below (indicate priority: 1, 2, 3, etc.):
___ Introduction to Limnology and Scientific Research on the Great Lakes

**A. Physical Limnology**
___ Temperature Profiles - compare seasonal cycle of stratification: temperature v. depth
___ Light Profiles – measure light attenuation and primary productivity
___ Sediment Cores – compare depositional zones and biochemical characteristics of sediments

**B. Chemical Limnology**
___ Developing a Depth Profile for Dissolved Oxygen and pH
___ Phosphorus – Compare concentrations at different stations, and discuss its impact on lake productivity
___ Dissolved Color: use spectrophotometer to develop an adsorption spectrum for dissolved color; discuss why Lake Superior water is blue, when all of the tributaries contribute tannic brown water.

**C. Biological Limnology**
___ Food Webs and the Microbial Loop
   • Collect and identify phytoplankton & zooplankton
   • Role of indicator organisms
   • Biomagnification
___ Benthic macroinvertebrate sampling
___ Fish populations

**D. Navigation**           ___ Compass & map-reading

**Email or Fax Reservation Request to:**
Joan Chadde, Education Program Director, Center for Science & Environmental Outreach
115 Great Lakes Research Center - Michigan Technological University, 1400 Townsend Dr., Houghton, MI  49931
Tel: 906-487-3341  Fax: 906-487-1029  Email: jchadde@mtu.edu

**Michigan Tech Scientist(s) available for Middle/High School Education Programs**
Dr. Marty Auer, Dept. of Civil & Environmental Engineering
Dr. Nancy Auer, Dept. of Biological Sciences
Dr. Casey Huckins, Dept. of Biological Sciences
Jamey Anderson, Great Lakes Research Center (Remotely-Operated Vehicles ROVs)
Dr. Charlie Kerfoot, Dept. of Biological Sciences
Dr. Judith Perlinger, Dept. of Civil & Environ. Engineering
Dr. Noel Urban, Dept. of Civil & Environmental Engineering
**R/V Agassiz Float Plan (Page 1 of 3)**

*Note: Fill out this online form, save it on your computer, and email it as an attachment to floatplan-l@mtu.edu. Bring a paper copy with you when you board.*

It is the responsibility of the Chief Scientist or the Captain to file and close a float plan for each date of use. Telephone Michigan Tech’s Department of Public Safety and Police Services at 487-2216 to close the float plan, indicating safe conclusion of the cruise. Modifications to the float plan, with respect to emergency notification, can be made while underway by contacting Public Safety at 487-2216. If Public Safety cannot be reached to file modifications, it is recommended that the US Coast Guard be notified of changes in anticipated arrival time by marine radio.

1. **Trip Expectations**

<table>
<thead>
<tr>
<th>Original</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Leave from (docking location)</td>
<td></td>
</tr>
<tr>
<td>b. Leave at (time)</td>
<td></td>
</tr>
<tr>
<td>c. Destination</td>
<td></td>
</tr>
<tr>
<td>d. Return to (docking location)</td>
<td></td>
</tr>
<tr>
<td>e. Return at (time)</td>
<td></td>
</tr>
<tr>
<td>f. Filed/Modified by (name)</td>
<td></td>
</tr>
<tr>
<td>g. Filed/Modified on (date/time)</td>
<td></td>
</tr>
</tbody>
</table>

2. **Emergency Notification**

Notify the authorities if this float plan is not closed by:

Time: __________ Date: __________

Contact: U.S. Coast Guard, 482-1520

Vessel information for transmittal to authorities is on page 3 of this form.

3. **Float Plan Closure**

The cruise was completed and all passengers have safely debarked.

Date: __________ Time: __________

Signature: _____________________________________________
### 4. Persons aboard

<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Captain</td>
<td></td>
</tr>
<tr>
<td>2 Chief Scientist</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
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<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
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<tr>
<td>10</td>
<td></td>
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<tr>
<td>11</td>
<td></td>
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<td>12</td>
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<td>13</td>
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<td>15</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
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<tr>
<td>17</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

### 5. Emergency Information

**Description of Boat**

<table>
<thead>
<tr>
<th>Name:</th>
<th>R/V Agassiz</th>
<th>Length: 36’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull Color:</td>
<td>white</td>
<td>Hull ID#: WNF111934D202</td>
</tr>
<tr>
<td>Cabin Color:</td>
<td>yellow</td>
<td>Federal ID#: 1132369</td>
</tr>
</tbody>
</table>

**Boat Power**

<table>
<thead>
<tr>
<th>Engine Type:</th>
<th>Diesel</th>
<th># of Engines: 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine HP:</td>
<td>200</td>
<td>Fuel Capacity: 200 gallons</td>
</tr>
</tbody>
</table>

**Survival and Emergency Equipment**

<table>
<thead>
<tr>
<th>PFDs:</th>
<th>Yes</th>
<th>Flares:</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashlight:</td>
<td>Yes</td>
<td>Liferaft:</td>
<td>Yes</td>
</tr>
<tr>
<td>EPIRB:</td>
<td>Yes (Agassiz)</td>
<td>Smoke Signals:</td>
<td>Yes</td>
</tr>
<tr>
<td>Cell Phone:</td>
<td>906-370-9321</td>
<td>Distress Signal Light:</td>
<td>No</td>
</tr>
<tr>
<td>Marine Radio:</td>
<td>VHF 156-158 MHZ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Great Lakes Education Resources

References


Michigan Sea Grant. Great Lakes Watershed Map (2’x3’)

NOAA. Map of the Great Lakes: from Lake Champlain to Lake of the Woods (#14500). (order from www.irnha.org)


Curriculum/Activity Guides


Web Sites
Center for Great Lakes Environmental Education http://www.greatlakesed.org/index.html
EPA Great Lakes National Program Office www.epa.gov/glnpo
Great Lakes Information Network http://www.great-lakes.net/
Lake Superior Streams http://www.lakesuperiorstreams.org/
Michigan Lake & Stream Association http://www.mlswa.org
Michigan Sea Grant http://www.miseagrant.org/
Michigan SeaGrant Project FLOW (15 lessons) http://www.projectflow.us/
GLOSSARY: GREAT LAKES VOCABULARY

ALGAE
Simple, photosynthetic aquatic plants that lack true roots, stems, or leaves. Extensive growth of algae, algal blooms, in a body of water often due to increased nutrients such as nitrates and phosphates from fertilizers can lead unsafe water quality conditions.

TEMPERATURE
Water temperatures may differ from air temperatures.

BENTHOS
Organisms that live on or in a lake bottom and its sediment (benthic zone).

BLOODWORMS
Midge fly larvae found in the bottom of the lakes. Their red color is due to a chemical similar to hemoglobin that is found in human blood.

BUFFER
Standard solutions of a known value, such as pH 7 and pH 10, used to calibrate pH meters. Buffers resist changes in pH. The buffering capacity of water refers to the ability to neutralize acids. Limestone (calcium carbonate) is a natural buffer that helps to maintain soil and water pH near neutral.

CALIBRATION
Determination of the correct value of each setting on an instrument by comparison with a standard or known value.

CONDUCTIVITY
The measure of a substance’s ability (in our case, water) to carry electricity. Conductivity depends on the concentration of charged particles (ions) and temperature.

CONSUMERS
Organisms that eat other organisms or plants for nutrition.

DENSITY
The ratio of the mass of a substance to its volume.

DETRITUS
Dead and decomposing organic matter

DIATOMS
Single-celled microscopic plants with hard “shells” of silica.

DISSOLVED OXYGEN
Oxygen gas molecules dissolved in water that are available for living organisms to use. Abbreviated DO. Measured in parts per million (ppm). DO solubility varies with water temperature and pressure.

ECOSYSTEM
A system of interrelated organisms and their physical and chemical environment. It includes both the biotic (living) community and the abiotic (non-living) environment.

EPILIMNION
Warm layer of water found at the top of a stratified lake system.

EROSION
The wearing away of land surfaces by running waters, glaciers, winds, and waves. Erosion occurs naturally from weather or runoff but can be intensified by loss of vegetation.

EUTROPHIC LAKE
A lake with high concentrations of nutrients and low dissolved oxygen.

EUTROPHICATION
The natural or artificial addition of nutrients to a body of water resulting in increased growth of plants. Acts as an aging process in a body of water and may cause decreases in dissolved oxygen. Accelerated aging of lakes by human activity is called cultural eutrophication.

EXOTIC SPECIES
Species or organisms found beyond their natural range or zone of potential dispersal. They have been intentionally or accidentally introduced outside their natural ranges. Also referred to as non-indigenous species. Examples are zebra mussel, spiny water flea, and sea lamprey.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>FOOD CHAIN</td>
<td>Feeding relationships where organisms at one level serve as food for higher levels of organisms. The interconnected food chains of a biological community make a food web.</td>
</tr>
<tr>
<td>GLOBAL POSITIONING</td>
<td>A system of satellites, ground stations, and GPS receivers. Ground stations monitor satellites in “known” positions and triangulation is used to determine such things as latitude and longitude or the location of the vessel or other vehicles.</td>
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<tr>
<td>HYPOLEIMNION</td>
<td>Colder, denser layer of water found at the bottom of a stratified lake system.</td>
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<tr>
<td>INDICATOR SPECIES</td>
<td>Certain organisms, in part, that help determine water quality (clean versus polluted).</td>
</tr>
<tr>
<td>IONS</td>
<td>Electrically charged atoms or groups of atoms that are capable of conducting an electrical current in water. They may be positively or negatively charged.</td>
</tr>
<tr>
<td>LATITUDE</td>
<td>A geographical measurement made up of degrees, minutes and seconds. It is measured north or south with reference to the equator. This measurement is obtained from the GPS.</td>
</tr>
<tr>
<td>LIMNETIC</td>
<td>Open water zone</td>
</tr>
<tr>
<td>LIMNOLOGY</td>
<td>The science of studying freshwater. Limnologists study freshwater systems and oceanographers study marine (salt water) systems.</td>
</tr>
<tr>
<td>LITTORAL</td>
<td>Water zone adjacent to the shore.</td>
</tr>
<tr>
<td>LONGITUDE</td>
<td>A geographical measurement made up of degrees, minutes, and seconds. It is measured east or west of the Prime Meridian.</td>
</tr>
<tr>
<td>MICROORGANISMS</td>
<td>Organisms too small to be seen with the unaided eye, including bacteria, protozoans, yeasts, viruses, and algae.</td>
</tr>
<tr>
<td>NEKTON</td>
<td>Larger sized organisms that swim freely in water</td>
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<tr>
<td>NUTRIENT</td>
<td>Chemical substances, such as nitrates, phosphates, or potassium, that are necessary for plant growth.</td>
</tr>
<tr>
<td>Oligotrophic Lake</td>
<td>Deep, clear lake with low nutrient supplies and little organic matter. Characterized by high transparency and high dissolved oxygen levels.</td>
</tr>
<tr>
<td>PELAGIC</td>
<td>Open water zone</td>
</tr>
<tr>
<td>PERCENT OXYGEN SATURATION</td>
<td>Percent of the potential amount of dissolved oxygen that water will hold at a given temperature.</td>
</tr>
<tr>
<td>pH</td>
<td>A numeric value that indicates relative acidity on a scale of 1 to 14. A pH value of 7.0 is neutral. Acids have pH values less than 7; bases have pH values greater than 7. Acid rain has a pH of less than 5.6. Each unit increment is logarithmic (represents a tenfold increase or decrease).</td>
</tr>
<tr>
<td>PHOTOSYTHESIS</td>
<td>Production of food (carbohydrates) and oxygen by plants from carbon dioxide and water in the presence of chlorophyll and sunlight.</td>
</tr>
<tr>
<td>PLANKTON</td>
<td>Plants (phytoplankton), animals (zooplankton), and other organisms that drift in the water column. They are often microscopic but range in size from single-cells to large oceanic jellyfish.</td>
</tr>
</tbody>
</table>
PLANKTON NET  A funnel-shaped device of fine mesh cloth that will permit water to pass through it, but not microscope organisms.

POLLUTANT  Any substance introduced into the environment that adversely affects the usefulness of a resource.

PRODUCER  An organism, such as a plant, that makes its own food through the process of the photosynthesis.

SEASONAL TURNOVER  A change in a lake that usually occurs in spring and fall when denser, cooler surface water sinks, forcing warmer and less dense water upward. This results in a stirring and mixing of nutrients.

SECCHI DISK  A small (20cm) disk that is used to measure the transparency of water. It is lowered into the water until it is no longer visible.

SEDIMENT  The bottom material in water bodies. Also, materials such as soil, sand and silt that are washed from land into water, usually after rain. The particles are deposited where the water is slowed.

SOLUBILITY  The relative ability of a substance (solid or gas) to dissolve in water or another liquid.

THERMAL STRATIFICATION  Separation of water into different temperature layers: EPILIMNION (upper layer), THERMOCLINE (middle layer), and HYPOLIMNION (bottom layer)

THERMOCLINE  Layer of water found separating the epilimnion and hypolimnion in a stratified lake system. An area of rapid temperature change.

TRANSPARENCY  The depth that light will penetrate water. A Secchi disk is used to measure the limit of visibility in water bodies such as lakes.

TRIBUTARY  A stream or river that flows into a larger stream, river, or lake.

WATER COLUMN  Vertical arrangement of water from the surface to the bottom of a water body.

WATER CYCLE  Movement of water from the air to land and water and back to the air. Evaporation, transpiration, condensation, infiltration, and runoff are all parts of the water (hydrologic) cycle.

WATER QUALITY  The physical, chemical, and biological characteristics of water as they relate to the use of the water.

WATERSHED  Land area that drains water toward a lake, stream, or river, also called a drainage basin.