Roger Tory Peterson Institute of Natural History

Vernal Pool Monitoring Project

Linking the outdoors to the curriculum

Top: Spotted Salamander, photograph courtesy of Solon Morse. Bottom: Wood Frog, photograph courtesy of Allen Benton.

Introduction

The Roger Tory Peterson Institute helps schools to make the natural world nearby a regular place for learning. RTPI's Peterson Teaming with Nature Program has trained hundreds of teachers to use the square kilometer occupied by their schools as a unifying theme for interdisciplinary studies that develops awareness of and appreciation for the places where teachers and students live. This work, supported in part by a grant from the Rural School and Community Trust, has also generated a book of lesson plans written by and for our region's teachers, *Learning About Our Place*, and a *Natural History Atlas to the Chautauqua-Allegheny Region*. The latter is a resource for the community at large, and has been well received as a showcase for the natural treasures of this area. RTPI is now creating, with the help of selected schools around the region, a teacher's companion to the atlas that enables teachers to take advantage of the learning opportunities available in the natural areas within a few miles of our schools. The book will include the work of selected school districts in our region to identify and study vernal pools near their schools, and ways they link this study to their curriculum. Vernal pools are temporary ponds that are important breeding areas and nurseries for certain kinds of salamanders, as well as Wood Frogs and fairy shrimp. They often occur in depressions in wooded areas, and contain water from snow melt and spring rains. Because of their temporary nature, vernal pools do not contain fish which prey on larval frogs and salamanders. A vernal pool is defined as a contained basin or depression, having no permanently flowing above-ground outlet, holding water for 2-3 months or more, which lacks breeding populations of fish and which supports the breeding of Wood Frogs or mole (*Ambystoma*) salamanders, or contains fairy shrimp.

Vernal pool studies have been chosen for this project because:

- It is possible to find vernal pools near all the school sites, some within walking distance, others within a short drive.
- They focus on salamanders, frogs, and other organisms that are fun to find and observe.
- Making the connections to the curriculum is easy. The skills of observation and data collection link directly to the learning standards for mathematics, science, and language arts.
- The timing is right. Vernal pool studies can take place from late winter through spring, making it a good subject for ongoing studies during the school calendar.
- Data on vernal pools is scarce. Scientists studying amphibians in New York and Pennsylvania can probably use the data collected by students.

Some of the skills and activities that vernal pool studies provide an opportunity to use are:

- Map reading (interpreting map symbols, reading elevation from a topographic map, using latitude and longitude or UTM grid data to pinpoint your location)
- Map making and recording spatial data in a field journal
- Using a compass to navigate over terrain and locate vernal pools
- Using GPS to pinpoint locations
- Using measuring tapes, trundle wheel, or one's own pace to measure distances in the field
- Calculating distances, areas, and volumes of pools
- Measuring temperature
- Measuring pH
- Measuring dissolved oxygen (DO)
- Observing physical and biological characteristics of vernal pools and recording these in field journals by writing and drawing
- Using camcorders, cameras, and audiotape recording equipment
- Using hand lenses and microscopes for observing small organisms
- Identifying organisms that inhabit vernal pools in various stages of development (egg, larva, adult) using field guides and keys
- Sharing data with other schools and RTPI using a database driven web site, doing statistical analysis of data, and generating graphics to help interpret results

Winter field work consists of locating one or more pools in the neighborhood or at a designated natural area. Students locate the pools, record data on location in their journals, write and sketch what they see and hear, and use surveyor's tape to flag the pools and the path to find them.

Spring field work involves listening for wood frogs chorusing, observing and recording data on physical and biological characteristics of pools and their surroundings, in particular, attempting to determine whether fairy shrimp, *Ambystoma* salamanders or Wood Frogs are using the pool to breed, which would indicate that it is a vernal pool.

Vernal Pools in the Ecosystem

A vernal pool is a temporary or semi-permanent body of water, typically filled in the spring by snow melt and spring rain, and holding water for two or three months in the spring and summer. Vernal pools form in contained basin depressions, meaning that while they may have an inlet, they have no permanent outlet forming a downstream connection to other aquatic systems. They are typically small, rarely exceeding 50 m in width, and are usually shallow. While most are filled with meltwater and spring rains, others may be filled during the fall or with a combination of seasonal surface runoff and intersection with seasonally high groundwater tables. Typical substrates are formed primarily of dense leaf litter. While most vernal pools are found in upland forest, several types have been identified, including floodplain basins, swamp pools and marsh pools.

Periodic drying is a key feature of the ecology of vernal pools. Drying precludes the establishment of permanent fish populations, which would otherwise act as predators on the eggs and larvae of species that live or breed in the pool. While a typical vernal pool is dry during at least part of the year, others may contain some water throughout the year (or for several years), but a combination of shallow water, summer heat, winter freezing, and periodic oxygen depletion prevent the establishment of fish populations.

Vernal pools support the ecologies of a diverse number of organisms that depend on temporary waters for reproduction. These wetlands are an important and fragile component of the landscape and a limiting resource for a number of species whose local persistence depends entirely on the continued availability of appropriate breeding habitat. Vernal pool communities are composed of a group of obligate invertebrate and amphibian species and a larger group of facultative species, including several plants. Obligate vernal pool species must live or breed in vernal pools, while facultative species may be found in vernal pools, but can reproduce in other aquatic habitats where they are available. The presence of obligate species helps to define a particular body of water as a vernal pool. Of the facultative species, some have life histories and ecological requirements that may indicate conditions suitable for obligate species even when the obligate species themselves are not detected.

Obligate vernal pool species in western New York and Pennsylvania include several species of fairy shrimp, the Wood Frog (*Rana sylvatica*) and several species of mole salamander (genus *Ambystoma*), including the Blue-spotted Salamander (*A. laterale*), the Jefferson Salamander (*A. jeffersonianum*), the Spotted Salamander (*A. maculatum*) and the Marbled Salamander (*A. opacum*.) In our area, the Marbled Salamander is only found in Pennsylvania from Westmoreland and Indiana Counties to Crawford County—it is absent from western New York.

There are many additional species you may encounter in and around vernal pools that don't depend on them for reproduction—the facultative species. Amphibians include the Four-toed Salamander, Red-spotted Newt, Spring Peeper, Gray Tree Frog, Green Frog, and American Toad. Facultative vernal pool reptiles include the Painted Turtle, Spotted Turtle, and Snapping Turtle. Facultative vernal pool invertebrates include freshwater fingernail clams, aquatic air-breathing snails, leeches and insects such as water scorpions, predaceous diving beetles, whirligig beetles, dobsonflies, caddisflies, dragonflies, damselflies, mosquitoes, springtails and water striders.

Plant communities in vernal pools are composed of facultative and obligate wetland species, typically including submergent and floating plants, but rarely emergents. Typical vascular plants include mannagrasses, Spikerush, Water Purslane, Duckweed, and Waterhemlock. Characteristic mosses include several sphagnum mosses.

To establish that a particular body of water is a vernal pool, in addition to establishing the physical characteristics of the pool (e.g. that it is seasonally flooded and

Obligate Vernal Pool Species

***Anostraca*—Fairy Shrimp**
- Fairy Shrimp spp.

***Caudata*—Salamanders**
- Jefferson Salamander
- Blue-spotted Salamander
- Spotted Salamander
- Marbled Salamander

***Anura*—Frogs and Toads**
- Wood Frog

Facultative Vernal Pool Species

***Myoida*—Fingernail Clams**
- fingernail clam spp.

***Lymnophila*—Land Snails**
- air-breathing snail spp.

***Hirudinea*—Leeches**
- leech spp.

***Odonata*—Dragonflies and Damselflies**
- dragonfly nymph spp.
- damselfly nymph spp.

***Coleoptera*—Beetles**
- diving beetle larvae spp.
- whirligig beetle spp.

***Hemiptera*—True Bugs**
- water scorpion spp.

***Neuroptera*—Fishflies, Snakeflies, Lacewings, and Antlions**
- dobsonfly larvae spp.

***Trichoptera*—Caddisflies**
- caddisfly larvae spp.

***Anura*—Frogs and Toads**
- Spring Peeper
- Gray Treefrog
- Green Frog
- Northern Leopard Frog
- Pickerel Frog
- American Toad
- Fowler's Toad

***Caudata*—Salamanders**
- Four-toed Salamander
- Red-spotted Newt

***Testudines*—Turtles**
- Spotted Turtle
- Wood Turtle
- Blanding's Turtle
- Painted Turtle
- Snapping Turtle

Photograph courtesy of Ken Roblee

contained) and that it is fishless, you may also want to establish that one or more obligate species is using the pool for reproduction—the mere presence of adult animals doesn't indicate a vernal pool. Most of the evidence you will encounter will be in the form of eggs and larvae—you will rarely observe adult amphibians, as most of their activity takes place at night and only for a short period of time. Outside of the breeding season for obligate species (i.e. late May through February), a combination of several features may establish a pool as suitable habitat for obligate species: seasonal flooding, breeding or presence of certain species of facultative amphibians or invertebrates, presence of certain plant species, and a lack of fish. If obligate species are present, you don't need to observe the pool dry or to establish that it is free of fish or seasonally occupied by facultative species.

Obligate Vernal Pool Species

Photograph courtesy of

Fairy Shrimp

There are several species of fairy shrimp in New York and Pennsylvania, all of which are easy to identify as a group but difficult to identify individually. For our purposes it is only necessary to establish them as fairy shrimp. They look like large brine shrimp, a little more than one inch in length and bluish-green to orange in color. Fairy shrimp are difficult to observe during the day, but are easily seen in the beam of a flashlight at night. They move slowly and "upside down," holding their undulating swimming appendages above their bodies. Careful examination of shallow areas and the water's surface may reveal them during the day as well, as might a few sweeps of a fine mesh dip net. They are easiest to recognize after one dumps the contents of the net into a bottle of water where the fairy shrimps can "expand" and swim about.

Wood Frog

Photograph courtesy of Thomas LeBlanc

Wood frogs have a short breeding season (one to two weeks) typically beginning in late March to early April following several consecutive warm days—there may be snow still on the ground and patches of ice on the water when adults migrate to their breeding pools. They are easiest to detect during this period when males are in chorus, as a full chorus is loud and unmistakable. Males make a clucking sound that collectively—and from a distance—sounds like a flock of ducks quacking. Observation of amplexus is evidence that Wood Frogs are breeding in your pool: during amplexus, the male uses his forelegs to grasp the female from above so that he might fertilize her eggs externally as they are laid. The pair usually moves into deeper water where the female may release between 500 and 3,000 eggs.

Choruses and amplexus both take place at night, however. An easier method for establishing Wood Frog breeding is to examine the pool for egg masses. Each female Wood Frog will produce a single egg mass, and several hundred females may lay their eggs in a single "nesting site" within the pool. Wood Frog eggs are black and surrounded by a clear jelly: a single egg mass may contain hundreds or thousands of eggs clumped together in a rounded gelatinous ball about the size of a fist. Older egg masses may turn greenish from symbiotic algae. The mass of eggs is attached to a branch, rush, or some other submerged vegetation, and is usually positioned so that it can float near the surface but in water deep enough that it won't become exposed as the pool's water level drops. Large numbers of floating egg masses can give the water's surface a bubbly appearance.

The incubation period is temperature-dependant, lasting anywhere from four days to four weeks. Eggs typically begin to hatch in mid- to late-April. Tadpoles are ready to transform in six to fifteen weeks. For the first several days after hatching the larvae remain in the sun attached to the vegetation near the spent egg mass and appear

Top to bottom: Pennsylvania vernal pool, fairy shrimp, Wood Frog eggs.

as greenish-black "apostrophes." By May the tadpoles are much larger—reaching up to 4.8 cm in length—and are brown or olive, sometimes speckled with black and gold, with a short, high tail fin and an iridescent whitish or bronze belly. By late May, they may share the pool with tadpoles of toads and other frogs. Without experience distinguishing between the various tadpoles may be difficult, so it is best to look for Wood Frog tadpoles no later than early May. The greenish, filmy spent egg masses may remain visible in the pool through April.

Mole Salamanders

In the spring, adult *Ambystoma* salamanders may be encountered in our area include Spotted, Blue-spotted and Jefferson Salamanders, and hybrids between Blue-spotted and Jefferson Salamanders. These hybrids can be very difficult to distinguish from either parental species, so we will refer to the whole group as the Jefferson/Blue-spotted complex. In western Pennsylvania in the fall one may also encounter Marbled Salamanders.

Spotted, Blue-spotted and Jefferson Salamanders emerge and migrate to breeding pools in the early spring—usually late March through mid-April—following several days of warm weather, heavy spring rains, and ground thaw. Males deposit spermatophores—small, whitish cone-shaped structures containing spermatozoa—on the pool bottom. These structures are often clearly visible scattered over the leafy bottom in shallow water, and are often concentrated in one area. A female will pick up spermatophores in her cloaca and fertilize her eggs internally. Within several days, she will lay a number of egg masses, each attached to a stick or other submerged vegetation six inches or so beneath the surface. Egg masses begin somewhat transparent but may become whitish or greenish over the course of several weeks. Each egg within the gelatinous outer layer has its own individual membrane and is clearly visible within the mass. Spotted Salamander egg masses tend to be large, containing fifty to several hundred eggs, and can expand to a diameter of 4–10 cm. Blue-spotted Salamanders lay their eggs singly or in very small masses, containing a dozen or fewer eggs. Jefferson Salamander eggs form elongate clusters containing 20–30 eggs (rarely more.) In the Spotted Salamander the distance between the egg and its external membrane is about the width of the egg, while in the Jefferson and Blue-spotted Salamanders this distance is less than the width of the egg.

By late April the salamander larvae should be clearly visible inside each individual egg. They typically emerge in May and hide in leaf litter on the bottom by day. They can be found foraging over the bottom or near the surface at night. During the day they may be captured with a fine-mesh dip net by running the net through leaf litter and vegetation at the bottom of the pool then carefully sorting through the debris by hand. The larvae resemble tadpoles but have four legs and external gills. They range in size from 0.8–1.4 cm at hatching to 4.0–7.5 cm at metamorphosis.

The larvae remain in the pool through June and into August depending on water level, temperature, food supply and other variables. Although they may be difficult to find, they provide evidence of vernal pool obligates well into the summer after Wood Frog tadpoles have transformed into adults and left the area. As the larvae salamanders transform, they may be found under debris around the pool margins. Newly transformed larvae will be close to the water's edge and will have gill remnants.

Photograph courtesy of Solon Morse

Photograph courtesy of Solon Morse

Photograph courtesy of Solon Morse

Photograph courtesy of Thomas LeBlanc

Top to bottom: Marbled Salamander, Jefferson Salamander, Blue-spotted Salamander, Spotted Salamander eggs.

Site Characteristics

- Pool ID
- Date and time pool discovered
- State
- County
- Township
- Latitude & longitude
- Public land, nature preserve, private land, or school-owned land?
- Placename
- Written directions
- Hand-drawn map
- Plot on topographic map
- Presence of permanent inlet or outlet

- Pool type
- Dominant substrate

- Surrounding habitat:
- Canopy cover (%)
- Dominant vegetation within 50 m of pool
- Percent vegetation cover within 50 m of pool (%)
- Distance to nearest road, lawn or agricultural opening, building, and forest edge (m)

Site Observations

- Date and time pool visited

- Weather
- Air temperature (°C)

- Water temperature (°C)
- Maximum length (m)
- Maximum width (m)
- Water depth (m)
- Dominant vegetation in pool
- Vegetation cover in pool (%)

- pH
- Dissolved oxygen (ml/l)
- Nitrates (ml/l)

- Obligate species observed
- Facultative species observed
- Other species observed

Finding And Mapping Vernal Pools

There are a number of methods for finding vernal pools and potential vernal pools sites, all of which involve fieldwork, but you may improve your chances by using maps to narrow the scope of your search. Because they are small and temporary, typical vernal pools won't register on many maps. Larger pools may show up on USGS 7.5 minute quadrangle maps, and the likelihood of encountering smaller pools can be inferred from subtle topographies even when the pools themselves are unmapped.

Data Collection

Because you might make several observations at any one pool we have broken the data collection process into several broad categories: *site characteristics* are unlikely to vary from visit to visit and are collected only once. *Site observations* will likely vary seasonally, and should be recorded with each visit. Site characteristics include pool location, surrounding habitat, and several pool characteristics such as pool type and presence of permanent inlets and outlets. Site observations include pool dimensions, water temperature, water chemistry, organisms using the pool, etc.

Identification & Location of a Vernal Pool

Hand-held GPS units are becoming economical and easy-to-use ways to pinpoint the location of objects in the field such as vernal pools. Even so, a map, compass, and your journal are probably the likeliest tools for recording the location of the pools you find.

Give the pool some sort of ID: we suggest using your initials in combination with the date and time the pool was discovered—e.g. SFM-03-26-02-13-20 in order to assure a unique identifier. Note the date and time. Using a USGS topographic map as a reference, note the state, county and town in which the pool resides. Indicate if the pool is located on public land, within the confines of a nature preserve, on school-owned land or on private land. Public land includes national forests, state forests, and recreation areas, and nature preserves include nature centers and nature sanctuaries. If the pool is located within a named area, please record the place name (e.g. Allegany State Park.) Record the pool's latitude and longitude in decimal degrees (see below for an explanation.) Finally, a hand-drawn map and a brief description of how to find the pool—using distance and direction from known landmarks—is critical so that others may visit it as well.

Keep careful note of your route in your journal, drawing a map as you proceed and noting the location of easily recognizable landmarks such as fences, roads, structures, etc. Measure distances in the field using the length of your pace. A pace is two consecutive strides: say from the right footfall to the right footfall again. This distance is about 5 feet, but of course varies from one person to another. Determine your pace by walking 50 meters with a natural stride a couple of times while counting your paces. Divide 50 by the average number of paces to find the number of meters in each pace. To determine distance in the field simply keep track of the number of paces and then multiply by the length of your pace.

To find your compass bearing from a landmark to the pool hold the compass in front of you and sight over the compass to the pool. Rotate the compass housing until the north arrow on the housing lines up with the north end of the compass needle. The degree reading on the housing in the direction of the pool is your compass bearing.

The map you draw in your journal should include a description of the pool and its

location, with sketches and written notes. Show the location of any features that may be used to distinguish this pool from any others that might be nearby. Additionally, you might plot the location of the pool on a USGS topographic map. Use topographic lines, landforms and other features to pinpoint the pool's location.

Hand-held GPS units can be used in the field to find the latitude and longitude of pools, which can then easily be plotted on a topographic map.

Using RTPI's Garmin® GPS 12 Personal Navigator®

1. You must be **outdoors** for GPS to work, as the receiver relies on data coming from navigation satellites orbiting overhead.

   Be aware of environmental conditions that may block signals and simply move into a more open area.
2. Turn the unit ON—press the red power key on the left-hand side of the unit for about 2 seconds.
3. The **Status Page** will appear (says ACQUIRING EPE at top of page.)

   When the unit acquires enough satellite signals the Status Page will be replaced by the **Position Page** (says TRACK…SPEED at top of page.)
4. When you have located a pool, stand at the pool's position and press the MARK key.

   The **Mark Position** page will appear, with a default 3-digit name (001) for the new "Waypoint" in the upper-left corner of the page.

   You can save the waypoint with the default name and symbol at this time - **highlight** SAVE and press ENTER. (This takes you back to Position Page.)

   Keep a log of each waypoint and its location. It is easier to rename it indoors.
5. To turn off the unit press the red power key for about 2 seconds.

You may be indoors to rename the waypoint (for example, with your school's initials) and to find out the position coordinates of a particular waypoint.

1. Turn unit ON.
2. Press PAGE several times, until you reach the **Main Menu**.

   Select WAYPOINT list by pressing ▲ or ▼ to highlight, then press ENTER.

   Highlight the WAYPOINT you want to rename and press ENTER.

   Highlight the RENAME field, then press ENTER.

   Now, to enter the Waypoint name 'SCHOOL,' for example:

   Press ▲ or ▼ to scroll through to the appropriate numbers or letters.

   Each time you choose a letter or number, press ▶ until you are finished.

   Then press ENTER.

   The WAYPOINT symbol field will become highlighted.

   Move the cursor to DONE and press ENTER. (You'll be asked, "Are you sure?")

   The WAYPOINT will now be saved under the new name you have entered.
3. To find out the position coordinates of a particular waypoint, turn the GPS unit ON, press PAGE until you reach the **Main Menu**, then highlight (by pressing ▲ or ▼) on Waypoint List and press ENTER.

   Then highlight the WAYPOINT you want the coordinates for, and press ENTER. Information on that waypoint's position will appear. RTPI's GPS is set for the latitude and longitude position system with decimal degrees (as opposed to degrees, minutes, and seconds.) The position information will look something like this:

```
POSITION
N  42    11849˚
W  079   225502˚
```

Identification and location of your vernal pool

Data Collected

- Pool ID
- Date and time the pool was discovered
- State
- County
- Township
- Latitude & longitude
- Public land, nature preserve, private land, or school-owned land?
- Placename
- Written directions
- Hand-drawn map
- Plot on topographic map

Equipment Needed

- USGS Topographic map, 7.5-minute series for your location
- Compass
- Meter stick
- 50-meter tape measure
- Stake wire flagging
- Flagging tape
- Hand-held calculator
- Journal
- Pencil or pen

Optional Equipment

- Hand-held GPS unit
- Trundle wheel
- Detailed map of site: tax assessor's map, school site map, etc.
- MapTech Topographic Map software
- Internet access to Topozone.com

GPS KEYPAD USAGE

▲ ▼ Selects alphanumerical characters and menu choices and moves the field highlights from field to field.

◀ ▶ Moves the selected character field and moves the field highlight from field to field.

Non-seasonal Pool Characteristics

Data Collected

- Presence of permanent inlet or outlet
- Pool type:
  forest depression, swamp pool, bog pool, marsh pool, impoundment, drainage system, flooded quarry, man-made dug pool, other
- Dominant substrate:
  leaf litter, mud, peat, sand, gravel, cobbles, bedrock, other

Equipment Needed

- Journal

Surrounding Habitat Characteristics

Data Collected

- Surrounding habitat:
  open wetland, forested wetland, open upland, forested upland
- Canopy cover (%)
- Dominant vegetation within 50 m of pool
- Vegetation cover within 50 m of pool (%)
- Distance to nearest road, lawn or agricultural opening, building, and forest edge (m)

Equipment Needed

- Meter stick
- 50 meter tape measure
- Rubber boots, hip boots, or waders depending on depth of water in pool
- Walking stick
- Stake wire flagging
- Journal

Optional Equipment

- Trundle wheel
- Tree, shrub, and wildflower guides

To find the point electronically, go to www.topozone.com. There, on the side bar, under "Get a Map", click on "Decimal Degrees." Then, type in the GPS position data. Make sure the longitudinal reading is entered as a negative number. Click on the "Map It" button. When the map showing your location comes up, select the 1:25,000 map from the choices along the top of the map. At the bottom of the map, select "Show Target Symbol," then click on "Print This Map." Finally, print a copy of the map on your printer. The map should show the location of the point with a ✣.

Non-seasonal Pool Characteristics

Look for both a permanent outlet and a permanent inlet.

Classify your pool by type. Most of the pools you will encounter will likely be isolated basins in forest tracts, and would be classified as **forest depressions**. If you find pools in a floodplain, they may be part of a larger aquatic system. Forested swamps may contain isolated **swamp pools**, and bogs may contain isolated **bog pools**. Open floodplain habitats such as marshes contain **marsh pools**. Many animals can be found breeding in a wide variety of man-made wetlands, including **impoundments**, **drainage systems**, **flooded quarries**, and man-made **dug pools**.

Identify the dominant substrate in your pool: this is the material lining the bottom of the pool. Most pools will have a substrate of **leaf litter** and **mud**, but **peat**, **sand**, **gravel**, **cobbles**, or **bedrock** may be found in some areas. You may want to use a dip net to sample substrates from deeper parts of the pool. When sampling for organisms, pay attention to the substrates you encounter.

Surrounding Habitat Characteristics

When you visit a site where a suspected vernal pool is located note the following habitat characteristics:

Surrounding habitat. Observe the area and describe the habitat in very broad terms. Is it part of a larger surrounding **open wetland**—e.g. an emergent marsh, shrub swamp, shrub bog, fen, wet meadow, or cultural wetland? Is it embedded in a **forested wetland** such as a floodplain forest, forested swamp, or a forested bog? Is it within an **open upland**—e.g. a grassland, shrubland, successional, cultural, or a **forested upland** like a barrens, woodland, or upland forest?

Canopy cover. For a larger pool the observer should be at or near the middle of the pool. Look up and note how much of the sky is covered by the tree canopy above. Since trees may not be leafed out at the time of your observation estimate to what extent leaves will create shade at the location. Express this estimate as a percent.

Dominant vegetation types within 50 m of pool. Measure a radius 50 m away from the pool on all sides. Within this circle observe the vegetation type that is most prevalent: trees, shrubs, or herbaceous plants, paying special attention to canopy trees if present. Identify vegetation to species (i.e. Red Maple) or genus (i.e. hickory spp.) if possible. The point of this exercise is to further refine your description of the surrounding habitat. For example, there are many kinds of broadly-classified forested wetlands, including red maple-hardwood swamps, silver maple-ash swamps, and hemlock-hardwood swamps. Upland forests might include oak-hickory forests, oak forests, beech-maple forests, or maple-basswood forests. Many communities can be classified by a single or several dominant species: these are what you should look for.

Percent Vegetation cover. Within this same 50 m radius circle observe how

much of the ground is covered by vegetation and express this as a percent.

Distance to nearest road, lawn or agricultural opening, building, and forest edge. Habitat fragmentation can have a number of (often negative) effects on many kinds of organisms. Disruptions and habitat boundaries such as forest edges and roads are an important component of landscape ecology. In many cases your pool will be within a few meters of a road or other forest edge. Depending on the distances involved make an actual measurement or estimate the distance to various edges and other landscape features using a topographic map or other map that depicts these features. USGS topographic maps show forest boundaries that are often accurate, and distance to roads can be measure directly from such a map.

Weather

Record the weather and air temperature when visiting your pool.

Weather options in the data collection form include **sunny** (no clouds), **partly sunny**, **cloudy** (no sun), **rain intermittent**, **rain light**, **rain heavy**, **snow intermittent**, **snow light**, **snow heavy**, or **other**. Although we have provided a list of weather categories, please describe the weather more fully in your journal if possible (especially if you chose "other") and add your description as a comment.

Air temperature should be measured on-site in degrees centigrade, but if your measurement is in Fahrenheit the on-line data entry form will convert it to centigrade for you.

Weather

Data Collected

- Weather:
  sunny, partly sunny, cloudy, rain intermittent, rain light, rain heavy, snow intermittent, snow light, snow heavy, other
- Air temperature (°C)

Equipment Needed

- Thermometer
- Journal

Seasonal Pool Characteristics: Temp, Dimensions, and Vegetation

Pool temperature, dimension, depth, dominant vegetation, and vegetation cover will vary seasonally. As the season progresses and the pool loses water its average temperature will rise and its length, width, and depth will shrink. Vegetation communities and cover may shift as well as seasonal vegetation types develop and gain prominence. These measurements should be taken every time you visit your pool.

Water temperature is an important indicator of water quality. Many of the physical, biological and chemical characteristics of a vernal pool are directly affected by temperature. For example, temperature affects the amount of oxygen that the water can dissolve and the rate of metabolism of various aquatic organisms. Water temperature should be measured in degrees centigrade. Take a reading some distance from shore where the water is deep enough that it is not overly warmed by the sun. You can take several measurements and report an average.

Record your pool's size: maximum length, maximum width and depth. Find the longest dimension and use this as the maximum length. It is probably easiest to pace the distance through the pool if the pool isn't too deep—otherwise use a 50 m measuring tape or just eyeball the distance. The width should be measured along a line approximately perpendicular to your maximum length. Record both measurements in meters.

Depth can be measured using a meter stick. If the pool isn't too deep, try to find the deepest point to take your measurement from. In order to minimize disturbance to the pool, only one person should enter to make this measurement. Record your depth measurement in meters. Many pools will be under one meter in depth: a 27-cm depth, for instance, should be recorded as 0.27 m.

Pool vegetation constitutes an important substrate for the attachment of amphibian eggs, may provide food for a number of species, and provides cover for shade and refuge from predators. Describe the dominant vegetation types in the pool. Many pools will have various species of shrubs and small trees growing in and around them,

Seasonal Pool Characteristics

Data Collected

- Water temperature (°C)
- Maximum length (m)
- Maximum width (m)
- Water depth (m)
- Dominant vegetation in pool
- Vegetation cover in pool (%)

Equipment Needed

- Thermometer
- Meter stick
- 50 meter tape measure
- Rubber boots, hip boots, or waders depending on depth of water in pool
- Walking stick
- Stake wire flagging
- Journal

Optional Equipment

- Trundle wheel
- Tree, shrub, and wildflower guides

Water Chemistry

Data Collected

- pH
- Dissolved oxygen
- Nitrates

Equipment Needed

- Sample jar
- pH paper & color chart
- Dissolved O_2 testing kit
- NO_3 testing kit
- Journal

with rushes, sphagnum and other wetland or terrestrial plants growing along the edges, and duckweed floating on the surface. Plants may be either submergent (growing entirely underwater), emergent (rooted underwater but emerging above the water's surface), or floating. Estimate the vegetation cover in the pool itself, expressed as a percent.

Water Chemistry

Measuring pH

Water (H_2O) contains both H^+ (hydrogen) ions and OH^- (hydroxyl) ions. The pH test measures the H^+ ion concentration of a solution. pH is measured on a scale of 0 to 14. On this scale pure water has a pH of 7, or neutral, because it has equal numbers of H^+ and OH^- ions. If a water sample has more H^+ than OH^- ions it has a pH less than 7 and is considered acidic. If a water sample has more OH^- than H^+ ions its pH is above 7 and is considered basic or alkaline. The pH scale is logarithmic, that is, for example, a sample with a pH of 4 has 10 times the hydrogen ion concentration (acidity) of a sample with a pH of 5, and 100 times the hydrogen ion concentration (acidity) of a sample with a pH of 6.

pH is a critical factor in determining the suitability of an aquatic environment for organisms. Some organisms have a relatively broad tolerance for acidity, while others are highly sensitive to changes in pH. Some ecosystems are highly acidic (bogs, for instance) and support only those organisms that are adapted to such conditions.

The pH of a body of water is affected mainly by the acidity of the water that enters it as precipitation and by the capacity of the substrate (rock or soil) to act as a buffer, thereby neutralizing some of the acid. Precipitation is normally somewhat acidic due to carbonic acid that becomes dissolved in water as it interacts chemically with carbon dioxide in the atmosphere. However, pollutants released into the atmosphere by industry, electric power production, and transportation include nitrogen and sulfur compounds that result in the formation of precipitation that may be quite highly acidic. Our region receives a considerable amount of acid rain and snow from sources upwind. However, the region's lakes and streams are generally in the neutral pH range (between 6.5 and 8), probably due to the buffering action of its rocks and soils. These are sedimentary in origin, primarily shale with some sandstone, siltstone, and limestone. In much of our region glaciers have deposited a thick layer of mixed-up rock particles of differing sizes and composition, called till. Wetlands such as bogs, marshes, and swamps, generally hold water that is at least somewhat acidic. However, a few of the region's wetlands are fed by groundwater that percolates through limestone deposited by the action of glaciers and are, in fact, alkaline enough to support certain rare orchids and other plants that are adapted to such conditions. These alkaline wetlands are known as fens.

pH: Using colorpHast® Indicator Strips for pH 0–14

1. Take a sample of water from the pool in a clean jar.
2. Dip one of the strips into the sample. Keep the strip immersed for 1-10 minutes until there is no further color change.
3. Compare the color of the strip to the color chart on the box. Note the pH that most closely matches.

Measuring Dissolved Oxygen

Dissolved Oxygen (DO) is a measure of the amount of oxygen gas (O_2) dissolved in water. Most aquatic plants and animals need oxygen to survive. In vernal pools the

larvae of salamanders, frogs, and toads, and some aquatic insects, have gills to absorb oxygen from the water.

Much of the dissolved oxygen in a body of water comes from the atmosphere. Plants and algae also add oxygen to the water as they conduct photosynthesis.

Many factors can influence the amount of dissolved oxygen in water. One of the most important physical factors is temperature. Gases, like oxygen, dissolve more easily in cooler water than in warmer water. Water temperature, of course, is strongly influenced by air temperature. Biological factors also influence dissolved oxygen. As stated above, as aquatic plants conduct photosynthesis they add oxygen to the water. Conversely, aerobic bacteria consume dissolved oxygen as they decompose organic material in the water and on the bottom of the pool.

DO: Using the Hach® DR 820 Portable Datalogging Colorimeter

1. Press PRGM.
2. Press 70 ENTER.
3. Fill a sample cell (the blank) with at least 10 mL of sample. Fill a blue ampule cap with sample. Collect at least 40 mL of sample in a 50-mL beaker.
4. Fill a High Range Dissolved Oxygen AccuVac Ampule with sample. Keep the tip immersed while the ampule fills completely.
5. Without inverting the ampule, immediately place the ampule cap that has been filled with sample securely over the tip of the ampule. Shake for about 30 seconds.
6. Press TIMER ENTER. A 2-minute reaction period will begin.
7. When the timer beeps shake the ampule for 30 seconds.
8. Place the blank into the cell holder. Tightly cover the sample cell with the instrument cap.
9. Press ZERO. The cursor will move to the right then the display will show: 0.0 mg/L O_2.
10. Place the AccuVac ampule into the cell holder. Tightly cover the ampule with the instrument cap. Wait about 30 seconds for the air bubbles to disperse from the light path.
11. Press READ. The cursor will move to the right, then the result in mg/L O_2 will be displayed.

Measuring Nitrates

Nitrogen is an element needed by all living plants and animals to build protein. It is most abundant in nature in its gaseous molecular form (N_2) in the atmosphere, where it makes up about 78% of the air we breathe. But most organisms cannot make use of nitrogen from the air for building protein. It first must be converted or "fixed" into chemical compounds by blue-green algae or by nitrogen-fixing bacteria present in the roots of certain kinds of plants. These compounds include ammonia (NH_3) and nitrate (NO_3^-). Animals get the nitrogen they need by eating plants and breaking down and converting their proteins into specific animal proteins, or by eating other animals and similarly breaking down and rebuilding their proteins.

When proteins are metabolized in the bodies of living organisms nitrogenous wastes are produced which must be excreted into the surroundings. Some of these wastes end up as nitrates in aquatic systems. Sources of these wastes may include

- human waste in septic systems or municipal wastewater treatment plants that are not working properly;
- the excrement of ducks and geese in areas where they are plentiful;
- runoff from cattle feedlots, dairies and barnyards;
- stormwater runoff from farms and lawns that have been fertilized with nitrate-containing fertilizers.

Species Observed

Data Collected

- Obligate species observed
  Chorus (frogs), adults, mating adults, spermataphores (salamanders), eggs, larvae, transforming juveniles
- Facultative species observed
- Other species observed

Equipment Needed

- Dip nets
- Collection containers
- Camera
- Drawing materials

Optional Equipment

- Invertebrate field guide, especially an insect guide
- Reptile and amphibian field guide
- Tape recorder

Because nitrogen in the form of ammonia and nitrates acts as a plant nutrient it also promotes plant growth and decay in aquatic systems, resulting in "algal blooms" and the proliferation of duckweed and other aquatic flowering plants.

NO_3: *Using the Hach® DR 820 Portable Datalogging Colorimeter*

1. Press PRGM.
2. Press 51 ENTER.
3. Fill a sample cell with 10 mL of sample.
4. Add the contents of one NitraVer 5 Reagent Powder Pillow to the sample cell (the prepared sample). Cap the sample cell.
5. Press TIMER ENTER. A one-minute reaction period will begin. Shake the sample cell vigorously until the timer beeps.
6. After the timer beeps the display will show 5:00 TIMER 2. Press ENTER. A five-minute reaction period will begin.
7. Fill another cell with 10 mL of sample (the blank). Wipe off any fingerprints or liquid.
8. Place the blank into the cell holder. Tightly cover the sample cell with the instrument cap.
9. When the timer beeps press ZERO. The cursor will move to the right, then the display will show: 0.0 mg/L NO3–N.
10. Place the prepared sample cell into the cell holder. Tightly cover the sample cell with the instrument cap.
11. Press READ. The cursor will move to the right, then the result in mg/L NO3–N (or alternate form) will be displayed.
12. NOTE: rinse the sample cell immediately after use to remove all cadmium particles. Save the spent sample for hazardous waste disposal in a small can of kitty litter for ultimate disposal in trash destined for landfill.

Species Observed

Adult amphibians are mostly nocturnal and are very secretive during the daytime. Adult frogs and salamanders and transforming juveniles may occasionally be found around the margins of pools, particularly if there are objects to hide under in the vicinity. You might try turning things over—carefully!—and looking underneath. Logs, tree branches, leaf litter, and rocks all make good hiding places. With a little careful searching, adult *Ambystoma* salamanders can be found with moderate ease when they are present. In our experience, they are frequently found under logs lying on top of water-saturated soil. Frogs are most easily detected at night when they are chorusing, although some will chorus during the day, especially under rainy or cloudy conditions. You might even observe amplexus. If you have a tape recorder available, try recording the frogs you hear, and be familiar with the Wood Frog call. Try to photograph or draw any adult amphibians you encounter. Remember that the presence of adult animals, unless they are observed mating, doesn't necessarily mean the pool is being used for breeding purposes. Juveniles with gill remnants on the edge of your pool, however, are good evidence of breeding because they don't travel far when recently transformed.

The most obvious evidence of obligate species breeding in your pool will be in the form of eggs. Many of the egg masses will be located close to the water's surface, often near shore, and can usually be observed and photographed from the bank. Try not to touch or otherwise disturb egg masses: they need to remain attached and near the surface in order to hatch properly. *Ambystoma* salamanders produce whitish spematophores that can often be seen scattered along the bottom over leaf litter.

Salamander larvae and tadpoles—and a host of other organisms—can frequently be captured by gently sweeping a dip net through the pool. Take care not to disturb the pool too much, but, to be effective, netting should be done around submerged vegetation and through the pool's substrate. Examine the net carefully, picking through leaf litter by hand in order to reveal the animals contained therein, but don't keep aquatic animals out of water for long! A wide-mouthed container (a large margarine tub works well) with a little water can be used for storing animals while you identify them. Return them to the pool as soon as you are satisfied you have identified them properly.

Recording Visual and Sound Data

Recording Sights

The most economical way to collect visual information about vernal pools and their environment is to have students keep journals in which they sketch what they see. This will require teaching students field sketching and techniques for making accurate observations. Start by having students sketch inanimate objects using pure contour drawing, modified contour drawing, and gesture drawing techniques.

Sit close to a stationary natural object, or hold a leaf, seashell or some other natural object in your hand. Place the point of your pencil on a journal page and focus your attention on one point on the surface of the object. Pretend that the place where you are looking is actually being touched by your pencil point. Once you are convinced of this, let you eye begin to wander slowly over the surface contours of the object, while your pencil moves in the same way across the surface of the page. Do not look at the page as you draw. Draw slowly as your eye explores all the ins and outs and nooks and crannies, and keep your pencil in contact with the paper the entire time. Be patient, and do not think you need to "finish" the drawing; it is the experience you are going through that is important here. Don't worry one bit about what your drawing looks like. Let it draw itself.

When you feel that your drawing is "finished" look at the page. The results may surprise or even amuse you. Great! This process should be playful and fun. Take several moments to note details in form, angles and textures that you have sketched and compare them to the real object. Ask yourself if you know the object more intimately as a result of having drawn it in this way. If your answer is "yes" you have achieved your goal.

Once you are confident about using the process of contour sketching (and that will come with practice) use this technique in a modified way to sketch objects and landscapes into your journal. "Modified contour sketching" means spending most of your time looking at your subject, not at your paper. For example, spend 80% of your sketching time looking at the rhododendron blossom you're sketching, the other 20% occasionally orienting yourself on the page, checking proportions and so on. The important thing is to actually see the object you are sketching, so that your result is a representation of what the object actually is, not your preconceptions about it.

Sketching objects in the field entails making accurate measurements. Keep a metric ruler handy and use it often to check the size of the object against the size of your sketch. Decide whether you want to make your sketch actual size, or smaller or larger than the specimen, and indicate this on your drawing by noting "x1", "x2", "one-half actual size," or whatever.

Field sketching also involves making written notes. Start each entry in your journal with the date, time of day, where you are, and an introductory note about the weather: temperature, percent cloud cover, and wind direction and speed. As your en-

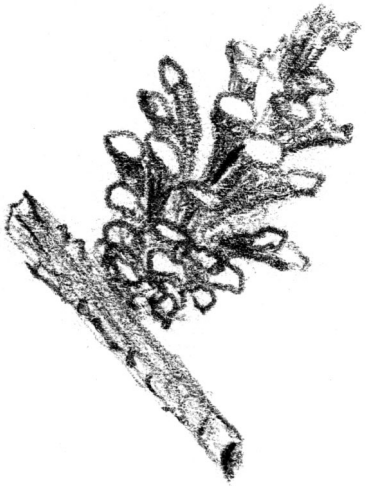
Recording Visual and Sound Data

Equipment Needed

- Newsprint or other inexpensive paper (for practice)
- Field journal
- Pens, Pencils, Colored pencils, markers, or watercolor paints
- Hand lens
- Metric ruler
- 3 by 5 cards
- Scissors
- Audio guide to vernal pool sounds
- Journal

Optional Equipment

- Camera, film or digital video camera
- Sound recording equipment
- Tapes, tripod, other accessories as needed



Illustrations courtesy of Mark Baldwin

try progresses decide, for each observation you record, whether a sketch, notes, or a combination of the two will be most effective.

If you have live animals in the classroom, whether goldfish or gerbils, these may be used to practice gesture drawing. Allow students to gather around and spend a few minutes just watching the animals' movements. Suggest to the students that the idea of "gesture" is to feel the movements of the animal in their own bodies and to record this movement on paper. The important thing here is to record what the animal is doing and to capture the action you see. Open your journal to a fresh page and begin to record the actions you see, as you see them. As with contour sketching, try to keep your eyes on your subject; let your pencil feel its way around the page, but this time move your pencil very quickly. Hold the pencil loosely, about halfway up, and involve at least your whole hand in expressing the movement you see. Focus your attention on a single bird and let its whole form spill onto the page, all at once. Your aim is to record movement, not anatomical detail. Make your pencil line playful and scribbly. A few sessions of drawing moving animals portrayed on a video or computer screen is also good practice for what you will be dealing with outdoors.

A flitting nuthatch, wind-blown leaves, water coursing over rocks in a brook…nature is in constant motion. Gesture sketching is used to record that motion. Birds make good subjects for observing and recording gesture. They're easy to find, usually, and they're often moving, doing a variety of things: feeding, bathing, flying, walking, preening, and so on. Position yourself near a place where there are birds, and spend several minutes watching their actions. As you do this, try to feel their actions in your own body. A chickadee diving in and out of a bird feeder may convey to your eye no more than a blur of movement; that is what you record. What you have drawn may be meaningless to some one else; that's fine. The point here is to accurately transfer the sensation of what the animal is doing, to give you a feel for the animal's action or expression. Try several of these quick gesture sketches, arranging them in a pleasing way on the page. When you have finished filling a page, stop to look at what you have drawn, and think back to the instant you reacted to a particular gesture, perhaps to a dabbling mallard duck. If your sketch brings to mind the duck's movement and energy (not necessarily its precise form or shape) you have achieved your goal.

You can practice gesture sketching even with stationary objects like leaves, feathers and pine cones by rapidly sketching them in your journal, allowing yourself only brief periods of time to do it, like 5-30 seconds. As you do this, concentrate on recording the whole rather than specific parts.

Gesture sketching may be used to capture the motion of any aspect of nature, even to indicate the direction of growth of trees or wildflowers, or the breeze blowing across a meadow. Your practice of this technique will subconsciously turn up throughout your field journal.

In the field around a vernal pool students may draw the pool itself along with its surrounding landscape. Here a simple viewfinder comes in handy. Have each student fold a 3 by 5 card in half and cut a rectangular piece out of the folded part, so that when the card is unfolded you have a "window" surrounded by a frame. Use this viewfinder to frame a picture and get the proportions and positions of various elements in the picture "right" as the sketch develops. A student in the picture will provide the scale needed. A series of such sketches done by several students from several different viewpoints will create a composite visual image of the place being studied.

Additional visual data may be collected using cameras, either film or digital; and video camera. Be sure to identify the pictures you are taking by noting the number of each exposure in your journal: exact place, time of day, photographer, and any other pertinent information. Place a student in each picture when a size reference is needed.

Illustration courtesy of Mark Baldwin

Recording Sounds

At certain times, particularly when frogs and toads are mating, sounds take over as the main sensory impression around vernal pools. Prepare your students for what they might hear on a springtime visit to a vernal pool by playing the calls of frogs and toads using a tape or CD of such sounds in the classroom.

Dim the lights to emphasize hearing. As you play the sounds of spring peepers, wood frogs, and American toads have students record their impressions of the sounds in their journals. What do they remind them of?

A video camera will collect sounds, too, of course, but you may also collect sounds by creating a sound map in your journal, or with sound recording equipment.

To make a sound map:

1. Draw a circle.
2. Place an X in the center to indicate your position, then start to listen carefully.
3. Each time you become aware of a sound, note its direction, volume and apparent distance away, and represent it graphically in some way.
4. After listening and recording for about 10 minutes, review what you have heard and summarize it in writing. What sounds were "natural" sounds? What were "man-made"? What sounds could you identify? Which are mysteries? Were any sounds annoying? Were any sounds pleasant?

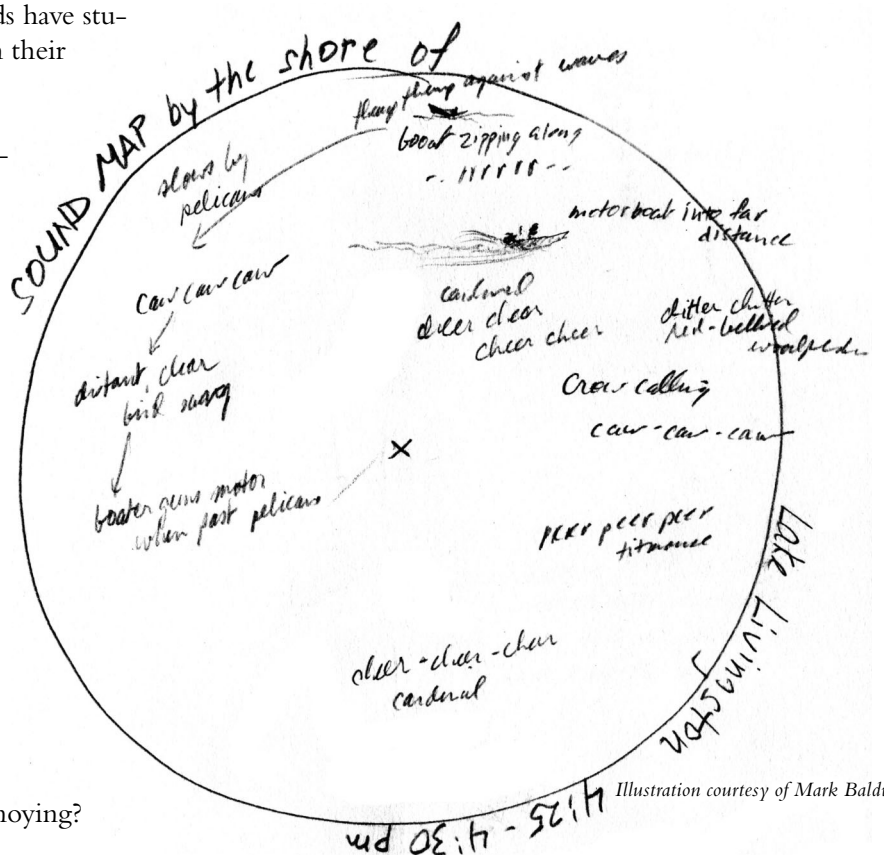


Illustration courtesy of Mark Baldwin