
Vermont Vernal Pool Monitoring Project



VPMon 2026 Manual



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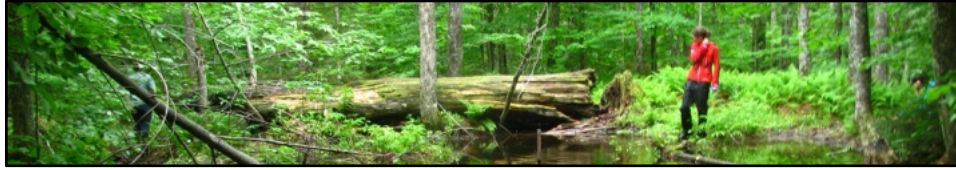
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For more information, please see:

<https://vtecostudies.org/what-we-do/projects/vernal-pool-monitoring>





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Chapter 1

Introduction to VPMon

What is a Vernal Pool?

Vernal pools are small seasonal wetlands that generally share four characteristics:

1. Seasonal wet-dry cycle

Vernal pools typically fill during the spring or fall, and then dry, at least partially, in the summer (and fully in drought years).

2. No permanent inlet or outlets

They are hydrologically isolated from permanent water. Although some may have groundwater connections, most are fed by surface runoff.

3. No resident fish populations

Vernal pool indicator species are highly vulnerable to fish predation. The seasonal hydroperiod and lack of in/outlets makes vernal pools predator-free nurseries for defenseless eggs and young.

4. Provide breeding habitat for vernal pool indicator species

“Mole” salamanders (*Ambystoma* sp.), Wood Frogs (*Lithobates sylvaticus*), and fairy shrimp (*Eubranchipus* sp.) are all adapted to the unique conditions of vernal pools and use them as their primary breeding habitat.

In northeastern North America, vernal pools are generally associated with forest ecosystems (though they can be found elsewhere). As islands of water in a sea of forest, these ephemeral wetlands are considered “keystone ecosystems,” meaning that they play a greater role in forest ecology than one may guess from their size alone (Calhoun and deMaynardier, 2008). An average sized vernal pool, for instance, can have thousands of Wood Frogs visiting it to breed every single spring (Kenney and Burne, 2000); one biologist estimated the biomass of pool-breeding amphibians in the 50 acres around a vernal pool to be greater than 150 pounds (Windmiller, 1996); and yet one hardly sees the thousands upon thousands of amphibians hiding in the leaf litter, within a few hundred meters of their breeding pool.



What is the Vermont Vernal Pool Monitoring Project?

Despite the importance of vernal pools for forest health and as critical breeding habitat for several animal species, relatively little is known about them. Numerous threats — ranging from climate change to development — make the future viability of vernal pools uncertain. The Vermont Vernal Pool Monitoring Project (VPMon for short) uses community science to confront this uncertainty.

Building upon the work of the Vermont Vernal Pool Mapping Project, VPMon volunteers annually collect a set of vital data on vernal pools across Vermont, providing an annual snapshot of the health of these pools each year. As time goes on, this dataset will provide a baseline with which we can compare future changes.

The overall goals of the Vernal Pool Monitoring Project are to:

- Build a base of knowledge regarding the state of vernal pools in Vermont
- Raise awareness about the value of vernal pools through public engagement.
- Advance vernal pool conservation planning at the state and local levels

The project is managed by the Vermont Center for Ecostudies. However, all the data is gathered by a cadre of passionate community scientists. Vernal pool monitors donate their time and energy to collect essential data on these critical wetlands that would not otherwise be accomplished so cost-effectively. As such, they deserve our thanks.

The Vermont Vernal Pool Mapping Project (VPMMap)

From 2009 to 2012, VCE partnered with Arrowwood Environmental and Vermont Fish & Wildlife to use color-infrared aerial imagery to remotely map the locations of almost 5,000 potential vernal pools in Vermont.

More than 1,000 of these potential pools have been visited in the field to verify their existence, but many more remain unvisited or just unmapped in the first place. This is where citizen science can come in! **If you find a vernal pool that hasn't yet been verified, you can benefit vernal pool conservation by filling out a VPMMap data sheet.**

An interactive map of all these pools and a printable VPAtlas data sheet can be found on VPAtlas.org.



Chapter 2

Survey Timing and Equipment

Egg Mass Survey Timing Guide

The ideal day on which to conduct your two egg mass surveys will vary from year to year and from pool to pool. The map and figure below can help you roughly estimate when to time your visit. **However, take note of local factors such as elevation, aspect, and snowfall, which can delay amphibian breeding—and thus egg mass counts.**

Generally, the first egg mass survey (Visit 2) should occur 1-2 weeks after the peak of the Wood Frog breeding period. The second egg mass survey (Visit 3) should happen about 2-3 weeks later, after the peak of Spotted Salamander breeding.



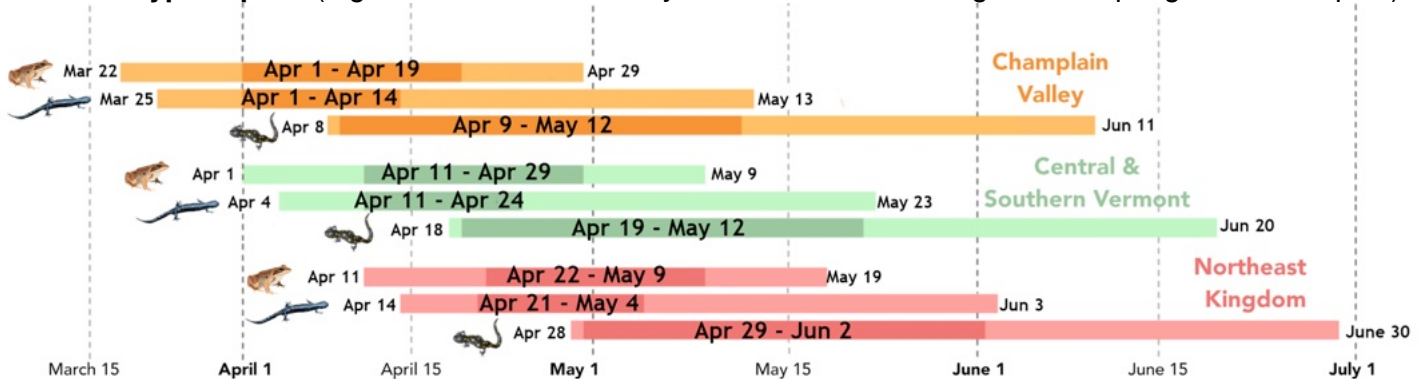
The different breeding patterns of the amphibian species monitored by VPMon differ in several ways, which influences the timing of egg mass surveys.

Wood Frog migration is triggered by warmth and humidity. They tend to migrate to pools on the first night with warm rains (>40° F), but some may migrate on warm, sunny days. There may still be some snow on the ground. The breeding season lasts only a few days to a week, and the eggs hatch after 2-4 weeks, depending on water temperature.

Jefferson / Blue-Spotted Salamanders are generally the first species to arrive at vernal pools, often when just the edges of the pool are thawed. Their eggs take about 3-6 weeks to hatch, depending on water temperature.

Spotted Salamanders begin migrating at the same time as Wood Frogs, but they are more dependent on warm nighttime rains for movement. Their breeding season is prolonged, and their eggs take about 3-6 weeks to hatch, depending on water temperature.

Use this diagram and its accompanying map to estimate the ideal time to visit an adopted vernal pool. Find the color of your region on the map and see the corresponding-colored bar below. Each bar represents the potential range of ideal surveying dates for each species in a region of Vermont. **The darker section within each bar shows the typical peak** (e.g. the best time to survey if conditions are average in that spring and at that pool).



Monitoring Equipment List

Water Depth & Temperature / HOBO Logger

Measures water temperature, hydroperiod (how long the pool has water in it), & water level.

- **HOBO Logger** (Onset HOBO® Bluetooth Pendant Temperature Data Logger)
 - Automatically measures water temperature.
 - Requires a CR2032 3V lithium battery.
- **5' PVC Pipe with 5 cm markings**
 - Depth Gauge
 - HOBO Logger is attached to it.
- **Meter stick / Tape Measure**
 - To know how to number the 5 cm markings. on the PVC pipe after it's put into the pool.
- **Sharpie**
 - To number PVC pipe markings.
- **Zip Ties** (at least 2)
 - To attach the HOBO Logger to the PVC pipe
- **Smartphone with "HOBO Mobile" app***
 - * Necessary for configuring the HOBO logger, though it doesn't have to be configured in the field
- **Waterproof boots / Waders** (If the vernal pool will be filled with water)
- **A tool to break through ice** (If there will be thick ice when you set up the HOBO Logger)

Egg Mass & Macroinvertebrate Survey

Conducted by Vernal Pool Monitors to assess the breeding population sizes / presence of pool- breeding amphibians, fairy shrimp & caddisflies.

- **Meter stick / tape measure / quadrat / etc.**
 - To identify survey areas for the egg mass survey (within 1 m of the pool's edge) and the macroinvertebrate survey (1 m² area).
- **Camera / Smartphone**
 - To take photos of vernal pool indicator species or their egg masses.
- **Polarized Glasses** (Recommended, but optional)
 - To counter glare on the water.
- **Binoculars** (Recommended, but optional)
 - To identify and count distant egg masses and to scan for swimming fairy shrimp

Frog Phenology / Audio Recorder

Records frog calls, from which we can determine phenology and species composition.

- **Audio Recorder** (AudioMoth)
 - To record the timing and species composition of chorusing frogs.
 - Requires three AA battery.
 - Should contain a 16 GB microSD card.
- **Waterproof case**
 - Protects the audio recorder.
- **Zip tie / strap / etc.**
 - To strap the audio recorder to a tree.
- **Flagging tape** (if the pool is on public land)
 - Write your or the VPMon Project Coordinator's phone number on it.
 - Tie it to the tree the acoustic monitor is strapped to.
- **Smartphone with "AudioMoth" app***
 - * Necessary for configuring the AudioMoth internal clock once batteries are inserted

Other

- **VPMon data sheet & writing utensil**
 - Use a sheet for every visit, even if you don't need to fill out the entire form.
- **ThermoPro Indoor Humidity & Temperature Monitor**
 - Measures the air temperature and humidity around the pool.
- **GPS / Smartphone with an app that can show GPS coordinates**

For Home Use

- **Boot/Wader Decontamination Equipment**
 - To clean waders and thus prevent the spread of amphibian diseases.
 - See page 19.

Chapter 3

VPMon Protocols

The Who, When, and Why of Each Monitoring Visit

| | When? | What equipment is needed? | Purpose | What data is collected?* |
|----------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Visit 1: Setup | While pool is entirely covered in ice About 1-2 weeks prior to the pool thawing in the spring | - AudioMoth + case | - Deploy AudioMoth - Document the ice conditions of the pool | <i>If There's Open Water:</i> - Egg Mass Survey - Macroinvertebrate Survey |
| Visit 2: Early Survey | 1-2 weeks after the peak of the Wood Frog chorus period <i>See Timing Guide, page 6</i> | - Device to take photos - 1m stick or PVC pipe quadrat - Binoculars (<i>recommended</i>) - Polarized sunglasses (<i>recommended</i>) | - Conduct egg mass survey for Wood Frog and Jefferson/Blue-spotted Salamander | - Physical data - Vegetation data - Egg Mass Survey - Macroinvertebrate Survey |
| Visit 3: Late Survey | 2-3 weeks after the peak of the Spotted Salamander breeding period (and Visit 1) <i>See Timing Guide, page 6</i> | - Device to take photos - 1m stick or PVC pipe quadrat - Binoculars (<i>recommended</i>) - Polarized sunglasses (<i>recommended</i>) | - Conduct egg mass survey for Spotted Salamanders - Retrieve the AudioMoth from the field. | - Physical data - Vegetation data - Egg Mass Survey - Macroinvertebrate Survey |
| Visit 4: Fall Visit | Anytime between late-August and November. Best when pool is likely to be dry. | - Replacement CR2032 battery - Replacement zip ties if HOBO is removed to replace battery | - Download HOBO data - Replace HOBO battery - Reconfigure HOBO <i>See page 15 for more information</i> | - Physical Data - HOBO Logger water temperature data |

*Complete "Pool & Observer Info", "Ice Cover", "Water Depth", and "Weather" sections of the data sheet at every visit. Additionally, include a photo of the pool at the time of visit.

Egg Mass Survey Protocols

The most time-intensive task for each Vernal Pool Monitor will likely be conducting egg mass surveys of pool-breeding amphibians. Counting egg masses and accurately identifying the species allows us to estimate the breeding population of amphibians at a given vernal pool. The correct identification of egg masses is of the upmost importance. For more information on identifying species and egg masses, see Chapter 4 (page 20).



How to Conduct an Egg Mass Survey

For pools with multiple Monitors, egg mass surveys do not need to be conducted at the same time but must be conducted on the same day. If surveys are conducted at the same time, each Monitor must conduct their survey independently to avoid bias.

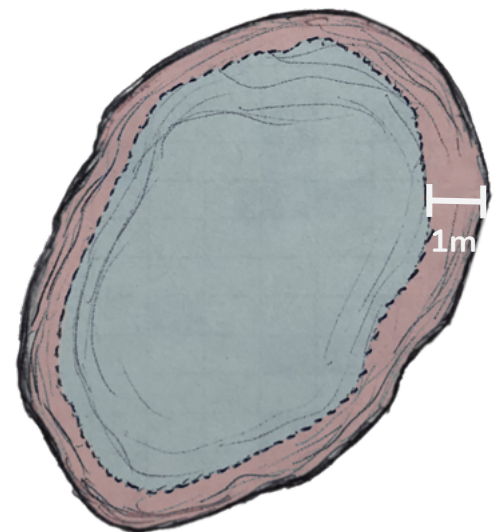
If you do visit your adopted vernal pool with your monitoring partner, your partner should not be paying attention to you. This is to avoid biasing their own independent survey.

1. **Mark your starting location and begin walking the perimeter of the pool. Count the number of egg masses, identified by species, that you see within 1 meter of the pool's edge (red zone in diagram); tally these values in the "Egg Mass Edge Survey" section of the data sheet. Species within 1m in the "Egg Mass Edge Survey" section of the data sheet. Egg masses more than 1 meter from the edge (blue zone in diagram) are tallied in the "Egg Mass Interior Survey" section of the data sheet.**

- Surveying for egg masses along the edge and interior simultaneous reduces the chances for eggs to be counted twice.
- A meter stick or walking stick marked at 1 meter in length is helpful for identifying what is within the survey area.

* **Keep the following points in mind when conducting Step 1**

- Bring a guide along with you to help identify amphibian egg masses as you go.
- **Polarized glasses** are highly recommended for the Egg Mass Surveys, as they help to counter glare on the water surface. If you do use polarized glasses, mark this on the data sheet. If your pool is well-shaded by conifers or it is an overcast day, polarized glasses may be too dark and actually hinder observations, so use your best judgement.
- **Binoculars** are highly recommended to aid in the identification of egg masses in the pool's interior.
- Make every effort to accurately count individual egg masses. Some Wood Frog egg masses will form a "raft"; in such case, estimate the number of masses by multiplying the number of soft-ball sized masses by a rafts' surface area and depth.
 - If it is impossible to count individual egg masses, the estimate the dimensions of the raft in square centimeters (or inches/feet, although these measures are less preferred) in the "Amphibian/Macroinvertebrate Notes" section.
- For each species of amphibian egg mass that you observe, take a **photo of one egg mass** and submit it with your data sheet.



Red: survey area for the **Edge** egg mass survey at a given vernal pool. **Blue:** survey area for the **Interior** egg mass survey at a given vernal

- If you observe signs of non-egg **amphibian presence** (tadpoles, adult amphibians, etc.) note this in the “Amphibian/Macroinvertebrate Notes” section of the data sheet.
- If you observe any sign of **amphibian disease** (See Table 4, page 19 for examples) write all details (including the affected species) in the “Amphibian/Macroinvertebrate Notes” section.
 - Take photos of the affected individual(s).
 - **Contact the VPMon Project Coordinator (VPMon@vtecostudies.org) to report any signs of amphibian disease.**

2. Estimate the proportion of the water within the edge zone, and the interior zone that is visually impaired due to depth, surface reflection, leaf litter, algae, etc.

- Use Table 3 — Visual Impairment (also on the data sheet) to quantify the impairment level.
- Visual impairment may be due to depth, surface reflection, particulate matter, algae, etc.
- Do not consider areas covered with ice within this estimate.
- If you used polarized glasses to counter pool reflectance, you should wear them while estimating visual impairment.

| Level | Description |
|-------|---------------------------------------------------------------------------|
| 0 | Clear - Survey area not visually impaired |
| 1 | Slightly impaired - Less than 25% of the survey area is visually impaired |
| 2 | Impaired - 25 to 50% of the survey area is visually impaired |
| 3 | Severely Impaired - More than 50% of the survey area is visually impaired |

3. If there are any non-contiguous vernal pools within 20 meters of your adopted vernal pool, check them qualitatively for egg masses presence and provide a rough estimate of their quantity in the “Amphibian/Macroinvertebrate Notes” section.

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## Macroinvertebrate Survey Protocols

Invertebrates are key to the functioning of all ecosystems, and vernal pools are no exception. Macroinvertebrates fill key roles across the vernal pool food web as predator and prey, and they make up the majority of the species and biomass in each one (Calhoun and DeMaynadier 2008). Vernal Pool Monitors conduct surveys for two kinds of macroinvertebrate: fairy shrimp and caddisfly larvae. In Vermont, fairy shrimp are only found in a subset of vernal pools, where they hatch, develop, and breed shortly after ice-out. Caddisfly larvae and their cases, on the other hand, are readily found in a variety of water bodies.

### How to Conduct a Macroinvertebrate Survey

The macroinvertebrate survey can be completed by just one Monitor. Make sure that you conduct this survey after you have estimated the Visual Impairment Level of the vernal pool as part of the egg mass survey. Macroinvertebrate surveys occur within four 1 m<sup>2</sup> survey plots distributed evenly around the pool (one plot at each cardinal direction: North, East, South, & West or at 90°, 180°, and 270° away from this first plot if you cannot identify North).

- Pick a 1m<sup>2</sup> area at the northern end of the vernal pool.**
  - Use a meter stick, walking stick marked at 1 meter, or 1m<sup>2</sup> PVC frame to demarcate each survey plot.
- Within each 1m<sup>2</sup> area, record the number of fairy shrimp & caddisfly larvae (including caddisfly cases) that you observe. Write this number in the corresponding boxes on the data sheet.**
  - Look, but don't touch while observing. Don't turn over any leaf litter or sticks in the survey area.
  - Polarized glasses are highly recommended for this, as they help to counter the glare on the water. If you use polarized glasses, mark this on the data sheet.
  - Fairy shrimp in particular can be difficult to count, but try to do so to the best of your ability.

- If you observe fairy shrimp or caddisfly larvae, be sure to take a photo and submit them with the data sheet.
- 3. **Repeat steps 1. and 2. as you progress clockwise around the vernal pool, making observations at the eastern, southern, and western ends of the pool.**

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VPMon Data Sheet Protocols

For field visits, the VPMon Data Sheet is available as a paper copy or digitally on the Survey123 Mobile App. I find it preferable to use paper notes while counting egg masses, then transcribing it into the app.

Submitting your Data Sheet

1. Download the Survey123 Mobile App
2. Click “Continue without signing in”
3. Click the QR icon in the upper right of the screen, in the far left of the survey box.
 - Scan this QR code to download the VPMon Data Sheet:



Filling out the Data Sheet:

POOL & OBSERVER INFO

Date: When is this field visit taking place?

Time: At what time did you begin data collection?

Observer Names: Who is/are collecting the data on this data sheet?

- Be sure observer names are listed in accordance with “Obs. 1” & “Obs. 2” for the egg mass survey.

Pool ID: A code of 3+ letters followed by numbers, which identifies a given vernal pool (e.g. ABC123).

- If the pool was mapped as part of the Vernal Pool Mapping Project, it will already have a Pool ID.
- If this was a previously unmapped pool, contact the VPMon Project Coordinator (VPMon@vtecostudies.org) to be assigned an ID

Town: What town is the vernal pool located?

GPS Coordinates: What is the latitude and longitude of the vernal pool?

Field Visit: Check which field visits you are conducting (see page 8 for visit descriptions).

Acoustic Monitor: Was the acoustic monitor deployed or collected on this visit?

- Deployed (Visit 1): Did you set up the acoustic monitor on this visit?
 - When deploying the acoustic monitor, **it’s essential to flip the switch to CUSTOM** (see page 14).
- Already deployed (Visit 2): Was the acoustic monitor was set up during the previous visit?
- Collected (Visit 3): Did you collect the acoustic monitor on this visit?
 - If you’re collecting the acoustic monitor, remember to flip the switch to OFF.

HOBO Logger: Have the HOBO Logger and PVC Pipe been set up on this visit? See page 15.

- Set up on this visit: Did you set up the configured HOBO Logger on this visit? (likely Visit 1 or 4).
- Already in the pool: Is the HOBO logger is already collecting data in the pool? (likely Visits 2 or 3).

- Reconfigured on this visit: Was the HOBO Logger already in the field, but you downloaded the data and reconfigured it on this visit? (likely Visit 4).

HOBO Water Temperature: Did you download water temperature data from the HOBO logger?

- For instructions on how to download data from the HOBO Logger see page 15.
- If you have trouble downloading the HOBO logger data, or if the HOBO logger is removed, note this in Physical Parameter Notes.

PHYSICAL PARAMETERS

% Ice-Covered: What percentage of the pool is covered in ice?

- Use the Veg / Ice Percent Cover table at the bottom of the data sheet to estimate this.

Water Level: How high is the water in the vernal pool, according to the PVC pipe?

- If you set up the PVC pipe on this visit, measure water level after having done this.
- If the vernal pool is dry, record 0 cm.

% Vegetation-Covered: What percentage of the pool bottom is covered/shaded by each of the following vegetation categories?

- Use the Veg / Ice Percent Cover Table at the bottom of the data sheet to estimate this.
- The vegetation categories are:

Submerged Aquatic

Rooted underwater, but don't breach surface.
Ex: short grasses

Floating Aquatic

Floating in the water.
Ex: duckweed, lily pads

Emergent

Rooted underwater and breach the surface
Ex: cattails

Shrubs

Wooded vegetation <3" in diameter rooted in, or overhanging, the water.

Trees

Wooded vegetation >3" in diameter rooted in, or overhanging, the water.

- Percent cover should account for any vegetation that covers or shades the pool (including tree canopy), regardless of whether the vegetation emerges from the pool itself.
- If trees and other vegetation aren't fully leafed out, don't attempt to predict percent cover under full leaf out. Instead, just report the actual, current percent cover.

Physical Parameter Notes: Any additional notes on the physical parameters of the vernal pool.

- This may also include any trouble you had connecting to the submerged HOBO Logger or any physical changes such as fallen trees that have occurred at the vernal pool since the VPM data sheet was filled out.

WEATHER

Air Temperature: What is the air temperature at the vernal pool?

- Place the ThermoPro Indoor Humidity & Temperature Monitor in a shaded location within 1 m of the edge of the vernal pool and leave it for at least one minute before recording the humidity.

Relative Humidity: What is the humidity at the vernal pool?

- Place the ThermoPro Indoor Humidity & Temperature Monitor in a shaded location within 1 m of the edge of the vernal pool and leave it for at least one minute before recording the temperature.

Wind (Beaufort Force): What is the wind speed at the vernal pool?

- Use the Wind: Beaufort Scale table at the bottom of the data sheet to estimate this.

Conditions: Which option best describes the weather conditions at the time of data collection?

Weather Notes: Any additional notes on the weather conditions at the vernal pool.

AMPHIBIAN & MACROINVERTEBRATE SURVEYS

Egg Mass Survey: Survey the vernal pool for egg masses using the protocols described on page 9.

Egg Mass Survey: Survey the vernal pool for egg masses using the protocols described on page 9.

— Only fill out this section on Visit 2: Early Survey and Visit 3: Late Survey or on Visit 1: Setup (if there is at least 1 m² of open water)

— The Egg Mass Survey is broken up into two sections:

- The **Edge Survey**, in which all water within 1 m of the pool’s edge is surveyed.
- The **Interior Survey**, in which all water more than 1 m from the pool’s edge is surveyed.

— Each acronym refers to a vernal pool-indicator amphibian:

- **WOFR:** Wood Frog **JESA:** Jefferson Salamander
- **SPSA:** Spotted Salamander **BLSP:** Blue-Spotted Salamander

— Remember to take photos and submit them with your data sheet.

Macroinvertebrate Survey: For instructions on how to conduct this survey, see page 10.

— Only fill out this section on Visit 2: Early Survey and Visit 3: Late Survey

- And on Visit 1: Setup (if there is at least 1 m² of open water)

— Remember to take photos and submit them with your data sheet.

Spermatophores Found?: Did you notice any spermatophores in the vernal pool? See page 25.

— Remember to take photos and submit them with your data sheet.

Amphibian/Macroinvertebrate Notes: Record any additional notes or observations from the surveys.

— Did you notice any sign of amphibian disease? See page 19 for the Amphibian Disease table.

- If you did see signs of amphibian disease, contact the VPMon Project Coordinator (VPMon@vtecostudies.org) immediately.

— Are there other, non-contiguous vernal pools within 20 meters of your adopted pool, and if so did you notice any egg masses in them? Roughly how many?

Visual Impairment: What proportions of the search areas are visually impaired (See page 10)?

— Use the Visual Impairment table at the bottom of the data sheet to estimate this.

— Make a separate estimate for the Egg Mass Edge Survey search area (all water within 1 m of the pool’s edge) and the Interior Survey search area (all water more than 1 m from the pool’s edge).

— Impairment may be due to water depth, surface reflection, particulate matter, algae, etc. Do not consider areas of the pool obstructed by ice.

— Use polarized glasses to estimate the Visual Impairment Level if you will also be using them for the Egg Mass Survey.

- If so, be sure to check the “Yes” box for “Did you use polarized lenses?”

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# Acoustic Monitor Protocols

What noise more evokes the thawing of winter than a chorus of Wood Frogs? By setting out an audio recorder at a springtime vernal pool, VPMon can investigate both which frog species are calling at a vernal pool and when they are calling. The latter is particularly important in the face of climate change; as winter grows shorter and shorter, will the phenology of amphibian breeding shift too?

Go to page 7 to see what equipment is needed to carry out these protocols.

When you receive your AudioMoth, it should already be programmed with the correct settings. Once you insert the microSD, followed by the batteries, you'll need to use the AudioMoth smartphone app to synchronize its internal clock. New batteries are needed for each new monitoring season.

## When to Set Up & Collect the Acoustic Monitor

The audio recording equipment should be placed in the field on Visit 1 when you first visit the vernal pool in the spring. **It is essential that it is placed in the field prior to the first date of frog chorusing**, so that the timing of this event can be recorded. Frog chorusing occurs on “big nights,” which are typically triggered by an evening rain above 40° F with some bare, snowless ground. To be safe, it is best to conduct Visit 1 before or when the pool begins to thaw.

The audio recorder should be taken out of the field on Visit 3 and its data should be promptly downloaded to your computer and submitted to VCE.

## Audio Recorder Settings

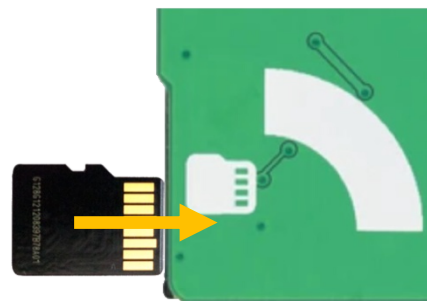
Your AudioMoth should have been sent to you pre-programmed with the necessary settings and specified time recording.

## Installing the Acoustic Monitor in the Field

### Prior to going into the field

1. **Ensure the AudioMoth's switch is set to “USB/OFF”.**
2. **Insert the microSD received from the VPMon coordinator into the AudioMoth. It will click into place.**
  - The microSD slot is marked with a white icon.
  - The microSD must be inserted with the metal contacts facing upwards.
3. **Insert three AA batteries into the battery compartment.**
4. **Switch the AudioMoth's switch from “USB/OFF” to “Custom”.**
  - a. The red light should remain constant while the green light blinks.
5. **Using the AudioMoth smartphone app\*, synchronize the AudioMoth's internal clock by hitting “play chime”.**
  - a. It is imperative that the internal clock is synchronized every time the batteries are removed and replaced. When not synchronized, the red light will stay constant while the green light flashes.
  - b. If the system is programmed correctly, once the chime is registered the red light will shut off while the green stays lit for 2 seconds.

\*if you need to program the AudioMoth using a computer instead of a smartphone, contact the VPMon coordinator.



How to insert a MicroSD to an AudioMoth



### In the field

1. **Place the AudioMoth into the waterproof case.**
2. **Using a zip tie, strap, or rope, mount the audio recording equipment on whatever sturdy and living tree is nearest to the northernmost edge of the pool.**

- If there is no tree within 3 m of the northernmost point of the pool, attach it to the closest tree and note the distance between the audio recorder and the pool on the datasheet.

### **Downloading & Submitting Data from the Audio Recorder**

- 1. Remove the microSD from the AudioMoth by pressing it in gently and letting it eject.**
  - Never pull on the green circuit board, it may separate from the battery compartment.
- 2. If possible, using a microSD to SD converter, backup the microSD to your computer before returning the physical microSD card.**
- 3. Place the microSD card between two pieces of cardboard and into a padded envelope and mail to the following address:**
- 4. Remove batteries from the AudioMoth reduce potential leakage and corrosion between seasons.**

Vermont Center for Ecostudies  
 Attn: Vernal Pool Monitoring Project  
 PO Box 420  
 Norwich, VT 05055

## **HOBO Logger Protocol**

The HOBO logger is strapped to a PVC pipe that is inserted into the deepest point in the pool. This compact and durable device automatically collects water temperature data. Once the pool dries up and the HOBO is out of the water, it begins measuring the air temperature; this transition is very obvious and it tells us when a vernal pool dries. Marking the PVC pipe at 5 cm increments also helps to gauge depth and determine the water level at the time of each vernal pool visit.

### **When to set it up**

HOBO Loggers and PVC pipes will be set up during the first visit in the early spring (Visit 1) or during the fall prior to recording (Visit 4). If possible, it is best to set up this equipment prior to your first monitoring season (summer or fall), when the pool is at its driest.

The HOBO Logger should only be set up during Visit 1 if it is safe to do so, meaning that the ice is thin enough to easily break through while walking with waders or thick enough to support your weight comfortably. **If the ice is at an intermediate thickness, (where it may break with a Monitor standing on top of it) it is best to wait until Visit 2 to set up the HOBO Logger.**

The HOBO logger will remain out until the volunteer no longer monitors for the project. If the HOBO logger has previously been set up, then it can be reconfigured during the fall visit (Visit 4). Bring your smartphone and a new CR2032 3V lithium battery with you during this visit

### **Installing the PVC pipe & HOBO Logger in a dry vernal pool (best option)**

- 1. Find the deepest point in the pool basin and secure the PVC pipe into the ground so that it is vertical and feels sturdy.**
  - Line up one of the 5 cm markings should line up with ground level.
  - If necessary, use a rock or hammer to pound the PVC pipe into the ground.
- 2. Attach the HOBO Logger to the bottom of the PVC pipe with 2 zip ties, so that it sits about 1 inch off the ground.**
- 3. Label the 5 cm marking at ground level as 0 and label all the markings above it in 5 cm increments.**

### **Installing the PVC pipe & HOBO Logger in water (difficult)**

- 1. Use 2 zip ties to attach the HOBO logger to one end of the 5' PVC Pipe.**
  - The HOBO Logger should be configured before you attach it to the PVC Pipe.
- 2. Locate the deepest point in the pool.**



The HOBO Logger, strapped securely to the PVC pipe.

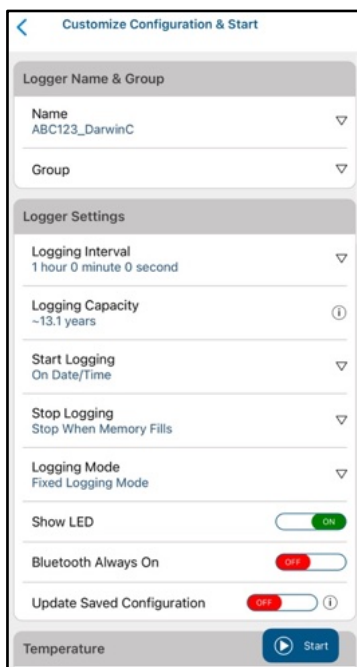
- This will likely require breaking through ice and wading into potentially deep water, so be sure to bring waders and a tool to break through ice (i.e. an ice spud or auger).
  - Don't worry if you can't locate the exact deepest point in the pool. The PVC pipe can be moved during a later visit when there is less water and ice.
3. **Push the end of the PVC pipe into the pool bottom, so that it is both vertical and feels very secure.**
    - Line up one of the 5 cm markings should line up with the water level.
  4. **Slide the HOBO Logger from the top of the PVC pipe to the bottom so that it sits just above the pool floor, but isn't buried in leaf litter or muck.**
    - You will likely have to stick your arm into the cold water, so dress appropriately.
  5. **Use a measuring tool to determine the depth of the water at the PVC pipe. Write this number on the 5cm marking at the water level and number every marking above it in 5 cm increments.**
    - As the water level drops you can add in lower increments.

## Downloading Data and Configuring the HOBO Logger

1. Make sure that your smartphone's Bluetooth is turned on.
2. **Open the HOBOconnect app (📲) on your smartphone.**
3. **Press the white target icon in the center of the HOBO Logger's blue face to activate Bluetooth broadcasting. The HOBO Logger should appear on your phone screen in a light blue rectangle under IN RANGE. Tap this rectangle.**
4. Click **Download Data** (📄), followed by **Export and Share** (📤).
5. Once exported, click **Share** (📤), then use an app of your choosing (eg. Gmail) to send the data to [vpmo@vtecostudies.org](mailto:vpmo@vtecostudies.org)
6. Tap on **Customize Configuration** (⚙️) and configure as follows:



Scan this QR code for video instructions



**Name** — The HOBO Logger should be named “**Pool ID\_Your Last Name & First Initial**”

- e.g. MLS699\_DarwinC

**Logging Interval** — Set the logging interval to “**1h 0m 0s.**”

- The HOBO Logger should take a temperature reading every hour.

**Start Logging** — The HOBO Logger should start collecting data on March 1 at midnight.

- Select **On Date / Time ...**
  - Set the DATE to **March 1** of the year the HOBO Logger will collect data.
  - Set the TIME to “**00 00 00.**”

**Stop Logging** — The HOBO Logger should only stop once it has run out of memory.

- Under STOP LOGGING select “**When Memory Fills**”.

**Bluetooth Always Off** — Make sure this is switched to “**off**” to save battery life!

- If it is on, the button to the right of it will be green, not white.

**Update Saved Configuration** — Make sure this is switched to “**off**”.

7. Tap on **Start** in the lower right-hand corner of the screen. Your HOBO Logger is now configured and ready to be placed in the vernal pool!

## Changing the HOBO Logger's Battery

A full battery will theoretically last a HOBO Logger for years, but to be safe, VPMon requires that batteries be changed once every two years.

1. **Twist the black cover of the HOBO Logger about 20° counter-clockwise (the direction that the arrows on the base show), so that it pops out of its socket.**
2. **Check the O-ring attached to the black cover, and make sure it isn't cracked or damaged.**
  - This black, elastic band helps to keep water from entering the interior of the HOBO Logger.
  - If it appears cracked or damaged contact the VPMon Project Coordinator.
3. **Note the orientation of the old battery and remove it. Put in a new CR2032 3V lithium battery.**
  - It is possible that the new battery will pop out of the socket on one side, but it should be pressed down by the black cover of the HOBO Logger when you put it back into place.
4. **Set the black cover back into place and twist it about 20° clockwise so that it sits snugly in the HOBO Logger.**
  - The key is to line up the groove on the side of the black base with the small, rounded tab.



Twist the cover counter-clockwise to remove it.



O-Ring

Line up the groove in the black cover with the small tab.



Scan this QR code for video instructions

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## Leaf Litter Survey Protocol

The composition of leaf litter in vernal pools plays an important role in both a pool's water chemistry and its detritus-based food web. It's important to develop baseline data on the species of leaves (or needles) that line the basin of a vernal pool to get a better understanding of future changes that may result. This survey will be conducted once every 5 years to track major changes in leaf litter composition.

A good supplemental guide, such as [The Forest Trees of Maine](#), is a useful resource that's available online for free from The State of Maine's website. Additionally, [iNaturalist.org](#) can be used to crowdsource unknown leaf species.

**Materials Needed:** Tape measure or walking stick marked at 1 m intervals *or* 1m<sup>2</sup> frame of PVC pipe

1. **Mark a 1m<sup>2</sup> survey area along the northern outside edge of the pool.**
  - You will survey four 1m<sup>2</sup> plots spaced around the outside edge of the pond in the four cardinal directions (north, east, south, and west).
  - The pool floor beneath each plot should be entirely covered in leaf litter (including needles but not bare dirt or rocks).

- Demarcate each survey plot with the tape measure, walking stick, or PVC pipe frame

**2. Estimate the percent cover of each species of leaf and needle present.**

- Only count top (visible) layer of leaf litter..
- Identify leaves down to species, if possible or genus, if not.
- If you are unsure about an ID, send photos of the leaf’s top and underside to the project coordinator, or post them on iNaturalist.

**3. Repeat steps 1. and 2. as you progress clockwise around the vernal pool, making observations at the eastern, southern, and western ends of the pool.**

- After sampling the four plots, add up each column’s percentages to ensure that each plot’s total leaf litter cover comes out to 100%.

Please enter the data into this spreadsheet and send it to the VPMon coordinator.

Name your file “Pool ID\_Your Last Name & First Initial\_Year\_LLSurvey”.

Example: “MLS699\_DarwinC\_2019\_LLSurvey”

If you don’t have a program to fill out the spreadsheet (Excel, Numbers, Google Docs, etc.), then please send your data sheet to the project coordinator.

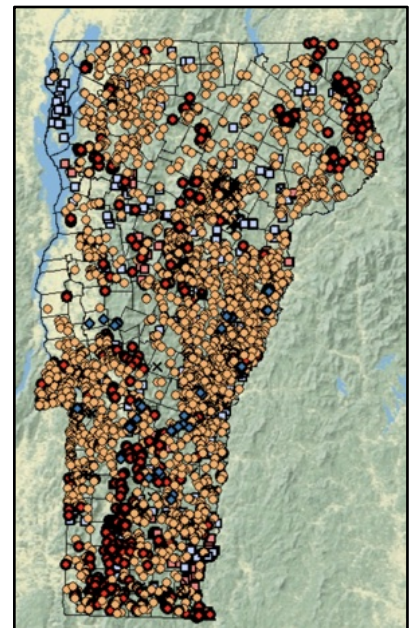
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Vernal Pool Atlas: a Prerequisite for Monitoring

More than 5,000 potential and known pools have been mapped by the Vermont Vernal Pool Atlas (VPAtlas), some of which are now being monitored through VPMon. More information on VPAtlas can be found on the [Vermont Atlas of Life website](#) or [VPAtlas.org](#).

One key aspect of VPAtlas is that citizen scientists fill out VPAtlas data sheets to confirm that remotely mapped vernal pools are actually vernal pools. These data sheets provide an idea of the important physical characteristics of a vernal pool and it is required that each monitored pool have a completed VPAtlas sheet. **If your adopted vernal pool doesn’t have a completed VPAtlas data sheet, please fill one out when you visit the vernal pool for Visit 3.** If you don’t know if your pool has a completed VPAtlas data sheet, ask the VPMon Project Coordinator.

A new VPAtlas data sheet doesn’t need to be filled out each year, but **if there have been any physical changes to the vernal pool since the data sheet was filled out, you should note this in the Physical Parameter Notes section of the VPMon data sheet.** For instance, if agriculture was not noted near the pool when the pool was first mapped, but now you find that a farmer is growing crops nearby, you should note this on the VPMon data sheet.



More than 5,000 potential pools were mapped with remote imagery through the Vermont Vernal Pool Atlas (VPAtlas), many of which were verified in the field with a VPAtlas data sheet.

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# Equipment Decontamination

The VPMon protocol is designed to minimize wading into the vernal pool, but it's always a good idea to decontaminate one's gear (boots, waders, buckets, nets, etc) after field monitoring. **It is imperative that you decontaminate your gear between visits to different vernal pools.** This limits the potential spread of amphibian diseases and pathogens, particularly the Chytridiomycosis fungus and Ranavirus.

- Suggested Decontamination Equipment**
- 3% bleach solution
  - Clean water for rinsing
  - Brush for scrubbing and/or removing mud & vegetation from equipment
  - Hand sanitizers
  - Handheld bottles and/or pump sprayers for applying bleach and water.

- How to Decontaminate your Gear**
- 1. Mix together a 3% bleach solution**
    - Most household bleaches are a 6% solution. To make a 3% solution add 1 part 6% bleach for 32 parts water.
    - Store in an opaque container. If exposed to sunlight or air this mixed solution will only last for five days.
  - 2. Thoroughly scrub and rinse all equipment to remove debris**
    - Be careful not to decontaminate your gear near a drainage, vernal pool, or any other aquatic ecosystem.
  - 3. Liberally spray bleach solution on all equipment, and then wait 5 minutes.**
  - 4. Thoroughly rinse and dry the equipment.**

**Table 4 - Amphibian Diseases:** Be alert to any sign of these diseases while at your adopted pool. If you see any sign of an amphibian disease note it in the “Amphibian/Macroinvertebrate Notes” section of the data sheet and **contact the VPMon Project Coordinator as soon as possible.** Take plenty of photos and submit them to the project coordinator.

| Disease                                                                        | Background                                                                                                                                                                                                                                                                                                       | Signs / Symptoms                                                                                                                                                                                                                   |
|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Chytridiomycosis / Bsal</b><br>( <i>Batrachochytrium salamandrivorans</i> ) | <ul style="list-style-type: none"> <li>— Not documented in North America, but high global concern due to risk of import through pet trade</li> <li>— Susceptibility of species in U.S. unknown</li> </ul>                                                                                                        | <ul style="list-style-type: none"> <li>— Skin lesions and deformities on salamanders.</li> </ul>                                                                                                                                   |
| <b>Ranaviruses / Rv</b>                                                        | <ul style="list-style-type: none"> <li>— Can infect amphibians, reptiles, &amp; fish</li> <li>— Usually occurs in larvae and metamorphs</li> <li>— Hundreds of sick/dead individuals over a few days.</li> <li>— Mass mortality events have been documented in New England</li> </ul>                            | <ul style="list-style-type: none"> <li>— Dead and/or decomposing individuals found in / along pool.</li> <li>— Extensive reddening and swelling (hemorrhaging) on body, especially at base of legs and vent.</li> </ul>            |
| <b>Chytridiomycosis / Bd</b><br>( <i>Batrachochytrium dendrobatidis</i> )      | <ul style="list-style-type: none"> <li>— Kills frogs and toads within 2-3 weeks of metamorphosis; occasionally lethal in adult newts</li> <li>— Die-offs gradual: rarely more than two dead at a site.</li> <li>— Detected in New England, but there have been no documented cases of mass mortality.</li> </ul> | <ul style="list-style-type: none"> <li>— Adults: skin abnormalities, extended back legs, lethargy, loss of righting reflex.</li> <li>— Larvae: jaw sheaths and tooth rows lack pigment or appear deformed (non-lethal).</li> </ul> |
| <b>Perkinsus-like Organism</b>                                                 | <ul style="list-style-type: none"> <li>— Kills tadpoles in the family <i>Ranidae</i></li> <li>— Die-offs may proceed for weeks at a pool</li> <li>— Often causes greater than 90% mortality</li> <li>— Has been detected in New England</li> </ul>                                                               | <ul style="list-style-type: none"> <li>— Dead, floating tadpoles</li> <li>— Enlarged light yellow liver/spleen</li> <li>— Abdominal distention</li> </ul>                                                                          |
| <b>Ichthyophoniasis</b>                                                        | <ul style="list-style-type: none"> <li>— Infects newts and larval / adult frogs in the family <i>Ranidae</i></li> <li>— Slight to severe infection of skeletal muscle</li> </ul>                                                                                                                                 | <ul style="list-style-type: none"> <li>— “Swollen rumps” in recently metamorphosed frogs.</li> </ul>                                                                                                                               |

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## Chapter 4

# Identifying Species and Their Egg Masses

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There are four species of amphibian in Vermont that are specifically adapted to breeding in the ephemeral waters of vernal pools. This section will give you a basic understanding of these amphibians and how to identify them in the field. Distribution maps are courtesy of the Vermont Reptile and Amphibian Atlas, <https://www.vtherpatlas.org>.

## The Basics

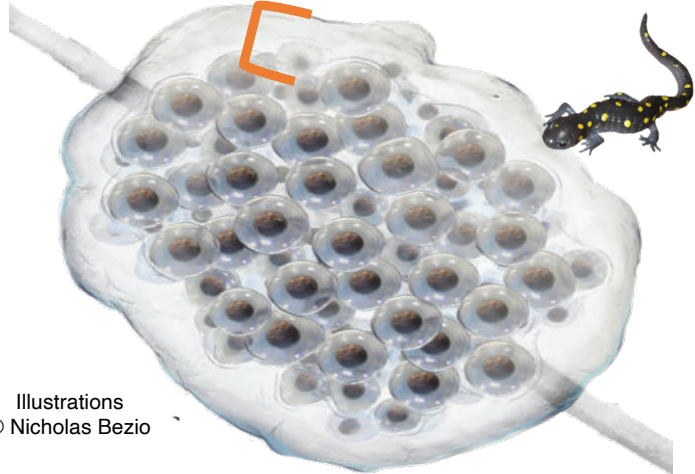
Salamanders which breed in vernal pools lay egg masses enclosed by an outer jelly matrix; it's very robust in Spotted Salamanders and less sturdy in Jefferson and Blue-spotted Salamanders. Wood Frogs lay egg masses with no outer jelly matrix, making their egg masses appear like lumpy bubbles, or a pile of marbles.

All embryos are visible with no enclosing jelly layer



Wood Frog

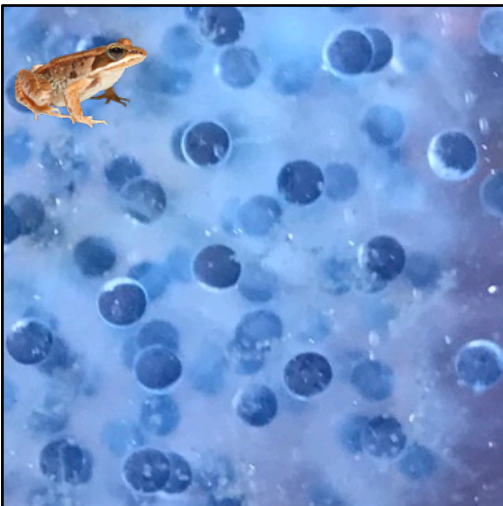
Outer jelly matrix encloses the mass of embryos



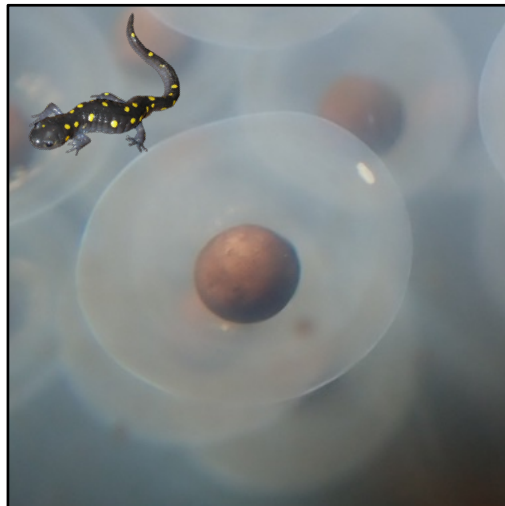
Illustrations  
© Nicholas Bezio

Spotted Salamander

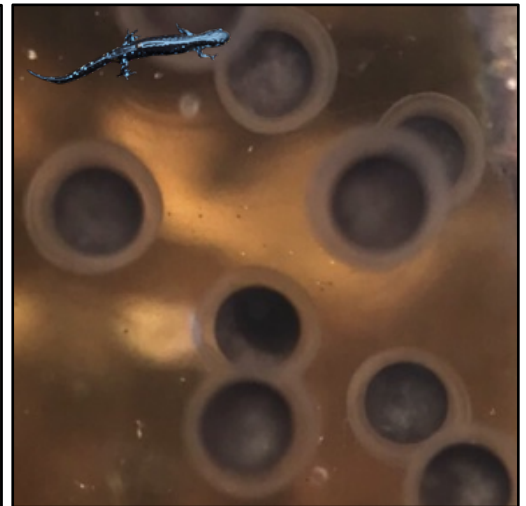
For individual embryos, salamanders have a visible vitelline membrane, which looks like a white "halo" surrounding each individual dark embryo. In comparison, vitelline membranes are not visible in Wood frogs.



Wood Frogs don't have a visible vitelline membrane



Spotted Salamanders have a robust vitelline membrane that's as wide as the embryo



Jefferson/Blue-spotted Salamanders have a slim vitelline membrane ~1/4 as wide as the embryo

## **Wood Frog — *Lithobates sylvaticus***

### **Natural History**

- Typically migrate to pools on the first spring night with warm rains (>40° F).
- Courting males make a duck-like quack.
- They are explosive breeders and may only call for 2-5 days.

### **Adult physical description**

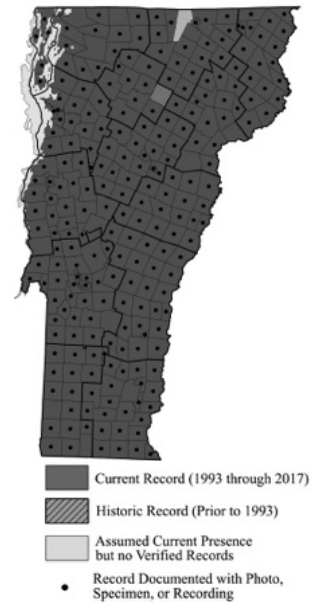
- Has a black or dark brown patch or “robber’s mask” extending back from each eye
- They vary in body color from dark brown, to light tan (usually in summer), to rust (especially in spring).
- Two pronounced ridges are present on each side of the back.

### **Egg mass description**

- Egg masses look lumpy because their egg masses lack the outer jelly matrix found in salamander eggs.
- There’s no white vitelline membrane “halo” surrounding each individual embryo.
- Each egg mass typically contains 800-1,000 eggs.
- Egg masses are ping pong ball-sized when first laid, but after a few hours they absorb water and swell to the size of a softball.
- The embryos are dark on top (to absorb heat) and light below (to reduce predation).
- Egg masses may turn greenish from a symbiotic alga.

### **Egg mass location in pool**

- Often laid in large, multi-layered “rafts,” consisting of up to 100 masses.
- After several days, the individual egg masses within the “raft” can become hard to distinguish.
- May be disproportionately laid on whichever side of the pool melts first (often the north end).
- Generally near the surface attached to twigs, but may sometimes be at the pool bottom.



## **Spotted Salamander** — *Ambystoma maculatum*

### **Natural History**

- Generally live within 100 meters of the vernal pool in which they breed.
- Spend most of the year underground (hence the nickname “mole salamanders”) in shrew or other small mammal burrows or along tree roots.
- The timing of their migration to pools is very dependent on warm, nighttime rains.

### **Adult physical description**

- Gray brown to blue-black body with two irregular rows of bright yellow spots.
- The largest terrestrial salamander in Vermont, they grow up to 9”

### **Egg mass description**

- Each mass typically contains 30-250 eggs.
- Around the size of a baseball when first laid (2-3 inches), but will roughly double in size after absorbing water
- Egg masses are oval, elongate, or kidney-shaped.
- Unlike other egg masses, the outer jelly matrix is very firm, like set gelatin.
- Outer jelly matrix may be clear, opaque white, or even green from a symbiotic alga.
- Vitelline membrane (cloudy halo around each embryo) is as wide as the embryo itself, unlike Blue-spotted and Jefferson Salamanders.
- Hatch in 3-6 weeks, depending on water temperature.

### **Egg mass location in pool**

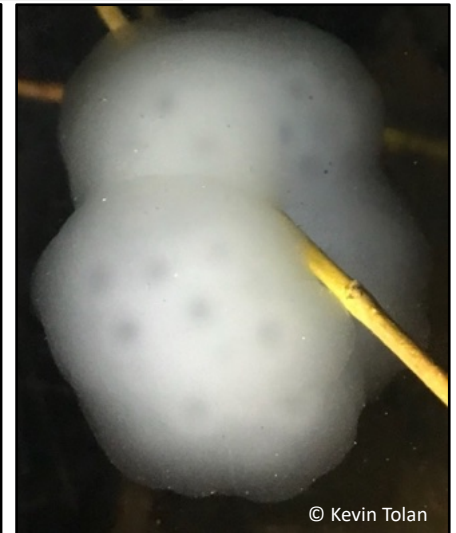
- Usually attached to sticks, weeds, or grasses.
- Typically within 8-10 inches of the surface, but may be much deeper.



© Bryan Pfeiffer



© Kevin Tolan



© Kevin Tolan



Mike Dunn



■ Current Record (1993 through 2017)  
▨ Historic Record (Prior to 1993)  
□ Assumed Current Presence but no Verified Records  
• Record Documented with Photo, Specimen, or Recording

## Jefferson Salamander — *Ambystoma jeffersonianum*

### Natural History

- Usually the first amphibian to arrive at breeding pools in spring.
- Typically found in low- to mid-elevation foothill regions of Vermont.
- Breed primarily on ridgetop pools.
- More sensitive to pH than other salamander species.

### Adult physical description

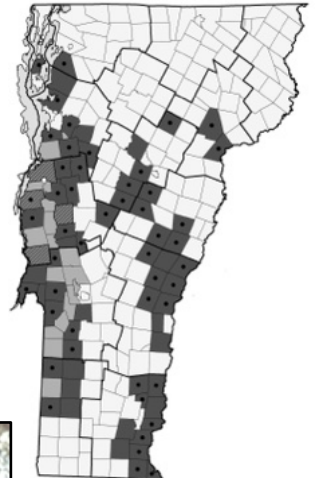
- Charcoal-gray to brown.
- Tiny white flecks on the belly and lower sides.
- Chunky, with a wide & long snout.
- Adults range from 5-7" long.

### Egg mass description

- Each egg mass typically contains **between 5 and 30 eggs**, and is about 1-3" long.
- Tend to be **cylindrical** or **sausage-shaped**. Several females may line their egg masses up to enclose entire branches.
- The outer jelly matrix is clear, making egg masses hard to see, and less firm than in Spotted Salamander, but not as drippy as Blue-Spotted egg masses.
- Vitelline membranes are very narrow, less than the diameter of embryo.

### Egg mass location in pool

- Eggs are typically attached to submerged sticks or vegetation.
- May be disproportionately laid on whichever side of the pool melts first (often the north end).



- Current Record (1993 through 2017)
- Historic Record (Prior to 1993)
- Assumed Current Presence but no Verified Records
- Record Documented with Photo, Specimen, or Recording



## **Blue-spotted Salamander** — *Ambystoma laterale*

### **Natural History**

- Found at lower elevations, primarily in the Champlain Valley, with scattered populations elsewhere in Vermont.

- Like the Jefferson Salamander, they typically migrate to the vernal pool earlier than Spotted Salamanders.

- Unisexual hybrid populations exist with Jefferson Salamanders (See below).

### **Adult physical description**

- Dark-colored with irregular blue or bluish-white flecks on its sides.

- Coloration is reminiscent of old enamelware pots.

- Slender, with a narrow head that tapers to a rounded snout.

- Adults are typically 3.5-5" long.

- Hybrids tend to be chunkier and browner.

### **Egg mass description**

- Each egg mass typically contains between 2 and 5 eggs.

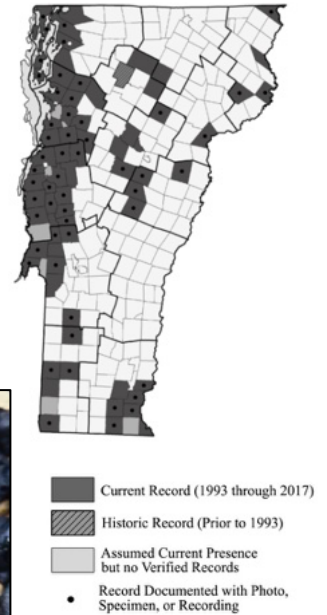
- Their small size and clear outer jelly matrix makes them hard to see.

- Very drippy; not firm whatsoever.

### **Egg mass location in pool**

- May be deposited individually in loose sheets on the pool floor, or in small, drippy masses attached to sticks.

- May be disproportionately laid on whichever side of the pool melts first (often the north end).



## **Blue-Spotted / Jefferson Salamander Complex**

### **Natural History**

Jefferson and Blue-Spotted Salamanders have historically interbred to create unisexual (all-female) hybrid populations, which are now widespread across Vermont. The physical appearance of these hybrids is highly variable along a gradient from pure Blue-spotted to pure Jefferson, depending on which species they're more closely related to. This can make identification difficult.

When these are observed during egg mass surveys, they should be included with either the Jefferson or Blue-spotted Salamander count, based on phenotype (appearance) and location. If you are having trouble identifying a salamander, send photos to the VPMon coordinator for assistance.

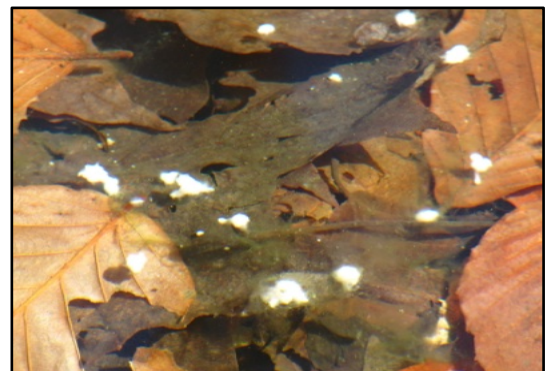
### **Egg mass description**

These egg masses can be highly variable and typically resemble whichever species the mother is more closely related to. One distinguishing trait is that hybrid egg masses contain many white, infertile (dead) embryos.



### **Spermatophores**

Spermatophores are packets of sperm deposited by breeding male salamanders on the submerged sticks and leaf litter of vernal pools. They resemble small, white flecks of paint.



## Macroinvertebrate Identification

Though there are hundreds of fascinating macroinvertebrate species that can be found in vernal pools across New England, VPMon only collects data on two groups: fairy shrimp and caddisflies.

### Fairy Shrimp — Order: Anostraca; *Eubranchipus* sp.

Several hundred species of fairy shrimp are known worldwide; at least three of which occur in New England vernal pools. Although their distributions are not well understood, they appear to be most common in woodland vernal pools, and uncommon in roadside pools impacted by runoff. Identification to species requires examination under a dissecting microscope.

- **Knob-lipped Fairy Shrimp** — *Eubranchipus bundyi*: common in Vermont and northern New England.
- **Intricate Fairy Shrimp** — *Eubranichipus intricatus*: common in Maine and probably other NE states.
- **Vernal Fairy Shrimp** — *Eubranchipus vernalis*: more common in southern New England.

### Description

- Adults are ½ - 1” long.
- All species of fairy shrimp feature stalked eyes, swim “upside-down”, & are orange, red, blue, or bronze-colored.
- They swim slowly, propelled by their 11 pairs of rhythmically beating appendages.
- Females have paired egg sacs just behind their feathery legs.
- Males appear to have enlarged heads due to their “claspers,” which are modified antennae used to grasp females during mating.

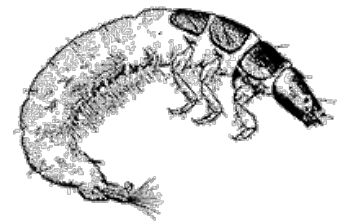


### Natural History

- After being fertilized, the eggs (technically “cysts”) may have to dry out *and* be exposed to winter temperatures before they will hatch in the late winter/early spring.
- Young fairy shrimp molt several times over a few weeks before reaching their adult stage, which live for only 1 - 3 weeks before dying or being predated.
- Most commonly seen in spring, 2-3 weeks after ice-out at a vernal pool.

### Caddisfly Larvae — Order: Trichoptera

Unlike fairy shrimp, caddisfly larvae can be commonly found in many bodies of water across Vermont. They’re monitored in VPMon because they are easy to identify, widespread, and a sentinel species, meaning that changes in their abundance and/or distribution can indicate changes to the health of a pool.



### Description



- They vary in size by species, but are rarely more than 1 inch in length.
- Most easily recognized by the cases that they construct with silk and pebbles, sticks, or bits of leaves.
- Larvae have 3 pairs of legs; long, cylindrical bodies, and a plate on the first thoracic segment.

### Natural History

- Aquatic as larvae and pupae. Adults emerge in late spring or early summer.
- Larvae can typically be found in a vernal pool around 1 to 3 days after flooding.
- The cases allow larvae to create water currents to increase oxygen flow in non-flowing environments.



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## References

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