Vermont Vernal Pool Mapping Project

2009 – 2012

Final Report to the Natural Heritage Information Project of the Vermont Department of Fish and Wildlife

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Technical Assistance

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Executive Summary

Vernal pools are typically small, shallow wetlands characterized by alternating flooded and dry phases. Yet, despite their small size and ephemeral nature, they support a rich assemblage of invertebrates and breeding amphibians. Many of these species are considered High and Medium priority Species of Greatest Conservation Need (SGCN) in the Vermont Wildlife Action Plan, including *Ambystomid* salamanders, Odonates, Fairy Shrimp (*Eubranchipus spp*.), and freshwater snails. However, due to their small size and seasonal nature, most vernal pools do not appear on National Wetland Inventory maps and their location and distribution across Vermont was largely unknown. From 2009 thru 2012, we used color infrared (CIR) aerial photo interpretation to map the location of "potential" vernal pools statewide, and trained volunteers to help field-verify a proportion of mapped pools. In addition, we incorporated information on vernal pool occurrence from other sources into the project database.

A total of 4,016 "potential" vernal pools were mapped in 235 (92%) of Vermont's 255 towns using CIR aerial photo interpretation. In addition, another 830 "probable" pools were imported into the database from other sources, bringing the total number of mapped "potential" pools to 4,846. Of these, 636 (13%) were field-visited; 54% of which were confirmed to be vernal pools. In addition, 221 unmapped pools were confirmed during fieldwork. Among potential sites that were not pools (n = 207), 71% were other types of wetlands (primarily seeps, but also beaver ponds, shrub swamps, etc.), while only 13% were artifacts of remote mapping, primarily shadows from conifers.

During remote mapping, each potential pool was given a confidence rank (*High*, *Med-high*, *Medium*, *Med-low*, or *Low*) that the site was indeed a vernal pool. Among 528 field-visited potential pools, ≥75% ranked as *High* or *Medium-high* were confirmed as vernal pools, while those ranked *Medium* or *Medium-low* were confirmed as vernal pools ≤53% of the time. No sites ranked *Low* were confirmed to be vernal pools, although the sample size (n = 5) was small. This suggests that field verification would be most efficient by prioritizing field work on *High* and *Medium-high* confidence pools, and possibly eliminating *Low*-ranked pools from the mapping process.

The distribution of mapped potential pools by biophysical region showed a distinct pattern, with the majority of mapped pools (55%) occurring in just three regions; the Northern Vermont Piedmont, Southern Vermont Piedmont, and Southern Green Mountains. Not surprisingly, just 5% (n = 199) of mapped potential pools were located in the Northeast Highlands, underscoring the limitations of CIR aerial photo mapping in landscapes dominated by conifer cover.

Among field-verified pools, the most commonly detected species were Wood Frog (*Lithobates sylvatica*) and Spotted Salamander (*Ambystoma maculatum*), which were found breeding in 78% and 73% of confirmed pools, respectively. Jefferson Salamander (*A. Jeffersonianum*) was found in 10% of confirmed pools, Blue-spotted Salamander (*A. Laterale*) in 3% of pools, and Fairy Shrimp (*Eubranchipus spp*.) in 5% of pools. At least 115 volunteers participated in field-verification of vernal pools, submitting data from 301 field visits.

INTRODUCTION

Vernal pools are typically small, shallow wetlands characterized by alternating flooded and dry phases. Many vernal pools are hydrologically isolated, filling primarily with precipitation and surface water runoff from the immediate surroundings (Brooks 2004), although inundation from local groundwater can also occur (Sobczak et al. 2003). Yet, despite their small size and ephemeral nature, these seasonal pools support a rich assemblage of invertebrates (Colburn et al. 2008) and breeding amphibians (Semlitsch and Skelly 2008), many of which are largely dependent upon vernal pools to complete their complex life cycles. Many of these species are considered High and Medium priority Species of Greatest Conservation Need (SGCN) as outlined in the Vermont Wildlife Action Plan, including Jefferson (*Ambystoma jeffersonianum*), Blue-spotted (*A. laterale*), Spotted (*A. maculatum*), and Four-toed salamanders (*Hemidactylium scutatum*), and vernal pool-dependent invertebrates including Odonates, Fairy Shrimp (*Eubranchipus spp*.), and freshwater snails. Additionally, vernal pools provide important foraging habitat for a variety of reptiles, birds and mammals (Mitchell et al. 2008), including SGCN such as Spotted Turtle (*Clemmys guttata*), Eastern Ribbonsnake (*Thamnophis sauritus*), Ruffed Grouse (*Bonasa umbellus*), Red-shouldered Hawk (*Buteo lineatus*), and both Masked (*Sorex cinerus*) and Smokey shrews (*S. fumeus*). As a result, the Vermont Wildlife Action Plan identified the need to "map and inventory vernal pools statewide" as a critical step in developing conservation strategies that will ensure the persistence of SGCN and other wildlife dependent on ephemeral pools.

Initiated in 2009, the overarching goals of the Vermont Vernal Pool Mapping Project (VPMP) were to advance vernal pool conservation planning at the state and local levels, and raise awareness about the value of vernal pools while developing momentum for statewide conservation. The project had three primary objectives:

1. To identify and map the location of potential vernal pools in Vermont using color-infrared (CIR) aerial photo interpretation;
2. Conduct a series of training workshops throughout the state to recruit a corps of skilled volunteers to field-verify the precise location and attributes of a sub-set of mapped potential vernal pools;
3. Through volunteer efforts and outreach, increase the knowledge and awareness of these critical habitats in Vermont's conservation community as well as the general public.

This report summarizes the results of remote mapping efforts and field work conducted from 2009 through 2012.

METHODS

Vernal Pool Mapping Data Sources

Several imagery sources were used to remotely map potential vernal pools. We primarily used paired, color infrared aerial photographs to detect potential pools. We then used digital orthophotos (both true color and black and white), along with digital topographic maps to help corroborate that the site detected was a vernal pool, and to accurately transfer the point location into a spatially-referenced GIS in ArcMap 10 (ESRI). Details of each data source are below.

<u>Color Infrared Aerial Photographs (CIR)</u>

To locate the presence of potential vernal pools we used stereo-paired color infrared (CIR) aerial photographs flown in the spring (April and May) of 1992-1993 at a scale of 1:40,000. CIR photos were available for the entire state of Vermont, with the exception of a few areas where individual photos were missing. These "false color" photos combine infrared reflectance with the green and red visible bands. In CIR photos, water presents a distinct, black photo-signature. Also, CIR photos were primarily taken prior to leaf-out during April and May, permitting a clear view of the forest floor in deciduous-dominated forests. Our ability to effectively map potential pools in conifer-dominated forest stands was limited.

Two types of CIR photos were available in the state; transparencies and traditional prints. In general, transparencies have better resolution and are much easier to "read" than prints, but they were not available for the entire state. Overall accuracy of pool detection and confidence determination was likely better in areas where transparencies were used. Each potential pool was tagged with the photo I-D number identifying the CIR photo that was used, including a "T" for transparency or a "P" for traditional print.

During remote mapping we were conscious of the fact that shadows (especially those from large conifers) can exhibit a dark photo-signature similar to water. This can result in "false positive" errors (e.g. identifying a site as a potential vernal pool when it is in fact the shadow from a large tree). This was a problem particularly where large white pines with spreading crowns created broad shadows, especially into canopy openings. Likewise, any pools that were located on the edge of conifer stands could go undetected (false negatives) because they might have been obscured by tree shadows.

<u>Digital Black and White Orthophotographs</u>

Digital black and white orthophotography, based on 1:5,000 geo-rectified orthophotos, were primarily used to digitally map locations of vernal pools detected on CIR photos, thus allowing the location to be spatially explicit with geographic coordinates. Available for the entire state, there are two sets of these photos, those taken in the 1990s and those taken in the early 2000s. These are spring "leaf-off" photos that show the forest floor under a hardwood canopy. Similar to water, conifers produce a dark photo-signature, preventing a view of the forest floor. Depending on site and resolution of the photos, potential pools were sometimes visible, thus leading to a high degree of location accuracy and confidence that the site was a vernal pool.

However, in many cases, the photo-signature of the potential pool was not visible, or could not be differentiated from shadows or conifers.

<u>National Aerial Imagery Program (NAIP) Color Orthophotos</u>

NAIP imagery are "true color" orthophotos taken during the summer season and are therefore considered "leaf on" imagery. Multiple sets of NAIP photos are available from different years including 2003, 2008 and 2011. Because these are "leaf on" images, views of the forest floor or vernal pools are very limited. Only pools that were large enough to create a significant canopy opening or those that occurred within forest gaps were typically visible. The primary value of these photos was to gain information about the hydroperiod of a wetland in question. If open water was visible in the NAIP photos, it suggested that the site had either a semi-permanent or a permanent hydrology.

<u>1:24,000 USGS Topographic Maps</u>

Digitized USGS topographic maps were often used as an aid in locating pools on digital orthophotos. Since pools were mapped using CIR photos viewed in stereo, topographic clues (which were not visible in digital orthophotos) were often helpful in determining a pool's precise location when transferring the point to GIS.

Aerial Photo Interpretation

To locate potential vernal pools, stereo pairs of CIR photos were examined at 3X magnification under a stereoscope, which allowed the photos to be viewed in three dimensions, enabling the interpreter to see topography. Observers examined paired CIR photos systematically for evidence of potential vernal pools. When the dark photo-signature of water was detected, we looked for evidence to distinguish the site from other types of permanent wetlands (e.g. ponds, seeps, larger wetland complexes), including pool shape and landscape context, presence of inlet or outlet streams and topography. The nuances of distinguishing vernal pools from other wetland types using CIR aerial photos are discussed in more detail below.

Once a potential vernal pool was located on paired CIR photos, the point location was then transferred to GIS using digital orthophotos and USGS topographic maps to pinpoint its precise location as close as possible. During this process a variety of data attributes were completed in the GIS database for each potential pool mapped (Table 1), including ranking each site for how accurately it was located in GIS and our confidence that the site was a vernal pool.

Although four individuals participated in aerial photo interpretation, the vast majority (99%) of pools were mapped by Co-PIs, S. Faccio and M. Lew-Smith. In a few cases, pools were also mapped by Jeff Parsons (JP) and Paul Wilson (PDW). In order to ensure consistency, all pools mapped by JP and PDW were reviewed by M. Lew-Smith.

<u>*Location Accuracy*</u>

Transferring the location of potential vernal pools from the CIR photos to digitized orthophotos involved varying degrees of uncertainty. Therefore, each mapped pool was given one of five ranks from *Low* to *High*, based on our confidence that the location was accurately transferred from aerial photo to GIS (Table 1). For example, in some cases a pool that was detected on the CIR photos was also detected on the corresponding digital orthophoto, resulting in a *High* location accuracy rank. However, if a pool was not visible on digital imagery, other landscape features were used to map the location of the pool with varying degrees of accuracy.

Pool Confidence

When remotely mapping vernal pools, there were varying degrees of certainty that a site was actually a vernal pool and not something else (e.g. shadow, seep, etc.). Therefore, based on professional judgment, each mapped pool was given one of five Confidence ranks from *Low* to *High* (Table 1). For example, if there were scattered conifers visible in the CIR photo creating uncertainty about whether a potential site was a pool or a shadow, the site was assigned a lower confidence rank and notes were often made in the *Comments* field.

Distinguishing Vernal Pools from Other Wetland Types

Ponds

In most cases, man-made ponds were obvious due to their shape and landscape context (located around homes with bordering mowed lawns). When a site occurred within a forested matrix however, we first looked for the presence of inlet and/or outlet streams, which would indicate a permanent hydrology. In addition, we often consulted digital NAIP true color orthophotos, which were taken during the summer. If a site was visible on NAIP photos, this suggested that it was large enough to create a sufficient canopy gap to be viewed, and it may have a permanent or semi-permanent hydrology. In most cases, these sites were not mapped as potential vernal pools. However, if there was some ambiguity, it was mapped with a lower confidence level and notes made in the *Comments* field.

Seeps

Groundwater seepage wetlands typically display a similar photo-signature to vernal pools. Seeps are sources of groundwater discharge and typically contain open water in the spring. They also typically occur in a forested context. The main distinguishing feature of seeps (in contrast to vernal pools) is that seeps often form the headwaters of streams or are located along stream margins. Therefore, if a distinct stream drainage was visible as an inlet or outlet to a site in question, the site was typically considered a seep wetland and not mapped as a vernal pool. Likewise, if a potential site was located along the margins of a stream, it was thought to be a seepage wetland and was typically not mapped as a vernal pool. Seeps also occur on slopes, whereas vernal pools do not. Therefore, if a site occurred on a slope lacking suitable topography it was not mapped as a potential vernal pool.

Another distinguishing feature between vernal pools and seeps is the nature of the wetland border. Many seeps have a fairly diffuse border, while vernal pools typically have a more distinct border or edge. In some cases, this characteristic could be used to distinguish the two wetland types. If there was some ambiguity however, the site was mapped with a lower confidence level and notes were made in the *Comments* field.

Table 1. Data attribute fields completed in GIS for each mapped potential pool.

Field Name	Comments	Entry
FID/OID	Database level Feature ID.	Auto-entry by ArcGIS, not used.
Shape	Auto-entry by ArcGIS	Auto-entry by ArcGIS
Unique_ID	Identification of pool by mapper. Serves as a unique ID.	Mapper initials followed by unique ID number (e.g. MLS3), serves as project-wide unique Pool identifier.
Confidence	Confidence that the site mapped is actually a vernal pool and not something else (shadow, seep etc.), based on professional judgment.	L = Low confidence
		ML = Medium-low confidence
		M= Medium confidence
		MH = Medium-high confidence
		H = High confidence
Loc_Accur	Location Accuracy. Confidence level that the pool location is accurately mapped.	L = Low confidence. Pool not seen on the digital orthophoto and actual location could be >250' from mapped location
		ML = Medium-low confidence. Pool not seen on the digital orthophoto and actual location could be 100'-250' from mapped location.
		M = Medium confidence. Pool not seen on the digital orthophoto and actual location could be 50'-100' from mapped location.
		MH = Medium high confidence. Pool likely seen on orthophoto OR not seen but actual location within 50'.
		H = High confidence. Pool can be seen on orthophoto and location accurately mapped.
Comments	Comments on the ecology, topography or physical features of pool as seen during mapping	General Text.
Photo_Num	CIR Aerial Photo Number.	Identification number of either of the paired CIR photo numbers on which the pool is found. "P" indicates a Print. "T" indicates a Transparency
Source	Data source used to locate potential pool	"CIR" for all pools found using color-infrared aerial photos during this project. See Table 2 and Appendix 4 for source of other pools.
Mapped_By	Initials of person that mapped the pool	MLS=Michael Lew-Smith; SDF=Steve Faccio; JP=Jeff Parsons; PDW=Paul Wilson
DateMapped	Date mapping was conducted	Date

Larger wetland complexes

Although vernal pool habitat can be found embedded within larger wetland complexes, these sites, which can be difficult to identify remotely, were beyond the scope of this project, and thus were not mapped. In addition, large wetland complexes have already been mapped by the Vermont Significant Wetlands Inventory (VSWI), and therefore already receive protection under the Vermont Wetland Rules and Vermont's Land-use and Development Law (Act 250). We used the VSWI layer in GIS to determine if a potential site was a mapped wetland. In a few cases, the VSWI maps included some larger vernal pools. If it was determined that the VSWI map referred to the vernal pool only (and not a larger wetland), then the site was included as a potential vernal pool.

Training Workshops and Volunteer Recruitment

A series of 13 training workshops were offered across the state during the first three years of the project (2009-2011), and were attended by more than 325 people. In 2009, when mapping efforts focused on the northern third of Vermont, three workshops were held (one each in Enosburg Falls, Craftsbury, and East Charleston), and were attended by approximately 80 individuals. After mapping potential pools in central Vermont during 2010, six workshops were held (one each in Shelburne, Huntington, Woodstock, and Ripton, and two in Montpelier), and were attended by approximately 166 people. In 2011, after mapping the southern third of Vermont, four training workshops were held (one each in Rutland, Grafton, Rupert, and Brattleboro), and were attended by approximately 88 individuals.

The 2½- to 3-hour long workshops, which were held during April or early-May, consisted of both indoor and outdoor components, including a powerpoint presentation covering the physical characteristics and ecological importance of vernal pools, as well as natural history information about vernal pool indicator species. In addition, detailed information was provided about the mapping project and how participants could get involved field-verifying potential pools. Finally, groups were taken outdoors to visit a nearby vernal pool where they learned to identify amphibian egg masses and were "walked through" how to complete a field-verification data sheet.

All workshop participants were provided packets which included a Volunteer Training Manual, indicator species I-D sheet, field-verification data sheets (Appendix 1), instructions for completing field-verification data sheets (Appendix 2), map of potential vernal pools, and other appropriate documents, all of which were also available for download on the project website (http://www.vtecostudies.org/VPMP/).

Field-verification

During the field-verification process, staff and volunteers navigated to mapped potential pools using GPS (volunteers were encouraged to use their own equipment, but six Garmin GPSMap 76 units were made available to volunteers to borrow for field-verification). Once at a site, observers completed a VPMP data sheet (Appendix 1), which included information about the pool location (directions, town, coordinates, etc.), landowner information (if needed), physical characteristics of the pool and surrounding landscape (pool type, presence of inlet or outlet, pool depth, approximate width and length of pool, etc.), and presence of indicator species or their eggs. All volunteers were provided detailed instructions for completing a field-verification data sheet (Appendix 2) and were encouraged to take photographs of field-verified pools and indicator species. All photographs were uploaded and archived at http://www.flickr.com/photos/vpmp. Uploaded photographs were named using the following protocol; Pool ID_Photographer Initials_Picture #, which allows each photograph to be linked to the appropriate field-verification data form.

Definition of a Vernal Pool

For the purposes of this project, a site was considered a vernal pool if it met the following four criteria; 1) occurred in a forested context, 2) had an ephemeral (seasonal) hydrology, 3) was hydrologically isolated from permanent water sources, and 4) had the presence of at least one of six indicator species (see below).

With the exception of the presence of indicator species, each of these criteria could, with varying degrees of accuracy, be assessed when remotely mapping potential vernal pools. During field-verification these criteria were used to help volunteers assess whether a site was a vernal pool or another type of wetland (see Appendices 1 and 2).

<u>Forested context</u>
Most pools that were remotely mapped as part of this project occurred within a forested context. Sites that appeared to be vernal pools but occurred in large agricultural fields were not mapped as potential vernal pools, while sites that occurred on field edges, with at least one side bordered by forest, were included. During field-verification, observers made a quick assessment of the forest type and condition within approximately 250 feet of the pool (Appendix 2).

<u>Ephemeral Hydrology</u>
An ephemeral hydrology is one of the most critical characteristics of a vernal pool. The hydrology must be long enough to allow egg and larval development through metamorphosis, but pools must dry completely, at least in some years, in order to inhibit fish populations. Since pools were not visited multiple times during field-verification, observers estimated the hydrology based on size, depth, and presence of wetland indicator plants.

<u>Hydrologically Isolated</u>
Most vernal pools are hydrologically isolated from other surface waters, although they often have ephemeral inlets or outlets which function only during high-water periods when pools are past capacity. During field-verification observers noted presence of inlets or outlets and assessed whether they were ephemeral or permanent based on evidence of channelization.

<u>Indicator Species</u>
Along with physical characteristics mentioned above, the presence of at least one of six “indicator” species was used during field-verification to confirm a site as a vernal pool. Indicator species were Wood Frog (*Lithobates sylvatica*), Spotted Salamander, Jefferson Salamander, Blue-spotted Salamander, Fairy Shrimp, and several species of Fingernail Clams. The latter group was primarily included since they can be located in the leaf litter of dry or nearly dry pools when other indicator species are not present. During field-verification, observers counted or estimated the number of egg masses present for any of the amphibian indicator species, and indicated if they observed amphibian larvae or adults, or either of the invertebrate species.

Landowner Permission

All field-verification for this project occurred either on public lands or on private lands for which landowner permission was obtained. During the first field season (2009), the job of obtaining landowner permission to visit mapped potential pools was left to the volunteer participants. However, for subsequent field seasons we contracted with ecologists Matt Peters and Erin Haney to obtain landowner permission in advance of the spring field seasons. Areas with both high concentrations of potential vernal pools and interested volunteers willing to help conduct field-verification, were targeted for landowner permission. First, potential pool locations were merged with digital town parcel maps (where available) to identify parcel IDs. Parcel IDs were then matched up with town tax maps and/or the state Grand List to identify landowners and mailing addresses of sites with potential vernal pools. Letters with self-addressed stamped return postcards were then sent to these landowners seeking permission to access their property to field-check potential pools.

A total of 682 letters were mailed to landowners, representing 1,075 potential vernal pools (due to multiple pools per owner). Of those, 178 landowners replied, for a response rate of 26%. The majority of replies from landowners were positive, although we did not keep track of the number of negative responses.

Pre-project Vernal Pool Data

In addition to collecting data on mapped potential pools and "new" pools that were missed during aerial photo interpretation, data from pre-VPMP records of "known" vernal pools were also incorporated into the VPMP database. These sources included several town-wide inventories (Bradford, Dummerston, Newbury, Norwich, Woodbury, and Woodstock), an inventory of the Ethan Allen Firing Range in Jericho and Underhill, pools sampled during a VT Department of Environmental Conservation (DEC) Bio-assessment project (VT DEC 2003), records compiled by the VT Fish and Wildlife Department (VFWD), and other records from private sources (see Table 2, Appendix 4). Data from 11 town-wide inventories that were conducted by M. Lew-Smith using the same methodology as VPMP, were incorporated into the potential pool layer, while those from other sources, which had little or no supporting data with which to determine the validity of the records, were coded as "Probable" pools in need of additional field-verification.

Data Entry and Management

We contracted with a programmer to develop a web-based, online data entry portal, with the data archived into a Microsoft SQL Server database. Project staff could access the database via a direct-linked Table View in MS Access or via GIS software. Users of the online data entry portal first needed to establish a username and password before being able to enter their data, but they did not have access to the database itself. Although the majority of volunteer participants entered their data online, some only mailed in their completed datasheets, requiring data entry by project staff. Spatial data was maintained in an ArcGIS File Geodatabase, which was tied to the field verification database through unique identifiers, and exported in a shapefile for periodic analysis or review.

Throughout the project spatial data was provided to project volunteers through web mapping platforms, initially hosted by the Agency of Natural Resources, and subsequently by Arrowwood Environmental. This platform allowed for volunteer access to potential pool locations, various pool attributes, including landowner permission status, and the ability to print basic field maps.

At the time of this writing, a subset of the data is available for public use at http://www.arrowwoodvt.com/VTVPmap.html.

Final QA/QC was conducted in Jan.-Feb. 2013, after all data collected to date had been entered. Most errors detected involved georeferencing mistakes, such as incorrectly entering coordinates, entering coordinates in the wrong format, duplicate entries of the same pool, and incomplete entries.

RESULTS AND DISCUSSION

Remote Mapping Success

A total of 4,016 potential vernal pools were mapped during aerial photo-interpretation, consisting of 3,779 potential pools mapped during VPMP and 237 mapped previously during town-wide inventories. In addition to potential pools, another 830 pre-project "probable" pools were imported into the database, bringing the total number of mapped pools to 4,846 (Table 2, Fig. 1).

Table 2. Number of mapped potential vernal pools by data source and type.

Data Source		Number	Data Type
VPMP		3,779	Remote CIR
Arrowwood Environmental Town Inventories		237	Remote CIR
Newbury	35		
Woodbury	34		
Mt. Holly	32		
Hartford	23		
Essex	19		
Waitsfield/Fayston	19		
Bradford	18		
West Fairlee	16		
Jericho	14		
Woodstock	14		
Warren	13		
Norwich Inventory		151	Other
Vermont State Lands		139	Other
Dummerston Inventory		137	Other
Vernal Pool Inventory Project		112	Other
Vermont Herp Atlas		79	Other
Orange County Headwaters Project		61	Other
DEC Bio-assessment Project		34	Other
Woodstock Vernal Pools		33	Other
A. Toepfer		27	Other
UVM - Ethan Allen Firing Range Inventory		25	Other
TNC - Shaw Mt., Bald Mt.		19	Other
VELCO Inventory		9	Other
NRCS		2	Other
VTDEC Bivalve Inventory		2	Other
Grand Total		**4,846**	

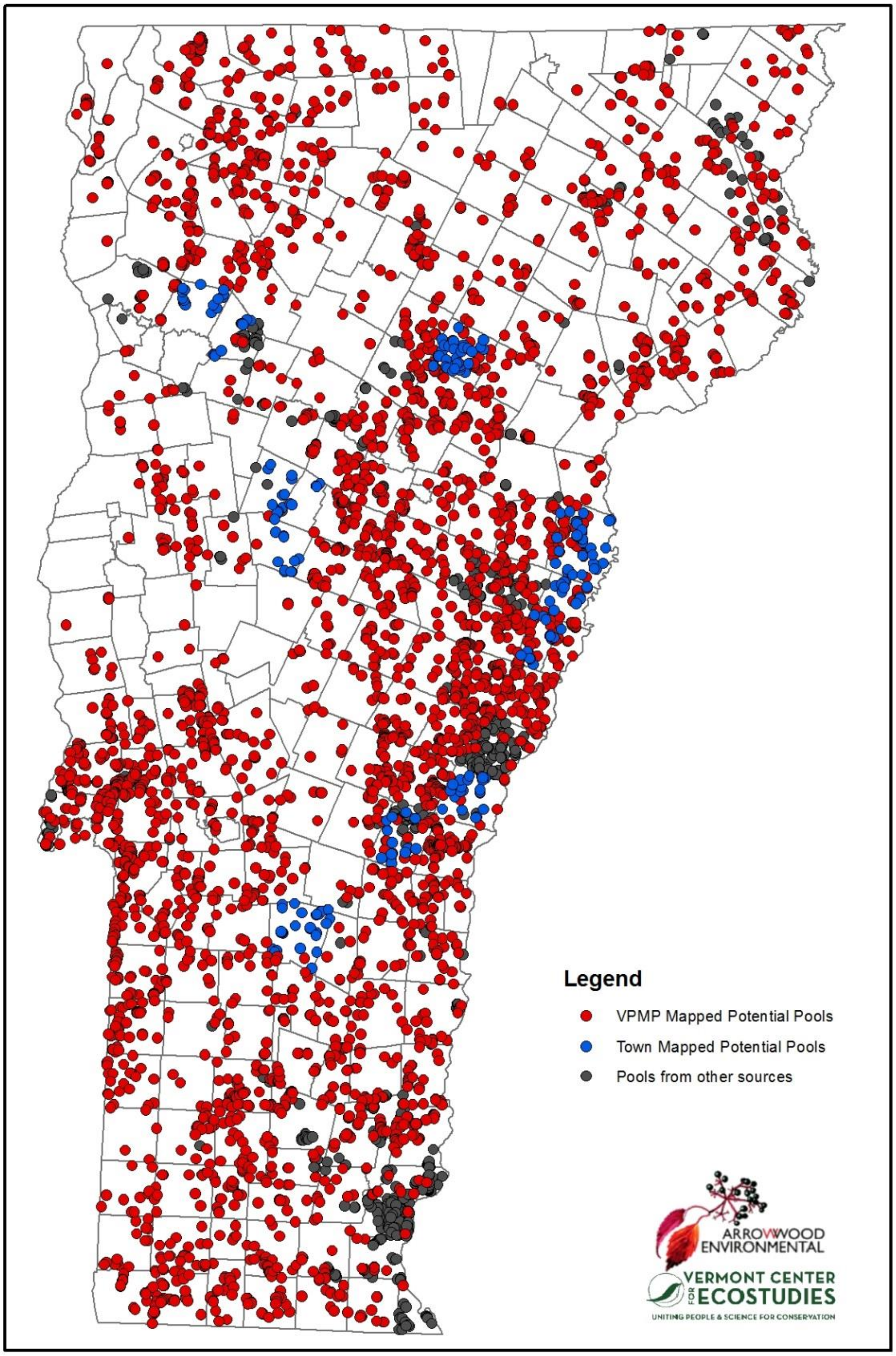

Figure 1. Distribution of 4,016 potential vernal pools mapped remotely using CIR photo-interpretation (VPMP and Town-mapped Pools), and 830 "probable" pools obtained from other sources.

Of these 4,846 mapped potential pools, a total of 636 (13.1%) were visited in the field during VPMP. In addition, another 221 "new" pools that were not previously mapped were confirmed in the field (Fig. 2). Among the 636 field-visited potential pools, 344 (54.1%) were confirmed to be vernal pools, while 292 (45.9%) were not (Fig. 3). However, 71% (n = 207) of the sites that were not pools turned out to be other types of wetlands (e.g. beaver ponds, shrub swamps, seeps, puddles, etc.), while only 85 were artifacts of CIR mapping, primarily shadows from conifers.

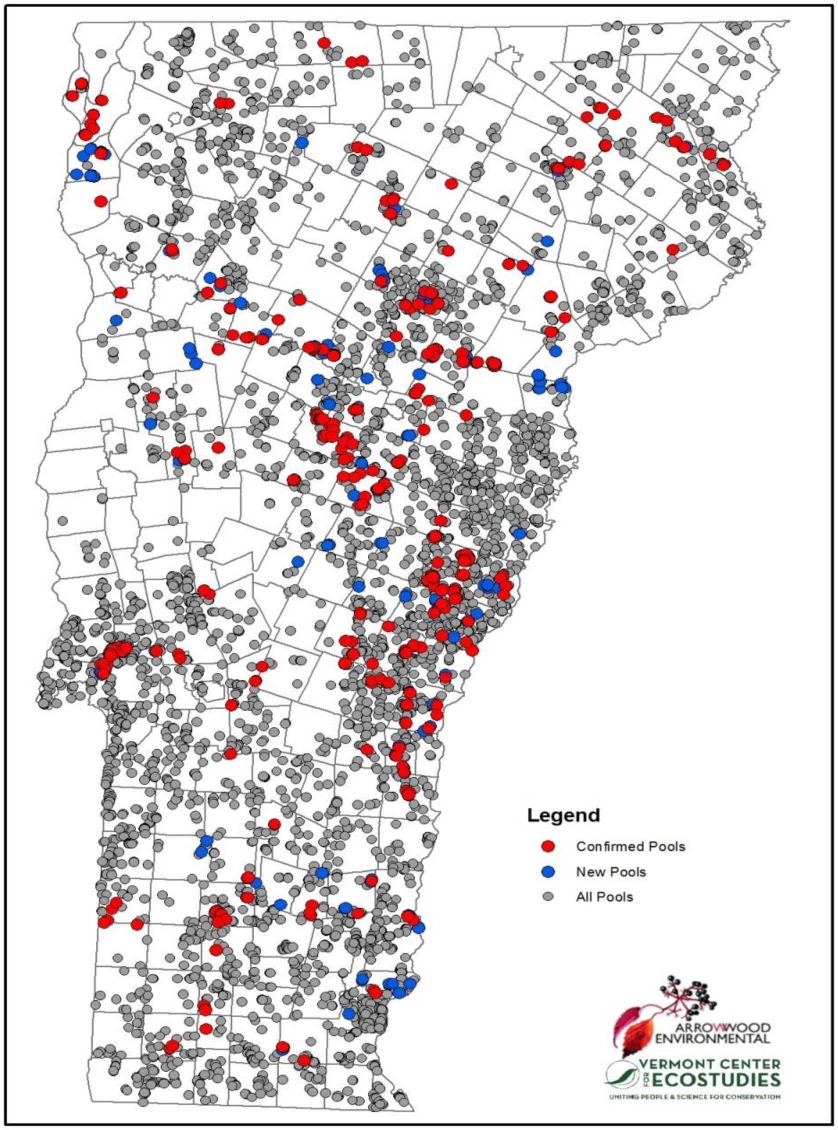

Figure 2. Distribution of 344 field-verified "confirmed" vernal pools, 221 "new" vernal pools, and all other potential pools that were not field-visited during VPMP field work, 2009-2012.

During remote mapping, each potential pool was given a confidence rank (*High*, *Med-high*, *Medium*, *Med-low*, or *Low*) that the site was indeed a vernal pool (see Table 1). Most remotely mapped pools (68.7%) were ranked as *Medium* or *Medium-high* confidence, while 14.9% were ranked *High*, 15.1% *Medium-low*, and only 1.8% *Low*. Among field-verified potential pools that were given a confidence rank (n = 528), ≥75% ranked as *High* or *Medium-high* were confirmed as vernal pools, while those ranked *Medium* or *Medium-low* were confirmed as vernal pools ≤53% of the time (Fig. 4). No sites ranked as *Low* were confirmed to be vernal pools, although the sample size (n = 5) was small. This suggests that field verification would be most efficient by prioritizing field work on *High* and *Medium-high* confidence pools, and possibly eliminating *Low*-ranked pools from the mapping process.

In addition, during remote mapping we noted variation between the quality of CIR prints from different flight lines, likely due to irregularities during the printing process. Some flight lines were much darker or had a bluish cast to the print, which often obscured the photo-signature of water, making detection of pools more difficult. This was especially true of many areas in Essex County. In other cases, resolution of the photos was poor, making pool detection difficult. Finally, some photos taken during May of 1992 and 1993 occurred after leaf-out, especially in southern Vermont and at lower elevations, obscuring the view of the forest floor and limiting our ability to detect pools that may have been present.

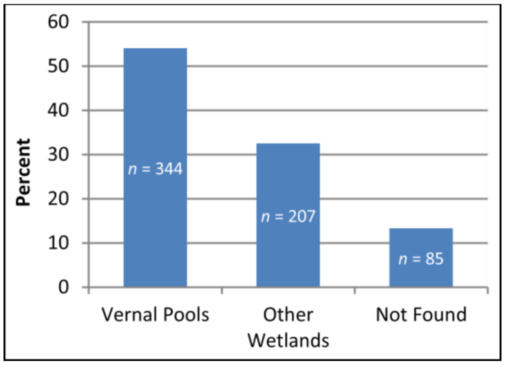

Figure 3. Percent of field-visited potential pools (n = 636) that were confirmed as vernal pools, other wetland types, or were not found.

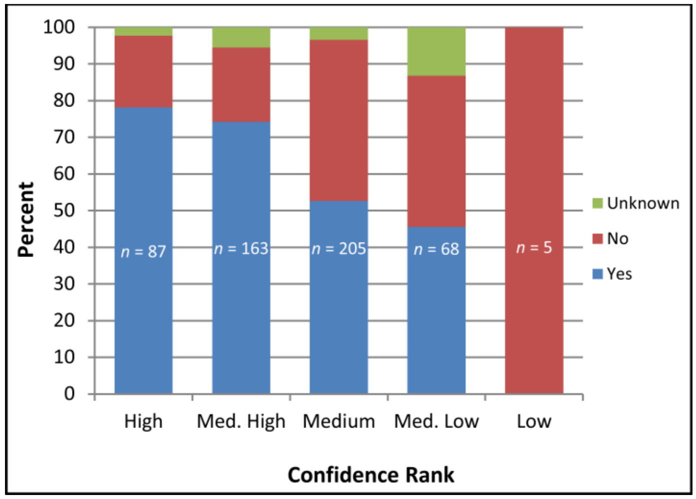

Figure 4. Proportion of field-verified pools (n = 528) by mapped confidence rank, that were either confirmed (*Yes*) or not confirmed (*No*) as vernal pools. *Unknown* pools were those where the field observer were uncertain if the site qualified as a vernal pool. Sample sizes inside bars represent number of pools in each category that were visited in the field.

State-wide Distribution of Mapping and Field-verification

A total of 4,016 potential vernal pools were mapped in 235 (92.2%) of Vermont's 255 towns (mean = 17.1 ±15.7 SD pools per town) (Fig. 1; Appendix 3). In addition, "probable" pools incorporated from other data sources increased that number to 237 towns (92.9%). The towns with the highest number of mapped potential pools included Benson (n = 93) (Rutland Co.), Strafford (n = 87) (Orange Co.), Pomfret (n = 74) (Windsor Co.), and Hartland (n = 73) (Windsor Co.). Eleven towns located in five counties had 50 or more mapped potential pools (Appendix 3). A total of 565 vernal pools were confirmed in 102 towns (40%) (Fig. 2). Among the 20 towns in which no potential pools were located using CIR photo interpretation, six were located in agriculturally-dominated Addison County, seven were in highly developed urban areas, and five were towns dominated by conifer cover, primarily in the Northeast Highlands (Appendix 3).

By county, Rutland, Orange, and Windsor had the highest number of mapped potential pools, while Washington, Windsor, and Orange counties had the highest number of confirmed pools

(Fig. 5). The distribution of confirmed pools by county was the result of several factors; including the number of potential pools mapped in the area, the number of pools that were "available" to survey (e.g. located on public lands or on parcels with landowner permission), and the location of active volunteers and VPMP staff.

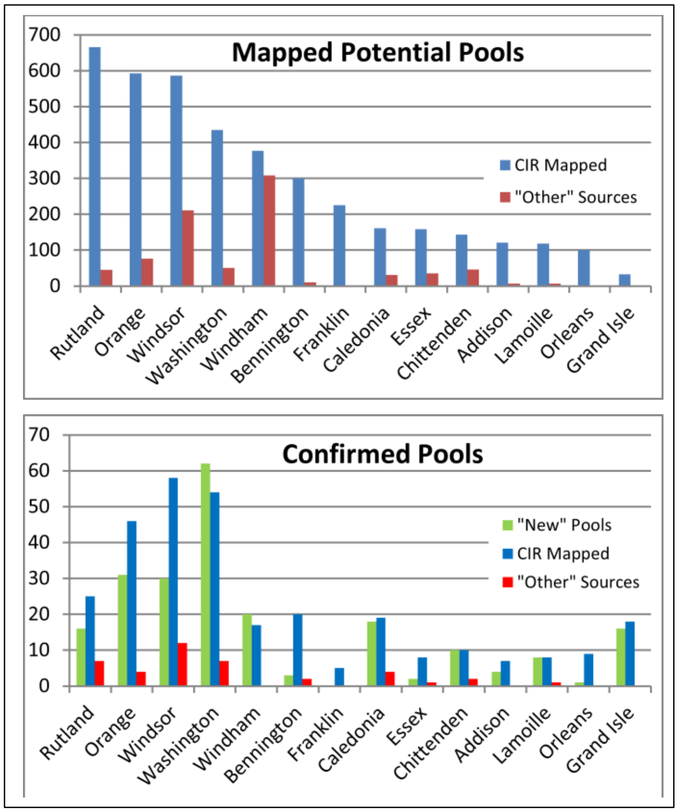

Figure 5. Number of mapped potential vernal pools and field-confirmed vernal pools by county.

The distribution of mapped potential pools by biophysical region showed a distinct pattern, with the majority of mapped pools (54.6%) occurring in just three regions; the Northern Vermont Piedmont, Southern Vermont Piedmont, and Southern Green Mountains (Table 3, Fig. 6). Not surprisingly, just 5% (n = 199) of mapped potential pools were located in the Northeast Highlands, underscoring the limitations of CIR aerial photo mapping in landscapes dominated by conifer cover.

Among potential pools that were field-checked, those located in the Southern Vermont Piedmont and Taconic Mountains had the highest proportion of confirmed pools, while those located in the Southern Green Mountains, Vermont Valley, Champlain Valley, and Northern Vermont Piedmont had the lowest proportion of confirmed pools (Fig. 6).

We estimated the density of mapped potential pools for each biophysical region by dividing the number of potential pools for a given region by the size of that region in acres. The Taconic Mountains and Southern Vermont Piedmont had the highest density of mapped pools, while the lowest density of pools was found in the Northeast Highlands, Vermont Valley, Northern Green Mountains, and Champlain Valley (Fig. 7). It seems likely that the density of pools in the Northeast Highlands was underestimated due to the high proportion of conifer cover in this region which makes it difficult to accurately map vernal pools remotely using aerial photo-interpretation. This may also be the case for some areas of the Northern Green Mountains that are dominated by montane-fir and boreal spruce-fir forests, although topography is likely a contributing factor in the mountains. The extensive agricultural and developed lands of the Champlain Valley, however, may have resulted in the loss or alteration of many vernal pools in this region. In addition, the extensive wetland habitats of the Champlain Valley reduce the amount of uplands where vernal pool depressions can form. The low density of mapped pools in the Vermont Valley may be due to differences in surficial geology and the prevalence of well-drained gravel terraces along the valley sides (Thompson and Sorenson 2000), which may prevent the formation of vernal pools (Rheinhardt and Hollands 2008). These terraces typically support forests of white pine and hemlock, which would also limit the ability to locate vernal pools using aerial photos if they were present. In addition, forested swamps account for much of the remaining forest cover in this narrow, agricultural valley.

Table 3. Number of mapped potential and field-confirmed vernal pools by biophysical region.

	Mapped Potential Pools			Confirmed as Vernal Pools						Total No. of
Biophysical Region	**No. of Potential Pools Mapped (%)**	**No. of "Other"[1] Pools (%)**	**Total No. Mapped (%)**	**Potential Pools Mapped (%)**	**Percent of Potential Pools Mapped**	**"Other" Pools (%)**	**Total No. Mapped (%)**	**Percent of Total Mapped**	**"New"[2] Pools (%)**	**Potential Pools Field-visited[3] (%)**
Champlain Valley	537 (13.4)	67 (8.1)	604 (12.5)	29 (9.5)	5.4%	0	29 (8.4)	4.8%	21 (9.5)	56 (8.8)
Northern Green Mtns	510 (12.7)	62 (7.5)	572 (11.8)	55 (18.1)	10.8%	8 (12.9)	63 (18.3)	11.0%	56 (25.3)	107 (16.8)
Northern VT Piedmont	786 (19.6)	89 (10.7)	875 (18.1)	68 (22.4)	8.7%	6 (6.7)	74 (21.5)	8.5%	54 (24.4)	139 (21.9)
Southern VT Piedmont	739 (18.4)	495 (59.6)	1,234 (25.5)	70 (23.0)	9.5%	16 (3.2)	86 (25.0)	7.0%	63 (28.5)	159 (25.0)
Southern Green Mtns	666 (16.6)	44 (5.3)	710 (14.7)	38 (12.5)	5.7%	2 (4.6)	40 (11.6)	5.6%	5 (2.3)	84 (13.2)
Taconic Mountains	521 (13.0)	16 (1.9)	537 (11.1)	24 (7.9)	4.6%	7 (43.6)	31 (9.0)	5.8%	15 (6.8)	50 (7.9)
Vermont Valley	58 (1.4)	1 (0.1)	59 (1.2)	1 (0.3)	1.7%	0	1 (0.3)	1.7%	2 (0.9)	6 (0.9)
Northeast Highlands	199 (5.0)	56 (6.8)	255 (5.3)	19 (6.3)	9.5%	1 (1.8)	20 (5.8)	7.8%	5 (2.3)	35 (5.5)
Total	**4,016**	**830**	**4,846**	**304**	**7.6%**	**40 (4.8)**	**344**	**7.1%**	**221**	**636**

[1] Mapped pools acquired from other data sources.
[2] Field-confirmed pools that were not previously mapped.
[3] Includes 292 sites mapped as potential pools that, when field-checked, were not vernal pools.

Physical Characteristics of Confirmed Vernal Pools

Among the 565 sites (344 mapped, 221 unmapped) that were confirmed as vernal pools, mean estimated width was 12.3 m (±9.2 m SD; range =0.9-106.7 m), and the mean maximum length was 29.2 m (±21.2 m SD; range = 3.1-198.1 m), resulting in an average surface area of 427.5 m^2 (0.11 acres). The smallest confirmed pool was estimated to measure 0.9 m x 3.1 m (2.8 m^2; 0.001 acres), while the largest was estimated at 76.2 m x 106.7 m (8,130.5 m^2; 2.01 acres). This unusually large pool was located on Grand Isle, where two other large (ca. 1 acre) pools were located, and was described by the volunteer observer as being on the edge of a larger wetland complex. The vast majority of pools (67.6%, n = 382) were estimated to be <0.1 acre in size, while only 2.5% (n = 14) were >0.5 acres (Fig. 8). It should be noted that surface area was calculated simply by multiplying estimated pool width by pool length. For most pools, this probably resulted in an over-estimate of actual size, since pools tend to be irregularly shaped polygons rather then rectangular.

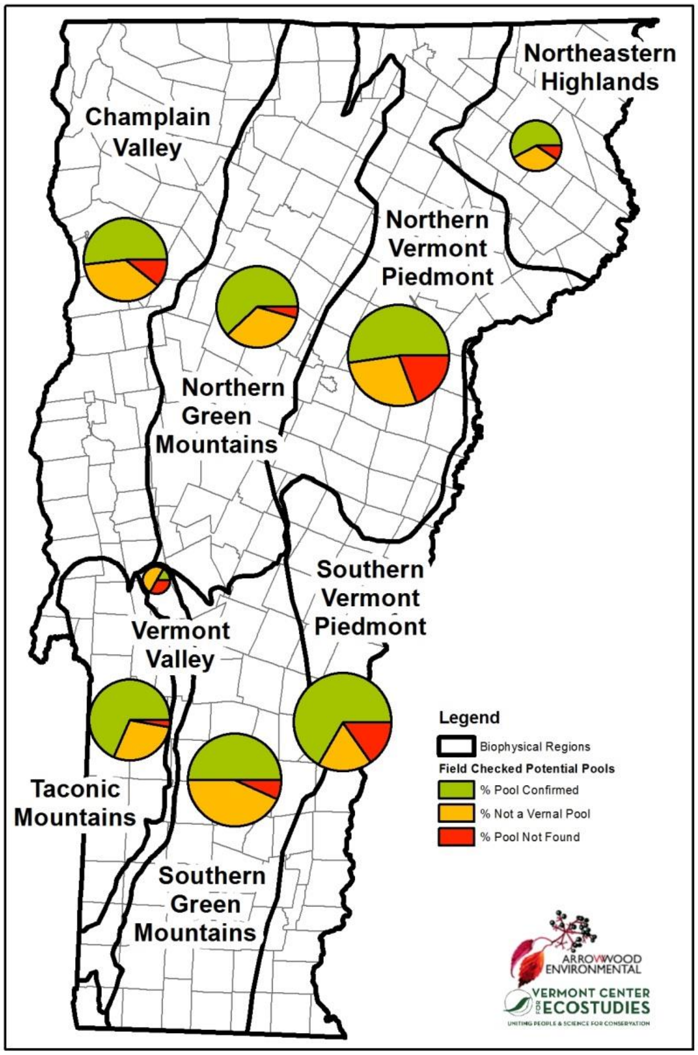

Figure 6. Proportion of field-visited pools by biophysical region that were either confirmed as vernal pools, not vernal pools (e.g. other wetland types), or not found. Size of each pie chart varies by total number of mapped potential pools for that region.

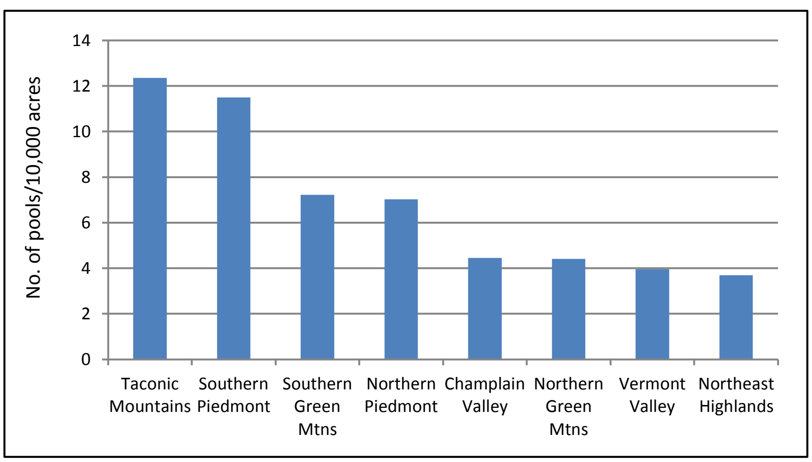

Figure 7. Density of mapped potential pools by biophysical region. Density = number of pools/number of acres x 10,000.

Seventy-seven percent (n = 434) of confirmed pools were estimated to be between 6 and 24 inches in depth at their maximum capacity, and 74% (n = 418) were considered to have ephemeral hydroperiods, defined as "completely drying in most years" (Table 4). Since most pools were not visited multiple times over the course of a year to accurately determine their hydroperiod, unless an observer was familiar with a particular pool this variable was estimated based on pool size, depth, amount of water present at time of visit, and presence of wetland plant indicators.

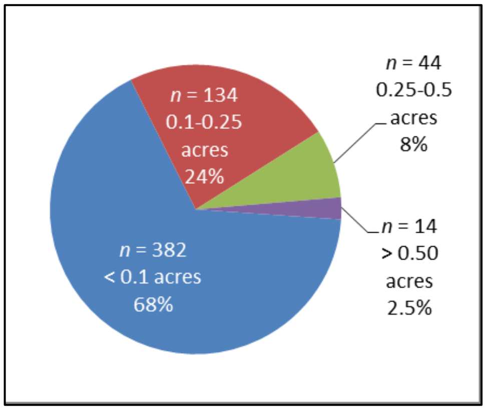

Figure 8. Proportion of confirmed pools by size class (acres).

Most pools (87%, n = 490) had no connection to water sources via a permanent or ephemeral inlet (Table 4), and were characterized as "isolated forest depressions." Just over half of confirmed pools (57%, n = 320) had no outlets, while 42% (n = 235) had ephemeral outlets where pools overflowed during high water periods. The overwhelming majority of confirmed pools (93%, n = 526) had a leaf litter substrate, with 51% (n = 287) located in mixed forest stands and 45% (n = 256) in deciduous forests.

Biological Characteristics of Confirmed Pools

Along with physical characteristics, the presence of at least one of six "indicator" species was used during field-verification to confirm a site as a vernal pool. Indicator species were Wood Frog (*Lithobates sylvatica*), Spotted Salamander, Jefferson Salamander, Blue-spotted Salamander, Fairy Shrimp, and several species of Fingernail Clams. The latter group was primarily included since they can be located in the leaf litter of dry or nearly dry pools when other indicator species are not present.

Amphibian Indicator Species

As expected, the most frequently detected species were Wood Frog, found in 77.7% (n = 439) of all confirmed pools in 98 towns, and Spotted Salamander found in 72.6% of pools (n= 410) in 78 towns (Table 5, Fig. 9). The two other *Ambystomid* salamanders were detected much less frequently, consistent with their state-wide distributions and state-ranks. Jefferson Salamander was found in 9.6% of pools (n = 54), while Blue-spotted Salamander was detected in just 3.4% (n = 19) (Table 5, Fig. 9). Such a low detection rate for both species is not unexpected, due to the secretive nature of adult mole salamanders, the difficulty in distinguishing between *Ambystomid* species by larval stage, and the difficulty in detecting the relatively small and inconspicuous egg masses of Jefferson and Blue-spotted salamanders. Moreover, both species have limited distributions in Vermont (Andrews 2013), which are reflected by the distribution of pools in which they were confirmed in this study (Fig. 10). Jefferson Salamander was detected in 20 towns, primarily east of the Green Mountains, while Blue-spotted Salamander was detected in just 8 towns, primarily in the Champlain Islands (Fig. 10).

Table 4. Physical variables and forest type of confirmed vernal pools.

Variable	Number	(%)
Pool Depth		
< 6 Inches	30	(5.31)
6-12 Inches	200	(35.40)
12-24 Inches	234	(41.42)
2-3 Feet	80	(14.16)
3-4 Feet	15	(2.65)
> 4 Feet	2	(0.35)
No Data	4	(0.71)
Pool Substrate		
Bedrock	1	(0.18)
Leaf litter	526	(93.10)
Mud	18	(3.19)
Other	8	(1.42)
No Data	12	(2.12)
Hydroperiod		
Ephemeral	418	(73.98)
Permanent	12	(2.12)
Semi-permanent	123	(21.77)
No Data	12	(2.12)
Inlet		
Ephemeral Inlet	73	(12.92)
No Inlet	490	(86.73)
Permanent Inlet	1	(0.18)
No Data	1	(0.18)
Outlet		
Ephemeral Outlet	235	(41.59)
No Outlet	320	(56.64)
Permanent Outlet	6	(1.06)
No Data	4	(0.71)
Forest Type		
Deciduous	256	(45.31)
Coniferous	20	(3.54)
Mixed	287	(50.80)
No Data	2	(0.35)

Table 5. Number (%) of confirmed vernal pools in which indicator species were detected by life stage.

	Number (%) of Pools Species Detected			
Species	**Adult**	**Eggs**	**Larvae**	**Total**
Wood Frog	56 (9.9)	175 (31.0)	302 (53.5)	439 (77.7)
Spotted Salamander	17 (3.0)	380 (67.3)	62 (11.0)	410 (72.6)
Jefferson Salamander	2 (0.4)	46 (8.1)	12 (2.1)	54 (9.6)
Blue-spotted Salamander	1 (0.2)	18 (3.2)	1 (0.2)	19 (3.4)
Fingernail Clams				115 (20.4)
Fairy Shrimp				26 (4.6)

Although most salamander detections (>85%) were confirmed by the presence of egg masses, the majority of Wood Frog detections (70%) were made by the presence of tadpoles (Fig. 9). Wood Frog egg masses develop and hatch quickly compared to salamander eggs, which persist longer in the pools. In addition, Wood Frog tadpoles are often the only frog larvae present in vernal pools and are relatively easy to distinguish from other anuran larvae that may be present. In many pools, confirmations involved detection of multiple life stages for a given species (e.g. eggs and larvae).

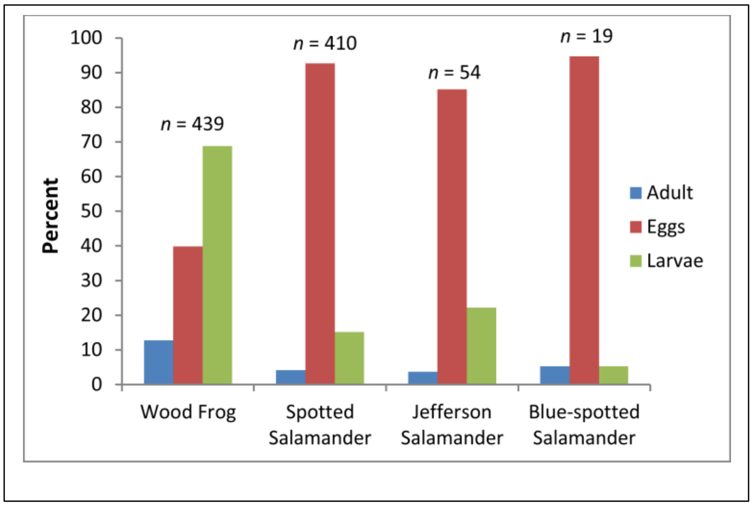

Figure 9. Proportion of amphibian indicator species by life stage detected at confirmed vernal pools. Sample size above bars is the total number of confirmed pools in which that species was detected. Species totals can exceed 100% due to detection of multiple life stages in individual pools.

Invertebrate Indicator Species

Fingernail clams were the most frequently detected invertebrate indicator species, found in 20% (*n* = 115) of confirmed pools in 46 towns (Table 5.). In contrast, Fairy Shrimp were only detected in 4.6% (*n* = 26) of pools in 17 towns (Table 5, Fig. 10). Although both invertebrates were encountered in relatively few pools, they occurred within all biophysical regions except the Vermont Valley. The presence of Fingernail Clams was probably under-represented in our sample of field-verified pools because they are small and relatively difficult to find. Many volunteers may not have searched carefully for these inconspicuous bivalves, especially if they already had confirmed other, more easily-detected indicator species such as Wood Frog or Spotted Salamander. Among the 115 pools with Fingernail Clams, 11% (*n* = 13) had no other indicator species present. Most of these appeared to be short-hydroperiod pools that may only support successful amphibian breeding in wet years.

Similarly, Fairy Shrimp presence was probably under-represented in our sample of field-verified pools. Fairy Shrimp are well-known to occur sporadically and unpredictably from year to year because their encysted eggs must dry and be re-submerged before they will hatch (Colburn 2004). Depending on the species, they are most commonly observed in early spring for a relatively short period (ca. 1-3 weeks). By month, April had the most observations of Fairy Shrimp (*n* = 10) in our study, while five observations occurred during May, seven in early June, and one in early July. Fifteen percent (*n* = 4) of pools with Fairy Shrimp observations supported no other indicator species.

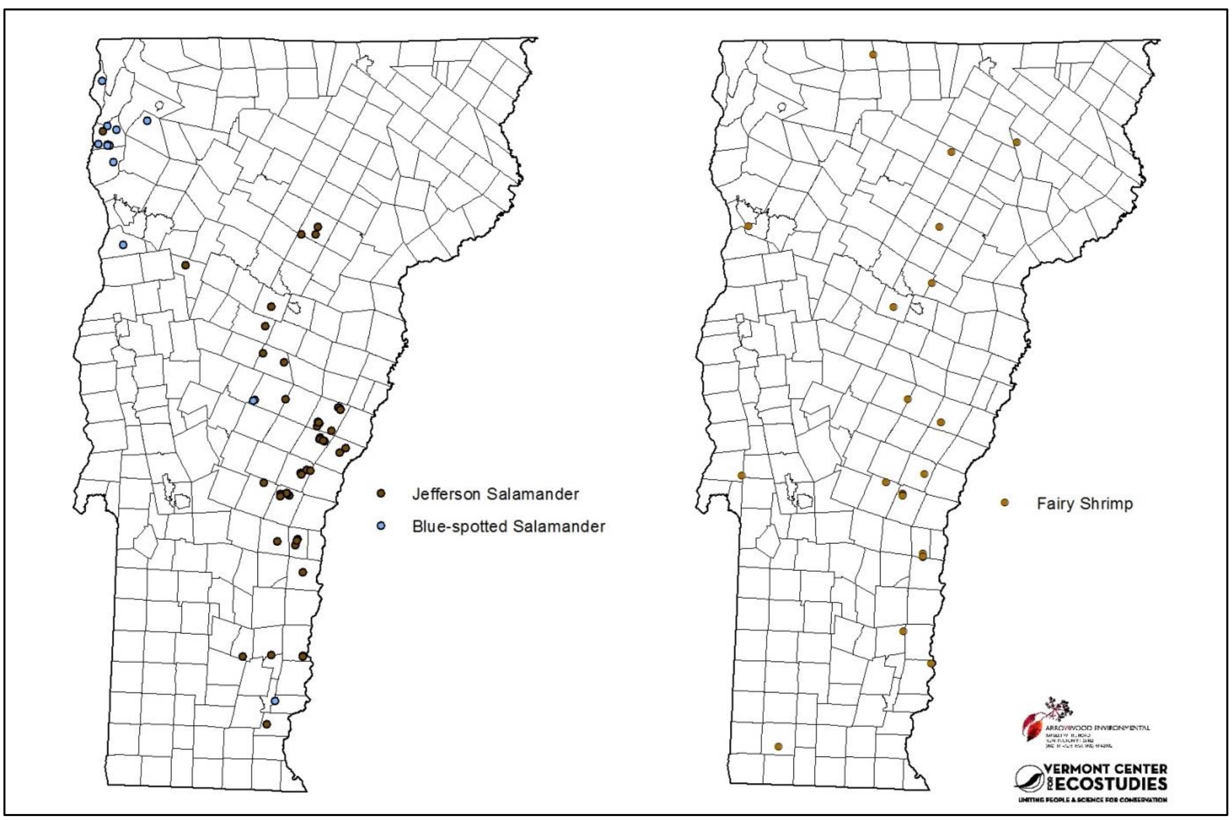

Figure 10. Distribution of confirmed vernal pools in which Jefferson and Blue-spotted salamanders (left), and Fairy Shrimp (right) were detected.

Volunteer Participation in Field-verification

At least 115 volunteers participated in field-verification of vernal pools, submitting data from 301 field visits. In addition, four VPMP staff submitted data from 587 field visits. Volunteer effort varied widely, from submitting data from a single pool visit to as many as 41. Most volunteers (76%; n = 87) submitted data on ≤4 pools each, while only 6% of volunteers (n = 7) visited 10 pools or more each. Two volunteers (D. Hoag and T. Ziobrowski) collected data on 24% (n = 72) of all pools visited by volunteers. At least five schools (Laraway School in Johnson, Lamoille Union Middle and High schools in Hyde Park, The Sharon Academy in Sharon, and Mt. Abraham Middle School in Bristol) participated in field-verification, along with three conservation commissions, a Vermont Youth Conservation Corps group, and students from a Natural Resource Management class at Green Mountain College.

To date, a total of 780 photographs of field-verified pools and indicator species were uploaded to the project's Flickr website (http://www.flickr.com/photos/vpmp), including 448 images submitted by 24 volunteers.

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Appendix 1. Field Verification Data Sheet.

VERMONT CENTER FOR ECOSTUDIES
UNITING PEOPLE & SCIENCE FOR CONSERVATION
PO Box 420 Norwich, VT 05055 802-649-

ARROWWOOD ENVIRONMENTAL
950 BERT WHITE ROAD
HUNTINGTON, VT 05462
(802) 434-7276 FAX: (802) 434-2102

Vermont Vernal Pool Mapping Project

☐ Was this form entered on website?

Vernal Pool Field-Verification Data Sheet

1a) Observer Information

Name: ______________________________ Address: ______________________________

Phone: ______________________________ ______________________________

Email:

1b) Credentials (please check all that apply)

☐ Professional Biologist/Ecologist ☐ Trained Citizen Scientist

☐ Natural Resource Professional (forester, land manager, etc) ☐ Self-informed Naturalist

☐ Educator ☐ Other

Have you attended a Vernal Pool Training Session? ☐ Yes ☐ No

2a) Vernal Pool Location Information

Pool ID:

Date: (mm/dd/yyyy)

Check one ☐ a). This pool was mapped as a "potential" pool

☐ b). This pool was unmapped

If a) above, was the pool located? ☐ Yes ☐ No

How certain are you that you were in the correct location?

☐ *Certain* ☐ *Pretty Sure* ☐ *Not Sure*

What navigation method was used? (check one)

☐ GPS ☐ Map & compass ☐ Prior knowledge of site

☐ Other________________

Brief site directions to pool:

Town:

Comments:

2b) Location of Pool

Source of Pool Coordinates ☐ GPS ☐ Topo map ☐ Google Earth ☐ VT ANR Mapping website

Enter coordinates in Decimal Degrees (for example: Latitude: 44.764322 Longitude: -72.654222)

Latitude/Northing: Longitude/Easting:

2c) Landowner Contact Information

Are you the landowner? _____Yes _____No

If no, was landowner permission obtained for this survey? _____Yes _____No

Landowner's contact information (if known). Name: ______________________________ Phone:__________

Address:____

Appendix 1 (cont.).

3. Vernal Pool Field-Verification Information

Is this a Vernal Pool? ☐ Yes ☐ No ☐ Don't know

3a) Pool Type (select one)

☐ Isolated Forest Depression ☐ Isolated Non-Forest Depression
☐ Floodplain Depression ☐ Pool associated with larger wetland complex
☐ Manmade (impoundment, quarry, excavated pond, etc.) ☐ Other (describe):

3b) Presence of Inlet and/or Outlet

Type of Inlet (an inlet is a seasonal or permanent channel providing water into pool)

☐ No Inlet ☐ Ephemeral Inlet ☐ Permanent Inlet (channel between well-defined banks)

Type of Outlet (an outlet is a seasonal or permanent channel draining water from pool)

☐ No Outlet ☐ Ephemeral Outlet ☐ Permanent Outlet (channel between well-defined banks)

3c) Surrounding Habitat (within 250 feet of pool) (check all that apply)

Forested Upland	**Forest Condition**	
☐ Deciduous	☐ Undisturbed	☐ Agriculture/grassland
☐ Coniferous	☐ Minor logging	☐ Light development (<25% developed)
☐ Mixed	☐ Major logging	☐ Intensive development (>25% dev.)
		☐ Road/driveway (☐ paved ☐ dirt/gravel
		☐ Powerline right-of-way
		☐ Other:________________________

Comments:

4. Pool Characteristics

Hydrology

4a) Approximate Maximum Pool Depth

☐ Ankle-deep (<6") ☐ Hip-deep (2-3 ft)
☐ Shin-deep (6-12") ☐ Chest-deep (3-4ft
☐ Knee-deep (12-24") ☐ Deeper than 4 ft

4b) Water Level at Time of Survey

☐ Full ☐ Less than 50%
☐ More than 50% ☐ Dry

4d) Approximate size of pool (at maximum capacity)

Width: _________ ☐ ft Length:_________ ☐ ft

4e) Vegetation Present in Pool Trees:______% Emergent:______% Shrubs: % Floating: %

4f) Substrate ☐ Leaf litter ☐ Bedrock ☐ Sand/Gravel ☐ Mud ☐ Other:

4g) Pool Disturbance (check all that apply) ☐ Siltation
☐ Dumping ☐ Vehicle ruts ☐ Agricultural runoff
☐ Ditching/draining ☐ Other:

4c) Hydroperiod (select the likely hydroperiod below)

☐ Permanent ☐ Semi-permanent (drying partially in all years and completely in drought years)
☐ Ephemeral (drying out completely during the growing season in most years)

5. Indicator Species

rovide a photograph of the pool & each indicator species (or egg masses) observe

SPECIES OBSERVED	Adults	Tadpoles/ Larvae	Egg Masses Number	Egg Masses Estimated	Egg Masses Counted	Photos? Yes	Notes/Photo ID#
Wood Frog				☐	☐	☐	
Spotted Salamander				☐	☐	☐	
Jefferson Salamander				☐	☐	☐	
Blue-spotted Salamander				☐	☐	☐	
Fairy Shrimp						☐	
Fingernail Clams						☐	
Other:				☐	☐	☐	
				☐	☐	☐	

Comments:

Were Fish Observed? ☐ Yes ☐ N How Many? ☐<10 ☐11-50 ☐>50 Size: ☐<1" ☐2-4" ☐>4"

Vermont Vernal Pool Mapping Project

Instructions for Completing the *Vernal Pool Field Verification Data Sheet*

The goal of field-verification is to determine whether or not a remotely mapped "potential" pool is indeed a vernal pool, and to collect biological and physical data about vernal pools in Vermont, whether previously mapped or newly "discovered."

Once you have completed entering all your data sheets at the online data entry website (see 1a below), mail the completed data sheets along with the completed State Wildlife Grants Volunteer Time Form to:

Steve Faccio
Vermont Center for Ecostudies
PO Box 420
Norwich, VT 05055

1a) Observer Information

Self-explanatory. The phone and email are required in case we need to ask you questions about the data form or the pool. For the "Address" line, please at a minimum enter the town in which you live in.

Was this form entered on website? Check this box if you entered the data on this form into the online database. Go to the project website at www.vtecostudies.org/VPMP/dataentry/ to enter the online database.

1b) Credentials

Please check the one that applies. Consider yourself a Trained Citizen Scientist if you have attended a Vernal Pool Training Workshop.

2a) Vernal Pool Location Information

***Pool ID*:** Enter this ID number if this was a previously mapped pool. The ID will be 3 letters followed by numbers. For example SDF34 or MLS23. If this was a previously unmapped pool, leave this space blank.

This pool was mapped as a potential pool. Check this box if the pool appeared on the potential pools map. Each potential pool will have a unique Pool ID.

This pool was unmapped. If you discovered (or knew about) a pool that we have not mapped, check this box.

If a) above, was the pool located. Check "Yes" if you found the vernal pool identified by the Pool ID number shown above. It is also important to document pools that were not found; so if you could not find the pool, check "No".

How certain are you that you were in the correct location? This is important for previously mapped pools only, and especially important for pools that you could not find. If you are navigating with a GPS and are receiving GPS reception, circle "Certain". Otherwise, use your judgment.

2b) Location of the Pool

Source of Coordinates. Check the GPS box if you used a GPS to obtain the coordinates of the pool. Check one of the other appropriate boxes if you used a topo map or online mapping program to locate the pool (typically for previously unmapped pools only).

***Enter Coordinates in decimal degrees*.** Enter the latitude and longitude coordinates in the decimal degree format (not as minutes and seconds). Most GPS units will default to this format. If your GPS unit is showing UTM or some other coordinates you can change the display, typically in the settings menu. UTM coordinates will be two numbers like decimal degrees but will not have a decimal point or a "°" symbol after them. Latitude and longitude in the non-decimal degree format will show degrees (°), minutes ("), and seconds (') symbols. Your coordinate reading format should match that shown in the example on the field form:
Latitude: 44.764322 Longitude: -72.654222

2c) Landowner Contact Information

Please answer the Yes/No questions.

If the Vernal Pool Mapping Project provided you with landowner information, the landowner contact information can be left blank.

3. Vernal Pool Field-Verification Information

3a) Pool Type

Is this a Vernal Pool? If the following conditions are met, check "Yes": 1) at least one of the indicator species is present, 2) the site does not contain fish, 3) the site is not a permanent water body, and 4) there is no <u>permanent</u> inlet or outlet. However, if these conditions are met, but the site is obviously not adequate habitat for the species present (e.g. eggs laid in skidder ruts or a ditch), check "No". If unsure, check "Don't Know".

***Isolated Forest Depression*:** Check this box for the typical Vernal Pool: no permanent hydrologic connection with other wetlands and the surrounding area is >50% forest.

***Floodplain Depression*:** Check this box if it appears that the pool is influenced by floodwaters from a stream or river at any time of the year.

Manmade Impoundment: Check this box if the pool originated from human activity.

Isolated Non-Forest Depression: Check this box if the site has no permanent hydrologic connection with other wetlands and the pool is located in open habitat away from forest edges.

Pool associated with larger wetland complex: Check this box if the pool is hydrologically connected to a wetland type other than another vernal pool. If it is connected to another vernal pool, check whichever box above is appropriate.

3b) Presence of Inlet and/or Outlet

No Inlet/Outlet. Check these boxes if there is no evidence of any channelized water entering or exiting the pool.

Ephemeral Inlet/Outlet. Check these boxes if there is evidence of channelized water entering or exiting the pool, but it doesn't appear to run continuously. Many vernal pools, for example, have an outlet that functions if the water level in the pool reaches a certain level.

Permanent Inlet/Outlet. Check this box if there is channelized water continuously running into or out of the site. These sites are typically not vernal pools.

3c) Surrounding Habitat

Forested Upland. Check the box that best describes the surrounding forest.

Forest Condition. Undisturbed: Check this box if there is no evidence of logging within 250' of the pool OR logging took place far enough in the past that the site has, for all practical purposes, recovered. ***Minor Logging:*** Check this box if there is evidence of thinning cuts which have left ≥ 70% of the canopy intact. ***Major Logging***: Check this box if there is evidence of aggressive thinning or clearcut logging leaving < 70% of the canopy intact. Be careful to distinguish between logging activity (flat-topped stumps) and natural disturbances (such as wind-throw and ice storms) that can leave canopy gaps.

Agriculture/ Development Within 250' of the pool, check all boxes that apply.

Roads/ Powerline. Within 100' of the pool, check all boxes that apply.

4. Pool Characteristics

4a) Approximate Maximum Pool Depth. This is an approximate depth at the deepest part of the pool (typically the center). Feel free to use a stick or other measuring device if you cannot wade into the deepest part. In most cases, an estimate from the pool edge will suffice.

4b) Water Level at Time of Survey. In order to estimate this and ***4d***, examine the edges of the pool for signs of high water (see comments under ***4d***).

4c) Hydroperiod. Permanent: Check this box for sites (like ponds) that appear to retain water throughout the year. ***Semi-permanent:*** Check this box for sites that appear to retain at least some water in most years. These sites may dry completely, but only in drought years. ***Ephemeral:*** Check this box for sites that appear to dry completely most years. Most "typical" vernal pools fall into this category.

4d) Approximate Size of Pool (at maximum capacity). Using a measuring tape to obtain the dimensions is preferable. Pacing or estimating the dimensions are also acceptable.

To obtain these measurements when the pool is not completely full, examine the immediate pool basin for evidence of high water. Signs include water-stained leaves, sediment deposits on the leaf litter, and water marks on tree trunks.

4e) Vegetation Present in Pool Estimate the percentage of the pool that is occupied by the different types of vegetation. More than one vegetation type can be filled in.

4f) Substrate Check the one appropriate box for the dominant substrate present in the pool.

4g) Disturbance. Check all forms of disturbance that have affected the pool.

5. Indicator Species

Species Observed. Use the Vernal Pool ID Sheet (or other sources) to help identify the species using the pool. Presence of other amphibian species (such as green frogs) is also noteworthy and should be included in the "Other" row.

Adults. Please enter the approximate number of adults observed for the amphibians present. For invertebrates such as Fingernail clams and Fairy Shrimp counting individuals is not necessary. An "X" in this column to indicate presence is sufficient.

Tadpoles/Larvae. Mark an "X" in this column to indicate the presence of tadpoles or larvae of each species present.

Egg Masses. Please enter the number of egg masses (not individual eggs) of each species present in the pool. Use the check boxes to indicate if the number entered was derived from an actual count or an estimate.

Photo? Please take a photograph of the whole pool AND a photograph documenting the presence of each indicator species at the pool (egg masses, tadpoles, metamorphs or adults). Put a check in the appropriate box if a photo was taken of a particular species.

Photo ID #/ Notes. Use this column to enter any comments on the species present or the Photo ID#s. Please name each photograph using the following protocol:
Pool ID_Your Initials_Picture #. For example: SDF34_JD_1.

This will allow us to link each photograph with the appropriate pool data form.

Were Fish Observed? Because vernal pool-dependent wildlife have no adaptations against predatory fish, it is important to know if fish were observed. Complete this section, being careful to avoid confusing fairy shrimp and other aquatic invertebrates with small fish.

Appendix 3. Number of mapped and field-visited pools by town and county. Listed by abundance of CIR-mapped pools.

Town	County	CIR Mapped Pools	Other Mapped Sources	New Pools Confirmed	CIR Mapped Confirmed	Other Mapped Confirmed	CIR Mapped Not Pools	Other Mapped Not Pools	CIR Mapped Not Found	Other Mapped Not Found
Benson	Rutland	93	5	1	6		3			
Strafford	Orange	87	7	12	22	4	11		2	
Pomfret	Windsor	74	1	4	12				1	
Hartland	Windsor	73		5	10		1		1	
Newbury	Orange	69								
Poultney	Rutland	66								
Sharon	Windsor	60	2	10	10		3		1	
Fairfield	Franklin	53			2					
Thetford	Orange	53	2	5	4		1			
Calais	Washington	52		1	2		1			
Woodbury	Washington	50	1	9	6		4		1	
Brandon	Rutland	48								
Barnard	Windsor	47			7		1		1	
Winhall	Bennington	46	8	1	10	2	9	3	2	
Roxbury	Washington	44		1	2		1			
Rupert	Bennington	44								
Northfield	Washington	43		10	27		4			
Fair Haven	Rutland	42		8	7		1			
Vershire	Orange	40	2							
Corinth	Orange	39	42							
Pawlet	Rutland	39								
West Fairlee	Orange	39					1		1	
Westminster	Windham	39	22	1						
Williamstown	Orange	36		4	3		1			
Hubbardton	Rutland	34	15	6	4	7	3	2	1	6
Berlin	Washington	33	10	2	2		1			
Marshfield	Washington	33	1	11	6	1	8		6	
Moretown	Washington	33		3			1			
Mount Holly	Rutland	33	1				1			
Woodstock	Windsor	33	42		2	7	1	10	3	
Milton	Chittenden	32								
Brookfield	Orange	31		3	9		4		3	
Randolph	Orange	31		4						
Topsham	Orange	30	2				3		2	
West Windsor	Windsor	30		4	5				1	
Bradford	Orange	29					1			
Highgate	Franklin	29								
Rockingham	Windham	29	1	3	3		1		1	
Royalton	Windsor	29		1						
Woodford	Bennington	29			2		5			
Hartford	Windsor	28	4	1		1			1	

Town	County	CIR Mapped Pools	Other Mapped Sources	New Pools Confirmed	CIR Mapped Confirmed	Other Mapped Confirmed	CIR Mapped Not Pools	Other Mapped Not Pools	CIR Mapped Not Found	Other Mapped Not Found
Mendon	Rutland	28			4		2		3	
Elmore	Lamoille	27	1	6	1		3			
Monkton	Addison	27			1					
Reading	Windsor	27			1		1			
Castleton	Rutland	26								
Concord	Essex	26								
Georgia	Franklin	26								
Pittsford	Rutland	25			2					
Shrewsbury	Rutland	25	1				1			
Stamford	Bennington	25								
Tunbridge	Orange	25	1	1	1					
Washington	Orange	25	20							
Wilmington	Windham	25					1			
East Montpelier	Washington	24		1						
Eden	Lamoille	24	1		2					
Orwell	Addison	24								
Somerset	Windham	24			3					
Springfield	Windsor	24	6							
Wells	Rutland	24								
Chelsea	Orange	23		1	5		2		3	
Jamaica	Windham	23	14							
Middlesex	Washington	23	9	11	2		1			2
Sandgate	Bennington	23			4		1			
Townshend	Windham	23	14							
Waterford	Caledonia	23								
Chittenden	Rutland	22			1					
Pownal	Bennington	22					1			
Stratton	Windham	22			1					
Weathersfield	Windsor	22	4		5			2		
Essex	Chittenden	21		1	2		1			
Londonderry	Windham	21		1						
Whitingham	Windham	21								
Bristol	Addison	19	1	4	4		1			
Chester	Windsor	19								
Danville	Caledonia	19		1	3		1			
Fletcher	Franklin	19								
Hyde Park	Lamoille	19	5	1	5	1	3	2		1
Tinmouth	Rutland	19								
Windham	Windham	19			3					
Guildhall	Essex	18	1							
Readsboro	Bennington	18								
Swanton	Franklin	18	1							
Walden	Caledonia	18	1	1	3					
West Haven	Rutland	18	22							

Town	County	CIR Mapped Pools	Other Mapped Sources	New Pools Confirmed	CIR Mapped Confirmed	Other Mapped Confirmed	CIR Mapped Not Pools	Other Mapped Not Pools	CIR Mapped Not Found	Other Mapped Not Found
Andover	Windsor	17		1			3			
Barre Town	Washington	17		2			1			
Brighton	Essex	17			3		4			
Colchester	Chittenden	17	6							
Grafton	Windham	17	5	5	2					
Jericho	Chittenden	17	23	2	3		4		4	
Mount Tabor	Rutland	17		1						
Sunderland	Bennington	17	1					1	1	
Bridgewater	Windsor	16	1		3					
Cabot	Washington	16								
Cambridge	Lamoille	16								
Ferdinand	Essex	16	6	2	1	1	1			1
St. Johnsbury	Caledonia	16	2							
Victory	Essex	16	1		1				1	
Westford	Chittenden	16								
Brattleboro	Windham	15	17					2		
Danby	Rutland	15								
Fairlee	Orange	15		1			2		2	
Glastenbury	Bennington	15							1	
Sudbury	Rutland	15								
Weston	Windsor	15			2		2			
Bennington	Bennington	14					2			
Dover	Windham	14					3			
Halifax	Windham	14								
Ira	Rutland	14	1							
North Hero	Grand Isle	14		1	9		5			
Warren	Washington	14					1			
Brunswick	Essex	13	2		3		2		1	
Cavendish	Windsor	13								
Franklin	Franklin	13								
Newark	Caledonia	13					1		1	
Underhill	Chittenden	13	2							
Clarendon	Rutland	12								
Enosburg	Franklin	12	1							
Granby	Essex	12								
Middletown Springs	Rutland	12								
Shaftsbury	Bennington	12								
Sutton	Caledonia	12	19	2	3		3			
Waitsfield	Washington	12	3				3	1		
Wardsboro	Windham	12	4							
Duxbury	Washington	11	1	1	2					
Greensboro	Orleans	11								
Guilford	Windham	11	1							

Town	County	CIR Mapped Pools	Other Mapped Sources	New Pools Confirmed	CIR Mapped Confirmed	Other Mapped Confirmed	CIR Mapped Not Pools	Other Mapped Not Pools	CIR Mapped Not Found	Other Mapped Not Found
Holland	Orleans	11								
Isle La Motte	Grand Isle	11		2	4					
Marlboro	Windham	11	11	1	3		1	1	1	
New Haven	Addison	11								
Newfane	Windham	11	4							
Norwich	Windsor	11	147	2	1	4		13	1	12
Orange	Orange	11			2				5	
Peru	Bennington	11			2					
St. Albans Town	Franklin	11								
Wolcott	Lamoille	11								
Athens	Windham	10	15							
Bakersfield	Franklin	10							1	
Bethel	Windsor	10								
Braintree	Orange	10								
Morgan	Orleans	10								
Ryegate	Caledonia	10		8						
Wallingford	Rutland	10			1		1			
Berkshire	Franklin	9			1		4		1	
Ludlow	Windsor	9	1							
Peacham	Caledonia	9	7	2	8	4	1	2		1
Plainfield	Washington	9	1	4	3	1	3		2	
Rochester	Windsor	9	1	2						
Windsor	Windsor	9								
Worcester	Washington	9	13							
Bolton	Chittenden	8	7	2	3	1	2			
Canaan	Essex	8								
Charlotte	Chittenden	8								
Fayston	Washington	8	3				1			
Maidstone	Essex	8	6							
Sheldon	Franklin	8								
Westmore	Orleans	8	2	1	4					
Wheelock	Caledonia	8		1						
Albany	Orleans	7								
Barnet	Caledonia	7		3						
Barton	Orleans	7								
Brookline	Windham	7	1				1			
Charleston	Orleans	7			4					
Hardwick	Caledonia	7			1					
Irasburg	Orleans	7								
Leicester	Addison	7								
Proctor	Rutland	7								
Richford	Franklin	7			2		8		1	
Rutland	Rutland	7								
Shoreham	Addison	7								

Town	County	CIR Mapped Pools	Other Mapped Sources	New Pools Confirmed	CIR Mapped Confirmed	Other Mapped Confirmed	CIR Mapped Not Pools	Other Mapped Not Pools	CIR Mapped Not Found	Other Mapped Not Found
Dorset	Bennington	6	1	1						
Fairfax	Franklin	6								
Glover	Orleans	6								
Grand Isle	Grand Isle	6		13	4		2			
Jay	Orleans	6					1			
Killington	Rutland	6					2			
Putney	Windham	6	36	8	2		1		1	
Searsburg	Bennington	6			1					
West Rutland	Rutland	6								
Belvidere	Lamoille	5								
Burke	Caledonia	5								
Lincoln	Addison	5	4		1		2		2	
Lowell	Orleans	5								
Morristown	Lamoille	5								
Plymouth	Windsor	5	2							
Stockbridge	Windsor	5								
Stowe	Lamoille	5								
Westfield	Orleans	5								
Arlington	Bennington	4			1		1			
Averill	Essex	4								
Bloomfield	Essex	4	4							
Craftsbury	Orleans	4			1					
Groton	Caledonia	4	2		1		1		1	
Johnson	Lamoille	4					1			
Landgrove	Bennington	4		1						
Lemington	Essex	4								
Lewis	Essex	4	12							
Manchester	Bennington	4					2			
Montgomery	Franklin	4								
Sheffield	Caledonia	4								
Starksboro	Addison	4								
Waterbury	Washington	4	8	5	2	5	1	2		
Bridport	Addison	3	2							
Goshen	Addison	3			1		1			
Granville	Addison	3								
Kirby	Caledonia	3								
Lyndon	Caledonia	3								
Norton	Essex	3	3							
Rutland City	Rutland	3								
St. George	Chittenden	3								
Brownington	Orleans	2								
Dummerston	Windham	2	140	1						
Hancock	Addison	2								
Huntington	Chittenden	2			1					

Town	County	CIR Mapped Pools	Other Mapped Sources	New Pools Confirmed	CIR Mapped Confirmed	Other Mapped Confirmed	CIR Mapped Not Pools	Other Mapped Not Pools	CIR Mapped Not Found	Other Mapped Not Found
Lunenburg	Essex	2								
Newport Town	Orleans	2								
Richmond	Chittenden	2	3	1		1		2		
Salisbury	Addison	2								
Shelburne	Chittenden	2		1						
South Burlington	Chittenden	2			1				1	
Warners Grant	Essex	2								
Waterville	Lamoille	2		1						
Alburgh	Grand Isle	1								
Baltimore	Windsor	1								
Coventry	Orleans	1								
Derby	Orleans	1								
East Haven	Essex	1								
Ferrisburg	Addison	1								
Middlebury	Addison	1								
Ripton	Addison	1								
South Hero	Grand Isle	1			1					
Vernon	Windham	1	23							
Waltham	Addison	1								
Addison	Addison									
Averys Gore	Essex									
Barre City	Washington									
Buels Gore	Chittenden									
Burlington	Chittenden		1							
Cornwall	Addison									
Hinesburg	Chittenden			3						
Montpelier	Washington			1						
Newport City	Orleans									
Panton	Addison									
Pittsfield	Rutland									
St. Albans City	Franklin									
Stannard	Caledonia									
Troy	Orleans									
Vergennes	Addison									
Warren Gore	Essex									
Weybridge	Addison									
Whiting	Addison									
Williston	Chittenden		4							
Winooski	Chittenden									
Total		4,016	830	221	304	40	164	43	62	23
Number of Towns		235	81	67	80	14	73	13	36	6
Percent of All Towns		92.2	31.8	26.3	31.4	5.5	28.6	5.1	14.1	2.4