Wayland Recreation Commission
Minutes
May 9, 2011
Recreation Meeting

Present: Virzi, Wright, Foster, Gayshan, Meliones

Meeting called to order 7:10 pm
4/13/11/ Minutes approved

Public Comment: Nancy Fulginite presented use of Wayland MS woods by teachers and students. Requested these uses be considered with respect to building soccer fields on this site;
Question: How much money is contributed to Recreation programs by out of town users? Virzi 30% of 800K

Middle School Fields:
Open meeting 5/25/11 Town Bldg. Meeting will be to present all issues as they pertain to developing fields at WMS. Not a discussion but issue oriented.
No linkage between leeching fields and development of soccer fields

Gale Report now available at Wayland Public library and link improved so that report is easier to access on line

Loker Recreation Update:
Have Gale Assoc review all parcels in Wayland that are available for recreation development. Review Recreation Commission's comments on 20 yr development plan

Hannah Williams update: Chris Brown DPW liason to Recreation Commission:
Trees tagged for removal;Tree work to be done in may. Date TBD.
Play Structure TBD later in May
Planning Board to be approached for approval in May New Play structure to have same footprint as current structure May have community Gardens Recreation Commission would like to have input re what equipment is selected

Beach House:
Scheduled to open in 3 weeks. Opening very much up in the air with respect to having to use a Trailer again this year or if structure will be condemned. DPW will meet 5/10/11 to discuss.

New business:
Wayland High School Light issue:
Lights have been out; circuits have had to be replaced. Lights completely misaimed in 1 corner. Since it is School property Scholl is responsible for fixing the problem

New Accounting procedures: Will discuss at June meeting. Go into effect 7/1/11

Lightning Policy for Field use. We need to establish safety policy for all user groups

Wayland Recreation Commission
Minutes
May 9, 2011
Recreation Meeting

Motion to accept minutes of selectman meeting 12/7/10 and add to Recreation meeting of same date. Motion passed unanimously.

Town Beach:
Nothing has been done to fix problems that existed last summer. Will close off changing rooms; Operate from Trailer this summer; Plan for upgrading bldg has been approved but cannot spend the money until Drainage problrm is successfully addressed. Meliones to attend DPW meeting 5/10/11 to address beach issues.

Meeting adjourned 8:01pm by unanimous vote

Residents of Joyce and Keith Roads
Wayland, MA 01778

May 3, 2011

Wayland Park and Recreation Department
41 Cochituate Road
Wayland, MA 01778

Nancy McShea - Director

Dear Members of the Wayland Park and Recreation Department,

Attached please find a letter that a group of Wayland residents is sending to the Conservation Commission, the School Committee, the Department of Public Works, the Board of Selectman, and the Finance Committee. As one of the key proponents of the Middle School Field project we would also like to keep you informed of our communication with the Wayland Conservation Commission.

At town meeting there were significant discussions of the Gale Associates report and how long it had taken to complete the study. The Gale Associates report does not address in any meaningful way the environmental impact of the proposed project. In fact with reference to the permitting process they cite the ease with which the permitting process could occur because "there are no environmental restrictions in proximity to the undeveloped area"

We have confirmed the existence of 2 vernal pools in a wetland area adjacent to the proposed fields. All necessary materials have been sent to the National Heritage and Endangered Species Program for their certification. We understand that the conversation will no doubt occur stating that the pools are far from where the fields are proposed, but we have found numerous spotted salamanders in the wooded upland area where the fields are proposed, and without this critical habitat they are not likely to survive. This is because the upland woods are the home to the creatures, while the vernal pool provides a breeding habitat.

Based on these finding we have asked that the Wayland Conservation Commission apply all applicable protection afforded under Massachusetts Law as well as Wayland Bylaws to ensure that the environmental impact of this project is properly addressed.

The residents of Joyce and Keith Roads
Wayland, MA 01778

April 23, 2011

Wayland Conservation Commission
41 Cochituate Road
Wayland, MA 01778

Roger Backman
Markey Burke
Ted Harding
Barbara Howell
Andy Irwin
Larry Kieman
John Sullivan
Brian J. Monahan

Dear Commissioners,

The residents who are signatories to this letter hereby formally request that the Wayland Conservation Commission require that an experienced wetland scientist/biologist complete a site inspection that will include identification and delineation of any Wetland Resource Areas [as protected under and defined by the implementing Regulations of the Massachusetts Wetlands Protection Act (M.G.L. c. 131 sec. 40 and 310 CMR 10.00) and/or any local wetland protection by-law] as well as any isolated, potentially non-jurisdictional wetland areas (which may be vernal pools) that are known to be or may be present in the forested areas on both the south side and the north side of the pathway where the proposed middle school fields have been staked out.

As part of the wetland delineation, we request that the Wayland Conservation Commission require that the wetland delineator provide a written findings report that includes completed wetland delineation field data sheets (Department of Environmental Protection Appendix G forms) for both wetland areas and upland areas. We request that these field data forms for upland areas be completed in any areas (regardless of size) on the north side of the path where the land topography appears low and where there is evidence that soils may be saturated to the ground surface. In addition to an assessment of plant community composition in these areas, we request that these field data forms include detailed documentation of observed soil profile features (including soil matrix color, soil texture, and any redoximorphic features) to a depth of at least 18 inches below the soil surface. We request that these field data forms be available for review by abutters to the project site and their representatives. We strongly recommend that the Conservation Commission require that the project proponent file an Abbreviated Notice of Resource Area Delineation (ANRAD) for the entire proposed project site in advance of a Notice of Intent in order that all jurisdictional wetland resource areas are properly identified and the limits of wetland resource buffer zones established.

We would further request that Massachusetts Surface Water Quality Discharge Standards (314 CMR 3.00 and 4.00) are applied since run-off will likely be routed through a vernal pool, as well as the Forest Cutting Practices Act (MGL Chapter 132, Sections 40-46) because of the degree to which the woodlands will be affected by the proposed fields.

At town meeting, we heard that the new plan, to conduct a $45,000 site design and analysis for the middle school fields was not being done to call into question whether this was a desirable site for such fields, but rather it was the design and preparatory work to constructing the fields in the summer of 2012, while determining whether the estimated $500,000 construction could be funded with the CPA account. A group of concerned citizens and abutters to this property would like to call this presumption into question on environmental grounds. Unlike many other options in town, this land is wooded, is enjoyed as conservation land with good public access and is used by the middle school for educational purposes as conservation land. Furthermore it is in a part of town with little such land. Based on our documented evidence, it has vernal pools and may have protected species. The proposed fields will require removal of all trees from 8 – 10 acres of land, likely more than 50% of the upland habbitat. Further because the site is on a hill, there will be a great deal of grading to create a flat site. Even if some areas can be left wooded as buffers, most likely the trees will need to be removed for grading with new planting to replace it. Unquestionably, such construction will be greatly damaging to any remaining acreage on the site with vernal pools and wetland, and to the wildlife on that land.

Because of these concerns, neighborhood citizens have recently engaged in field observation of the proposed sites to determine whether or not there is conclusive evidence of the presence of species protected under the wetlands protection regulations. Field observations have occurred within a swampy area adjacent to the proposed fields and in the upland habitat on which the proposed fields would be built. Significant photographic evidence has been gathered in support of these efforts. We have compiled evidence that indicates the presence of both obligate and facultative species dependent upon vernal pools for their survival. These species are living in upland habitat in the very woods that will need to be removed to create the fields,

Evidence of Vernal Pools

You will find attached evidence of these observations which include photographs of a yellow spotted salamander, found in the upland habitat area where the fields are proposed. We are also attaching evidence of a possible blue spotted salamander which is a species of special concern. A number of experts have reviewed the photographs, with at least 2 groups indicating the species appears to be a blue spotted salamander and with other indicating it is a lead backed salamander. We have taken GPS readings that correspond to where photographs have been taken. The ease with which we have found these woodland creatures leads us to believe there could be a substantial population inhabiting the wooded uplands. By virtue of their presence we concluded that there must also be a vernal pool within the boundaries of the area which must be protected under wetlands regulations.

An FAQ posted on the recreation department states:

"As far as run off, it is a concern. The Recreation Commission has been advised by a member of the Surface Water Quality Committee that the fields could be designed to shed most of the water towards Snake Brook, away from Dudley Pond."

Unfortunately this would route potentially harmful runoff directly through what we have confirmed through the observation of as many as 30 spotted salamander egg masses to be a vernal pool. There is a second pool adjacent to School Street where we have also observed sufficient egg masses (6-10) to certify it as a vernal pool. We have initiated the vernal pool certification process with the National Heritage and Endangered Species Program (NHESP)

Evidence of Upland Forest Habitat used by Spotted Salamander

During the course of our observations we have found and photographed spotted salamanders living in the forest on the North side of the path well beyond what would normally constitute the buffer zone for a vernal pool. We have found Salamanders in the Northern most portions of the woods, and these Salamanders migrate annually to the vernal pools in early spring to breed.

There is ample evidence that the destruction of these upland forests can have a disastrous effect on breeding populations of Amphibians. In fact there could be no more relevant study than the one which is attached as enclosure #6 to this letter. The study documents the rapid decline of amphibian populations in the area of Shoppers World as a result of the construction of the movie theater complex there in 1994. One diagram clearly shows that the deforestation of the upland habitat was so significant it resulted in a rapid decline in a wood frog population, resulting in the complete elimination of these animals from the vernal pool. There is clear evidence that current wetlands regulations do not adequately address the upland habitat areas which are absolutely vital to the survival of amphibian populations.

Daniel Wells of Hyla Ecological Services, who assisted in our identification of the vernal pools near the Middle School was a key contributor to the Shoppers World study. He characterized the woods on the north side of the path as "ideal" upland habitat for breeding salamander populations and based on information we provided indicated that the wooded area represented an "isolated and fragile" habitat. He also commented that he was surprised to see such diversity in a relatively small piece of land.

Upland Forest provides for many other Fauna and Flora

While we believe the existence of a population of breeding amphibians renders this land a valuable resource which should be defined as conservation land, we would also like to point out that the wooded area provides habitat for a wide range of other plants and animals. In spite of being limited by its size and encroached upon on all sides by residential development, the woodlands provide important habitat for a diverse and interesting variety of plants and animals many of which you will find evidence of in enclosure 4.

Our Conclusion

To date none of the conversations we have heard reflect any sensitivity to the environmental impact of the proposed field project. This is a critical element in the decision on whether or not to move forward with this project. The value of this land and the vernal pools it contains are a resource that cannot be replaced. The proximity to the Middle School creates a valuable teaching resource for a variety of scientific studies.

We support athletics and understand the desire to have the very best facilities for our children. We also feel strongly that striking a balance between our own needs and the needs of nature are defining aspects of this town. We hope as elected officials charged with the preservation of Wayland's natural resources that you agree, and we look forward to working with you as we move through this process.

Respectfully,
Residents of Joyce and Keith Road

Enclosures

1. Signatories of this letter
2. Photographs Documenting Vernal Pool and Obligate Species
3. Photographs documenting other Fauna and Flora
4. E-mail Correspondence
5. Map with plotted siting's
6. Document "Breeding Amphibian Population Declines Following Loss of Upland Forest Habitat Around Vernal Pools In Massachusetts, USA

CC: Wayland School Committee
Wayland Department of Public Works
Wayland Park and Recreation
Wayland Board of Selectman
Wayland Finance Committee

Enclosure 1: Residents in support of this letter

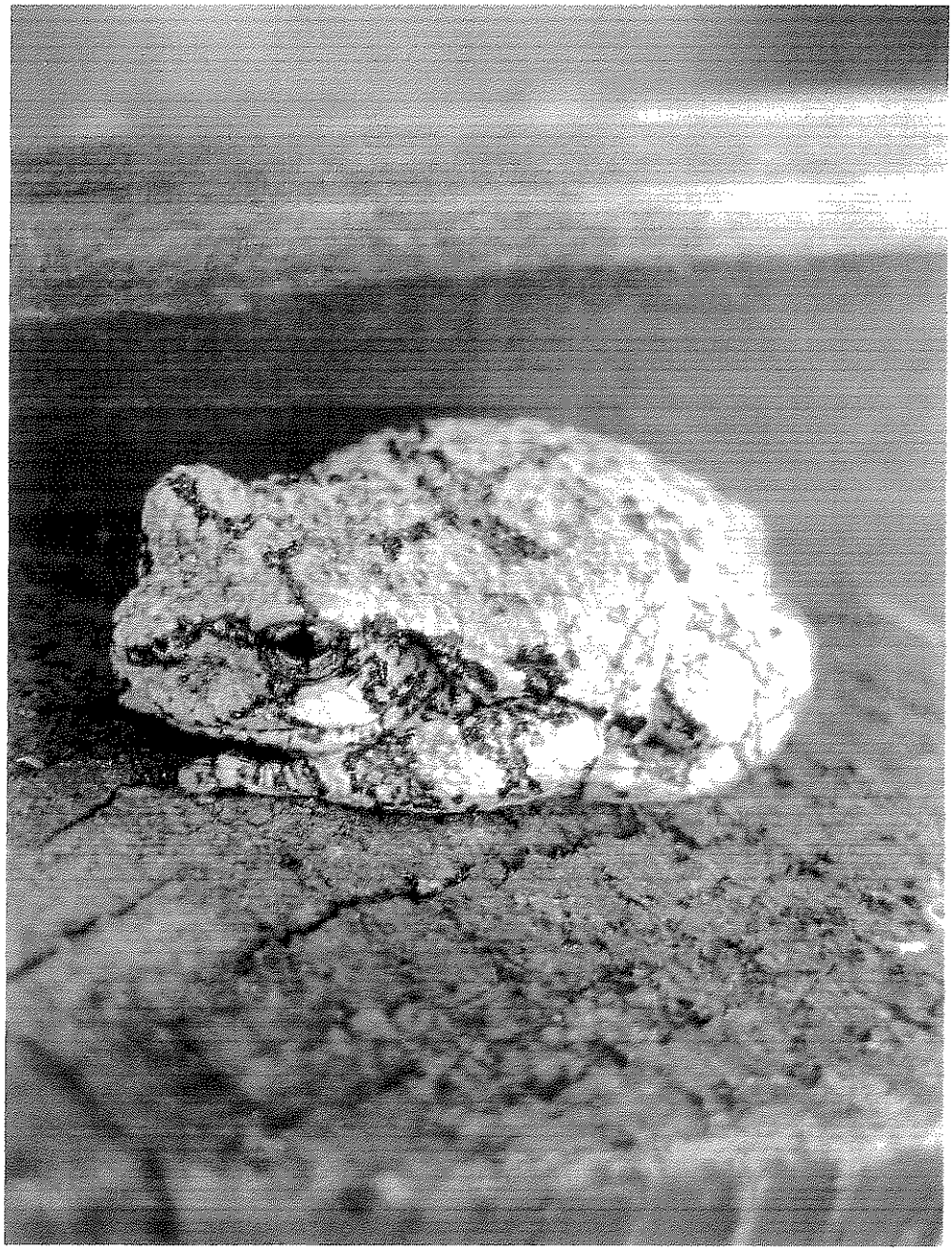
Anthony and Gina Christakis	32 Joyce Road
Chris and Insung Park	34 Joyce Road
Bill Hearne	16 Keith Road
Ed and Robyn Miller	12 Keith Road
Harvey Michaels	41 Joyce Road
Bernie and Linda Grubstein	19 Joyce Road
George and Ana Maria Vinha	14 Joyce Road
Edward and Janet Warner	17 Joyce Road
Roland and Sheila Carel	18 Joyce Road
David and Carol Kaplan	24 Joyce Road
Ellie Ball	15 Keith Road
Bill and Nancy Fulginite	8 Joyce Road
Jean Kashian	12 Joyce Road
Peter and Kim Kashian	44 Country Corners
Frank and Marilyn Scimone	20 Joyce Road
Bethann Monahan	16 Leary Street
Alan and Myra Orth	9 Keith Road
Kurt and Sue Linden	17 Keith Road

Enclosure 2: Photographs Documenting Vernal Pool and Obligate Species
Species requiring a vernal pool for breeding habitat

Enclosure 2 Exhibit 1: Yellow-spotted Salamander (*Ambystoma maculatum*) – This obligate species requires a vernal pool for breeding, presence indicates vernal pool exists. Multiple findings of this species sited with map coordinates. These photographs were taken on April 16th and 17th 2011 in the woodlands behind 18 – 28 Joyce Road.

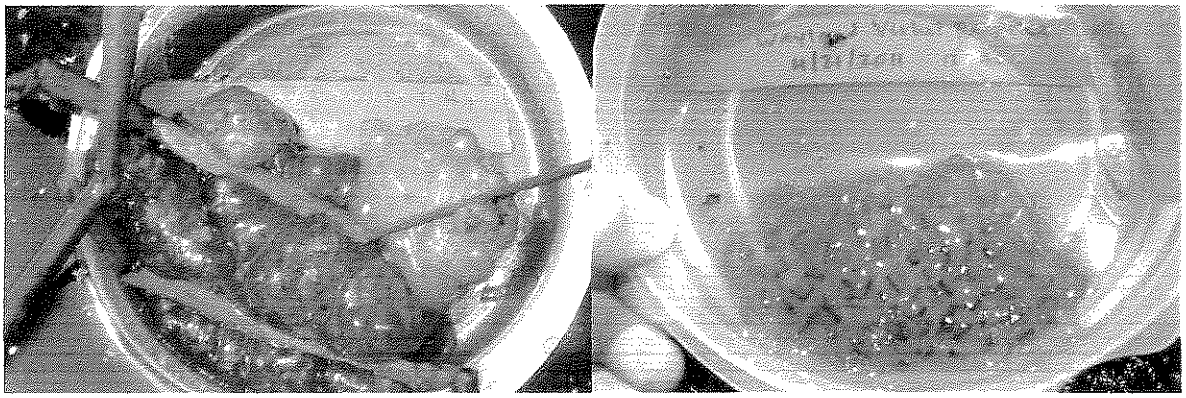
Enclosure 2 Exhibit 2 Possible Blue-Spotted Salamanders (Ambystoma Laterale) – This obligate species requires a vernal pool for breeding, presence indicates vernal pool exists. Multiple findings similar to this sited with map coordinates in Enclosure 5. These photographs were taken in on April 16th, April 19th and April 23rd 2011 in the woodlands behind 12 Joyce Road within the area staked out for the fields. Positive identification will require additional research. Blue Spotted Salamanders are on the Massachusetts Endangered Species list as a Species of Special Concern.

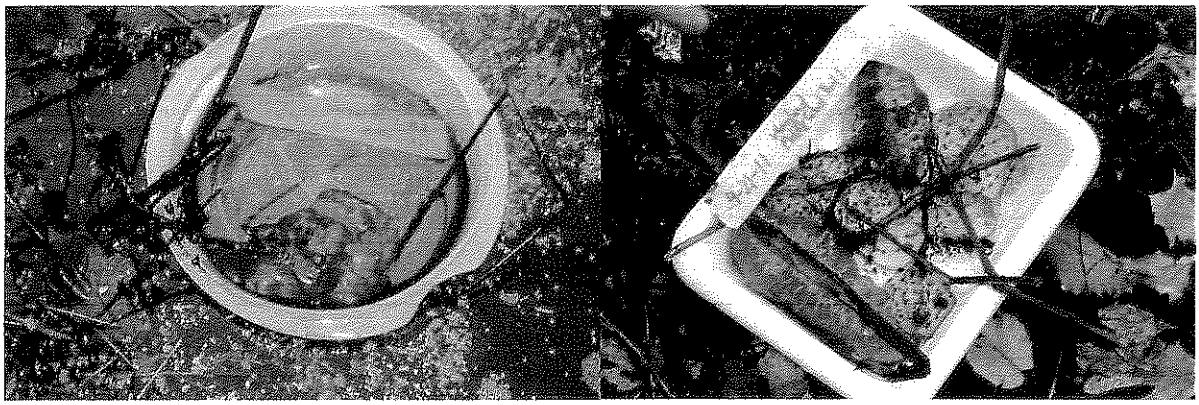
Findings include amphibians on the north side of the path in the staked out area for the field closest to Joyce Road.



Enclosure 2 Exhibit 3: Gray Tree Frog (Hyla versicolor) This facultative species often uses a vernal pool for breeding, presence can indicate vernal pool exists. Multiple audio recordings of this frog's call taken with map coordinates. This photograph was taken adjacent to the woodlands behind 18 Joyce Road.

Enclosure 2 Exhibit 4: Green Frog (Rana Clamitans) This species often uses a vernal pool for breeding, presence can indicate vernal pool exists. Multiple audio recordings of this frog's call taken with map coordinates. This photograph was taken in the pool behind the Wayland Middle School on April 19th 2011.





Enclosure 2 Exhibit 5: Spotted Salamander Egg Masses. These specimens were collected in 2 separate vernal pools on April 21st and April 22nd. In what we are referring to as Wayland Middle School vernal pool # 1 between 15 and 20 Egg masses were observed with several hundred salamander larvae. In what we are referring to as Wayland Middle School vernal pool # 2 between 5 and 10 Egg masses were observed with several hundred salamander larvae.

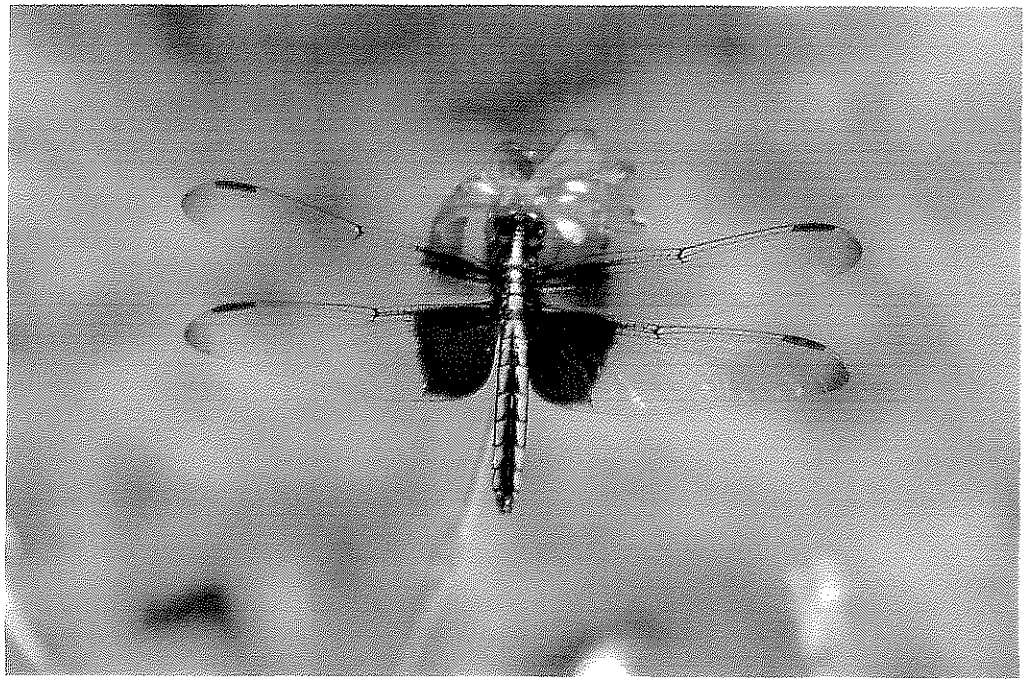
Enclosure 3: Wildlife photographs

Enclosure 3 Exhibit 1: Eastern Wild Turkey (Meleagris Gallopavo Silvestris). The wild turkey was designated the official state game bird of Massachusetts in 1991. This photo was taken in the woods behind 18 Joyce Road.

Enclosure 3 Exhibit 2: New England cottontail (Sylvilagus Transitionalis). This photo was taken in the woods behind 16 Joyce Road.

Enclosure 3 Exhibit 3 White-Tailed Deer (*Odocoileus Virginianus*) This photo was taken in the woods behind 18 Joyce Road.

Enclosure 3 Exhibit 4 Silk Moth (Antheraea Polyphemus) This photo was taken in the woods behind 18 Joyce Road.



Enclosure 3 Exhibit 5 Widow Skimmer Dragonfly Female (Libellula lactosa) This photo was taken in the woods behind 18 Joyce Road.

Enclosure 3 Exhibit 6 Gray Comma Butterfly (Polygonia Progne) This photo was taken in the woods behind 18 Joyce Road.

Enclosure 3 Exhibit 7 Common Garter Snake (Thamnophis Sirtalis) The garter snake was designated as the official reptile of the Commonwealth of Massachusetts in 2007. This snake was photographed in the woods behind 12 Joyce Road.

Enclosure 3 Exhibit 8 Pink Lady Slipper (Cypripedium Acaule) thrives in dry, acidic soils under a thin canopy of deciduous or evergreen trees. This was taken in the woods behind Joyce Road.

Enclosure 3 Exhibit 9 Sphagnum Moss This was taken in the vernal pool adjacent to the middle school. This moss provides vital habitat to the 4 toed salamanders.

Other species observed in the woods behind Joyce and Keith Roads include, Red Tailed Hawk, Great Blue Heron, Fisher Cat, Red Fox, Red Cardinal, Downy Woodpecker, Nuthatch, Tufted Titmouse, Ribbon Snake, Red Back Salamanders, Lead Back Salamanders, Unidentified Owl Species, Unidentified Turtle Species and numerous other common animals.

Enclosure 4: E-Mail correspondence

-----Original Message-----
From: Regosin, Jonathan (FWE) [mailto:Jonathan.Regosin@state.ma.us]
Sent: Tuesday, April 19, 2011 7:11 AM
To: Sheila Carel; 'Kubel, Jacob (FWE)'
Subject: RE: Possible hybrid? Another salamander

Sheila:

This is a spotted salamander (Ambystoma maculatum). It is closely related to the blue-spotted salamander, although it is common and not listed. This species typically breeds in vernal pools.

Jon

-----Original Message-----
From: Ball, D Michael [mailto:Derek.Ball@aecom.com]
Sent: Friday, April 15, 2011 10:25 AM
To: Sheila Carel
Subject: RE:

The consensus from staff here is blue spotted salamander (Ambystoma laterale).

If you get images of any additional salamanders, try to get images without handling them. Or handle them with wet hands. In small net would be ok. Best I believe would be image of individual on soil in location they were found. Get image of fallen log under which the individual was observed. Do you have a hand-held GPS unit to get location coordinates? Date-stamped images also good.

You may want to contact someone at Natural Heritage and ask them if they think that you should apply to obtain a collection permit, so you are authorized to handle. May not be necessary, but Natural Heritage would appreciate the contact and this will essentially start your vernal pool certification process and mapping of these wetlands as known rare species habitat.

Nice find.

Thanks,

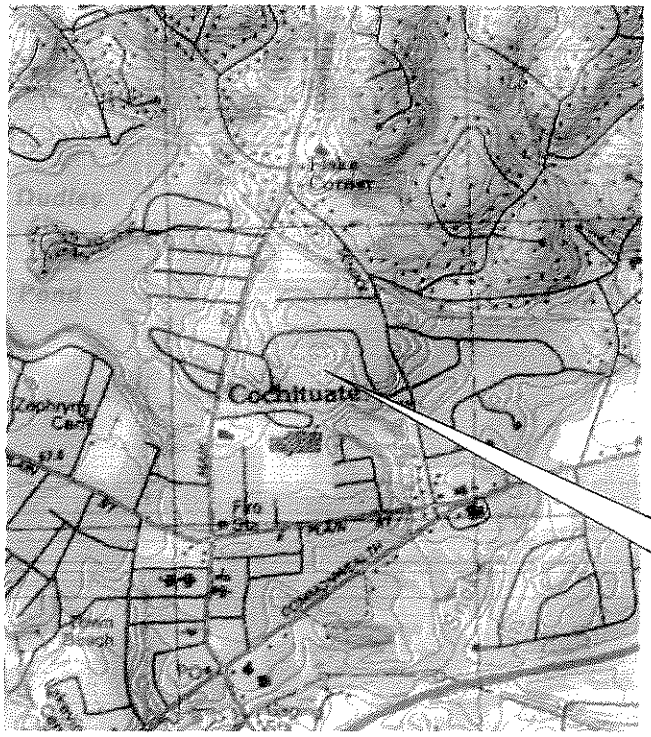
Mike

D. Michael Ball, CWS

Sr. Wetland Scientist / Plant Biologist - Environment - Sagamore Beach, Massachusetts

Enclosure 5: Topographic Maps corresponding to photographic materials

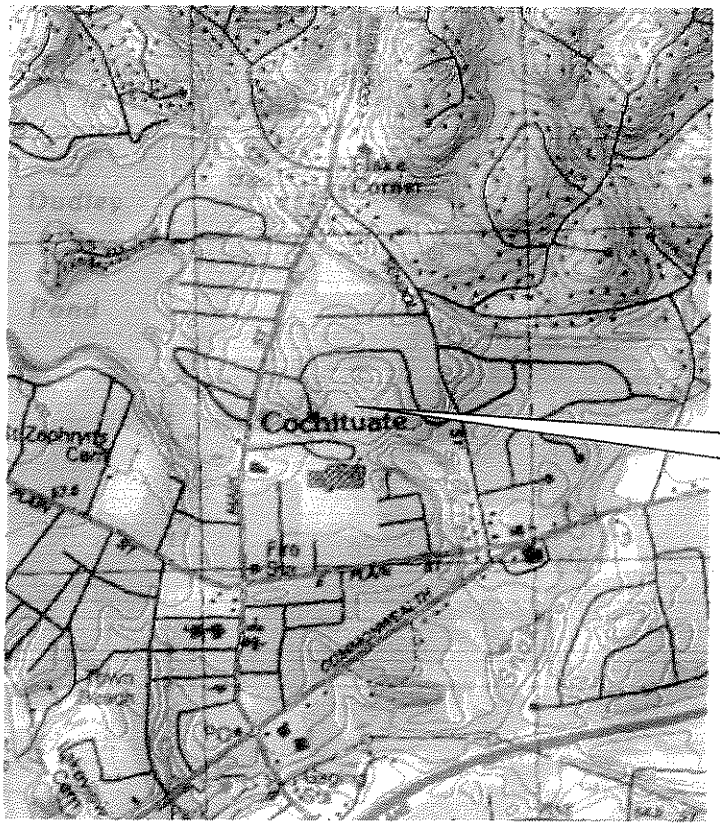
Trails.com



Yellow Spotted Salamander # 1
Photographed on 4/17/2011

Center: 42° 16.59' N 71° 21.59' W
Elevation at center: 240 feet (73 meters)
Quad: USGS Framingham
Org Name: k42071c3
Org Source Scale: 1:25,000

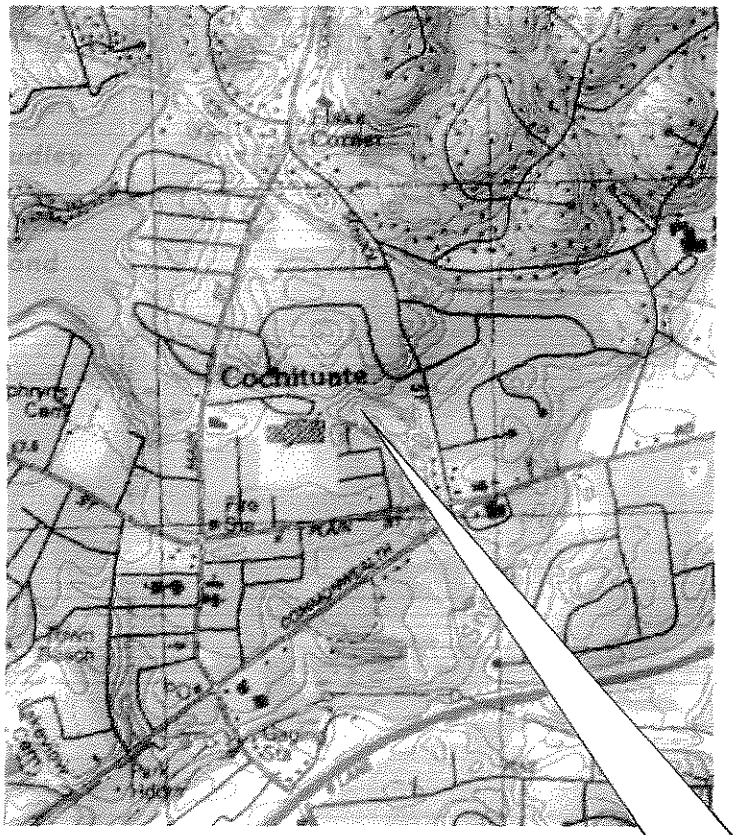
Trails.com



Yellow Spotted Salamander # 2
Photographed on 4/16/2011

Center: 42.328°N 71.3602°W
Elevation at center: 220 feet (67 meters)
Quad: USGS Framingham
Drg Name: k4207ic3
Drg Source Scale: 1:25,000

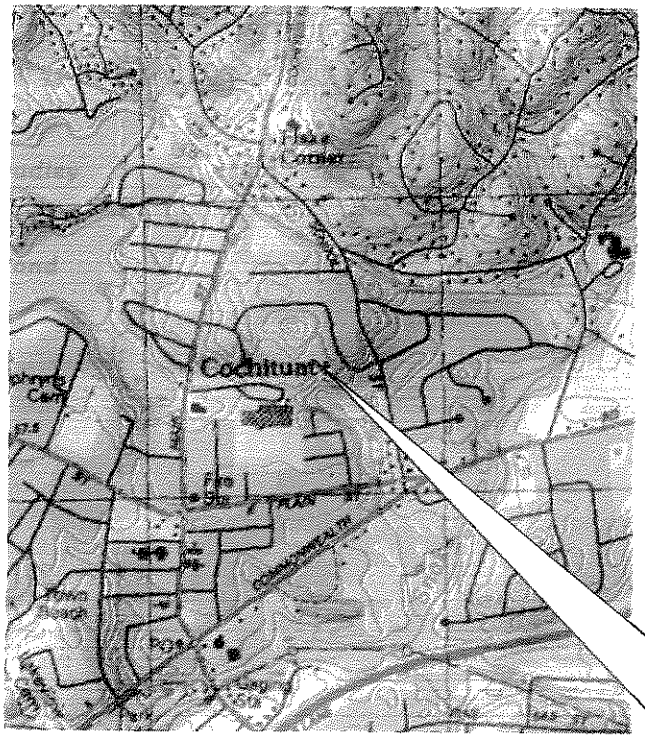
Trails.com



Center: 42° 19' 48" N 71° 21' 52" W
Elevation at center: 190 feet (58 meters)
Quad: USGS Framingham
Drg Name: k4207fc3
Drg Source Scale: 1:25,000

Possible Blue Spotted Salamander
Photographed on 4/18/2011
Differing verification from multiple sources

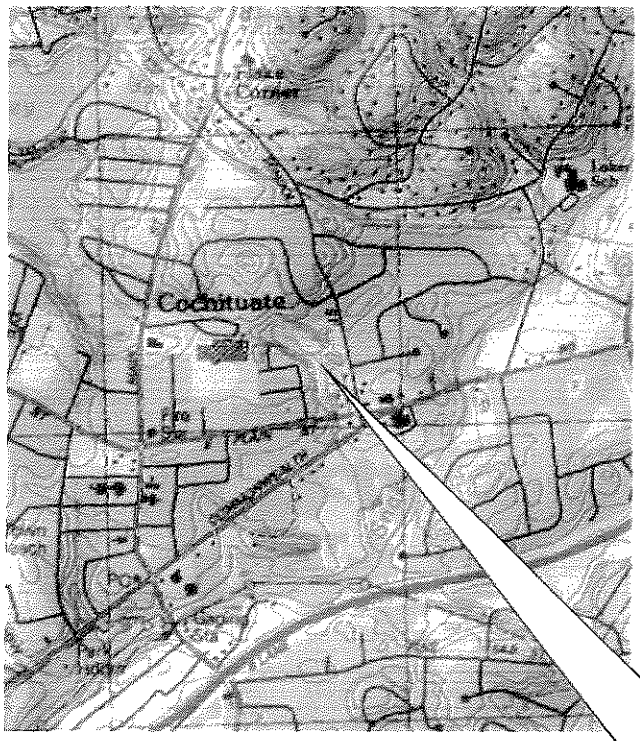
Trails.com



Center: 42.3257°N 71.3588°W
Elevation at center: 217 feet (66 meters)
Quad: USGS Framingham
Org Name: e4257c3
Org Source Scale: 1:25,000

Possible Blue Spotted Salamander
Photographed on 4/16/2011
North of Path in staked area
Differing verification from multiple sources

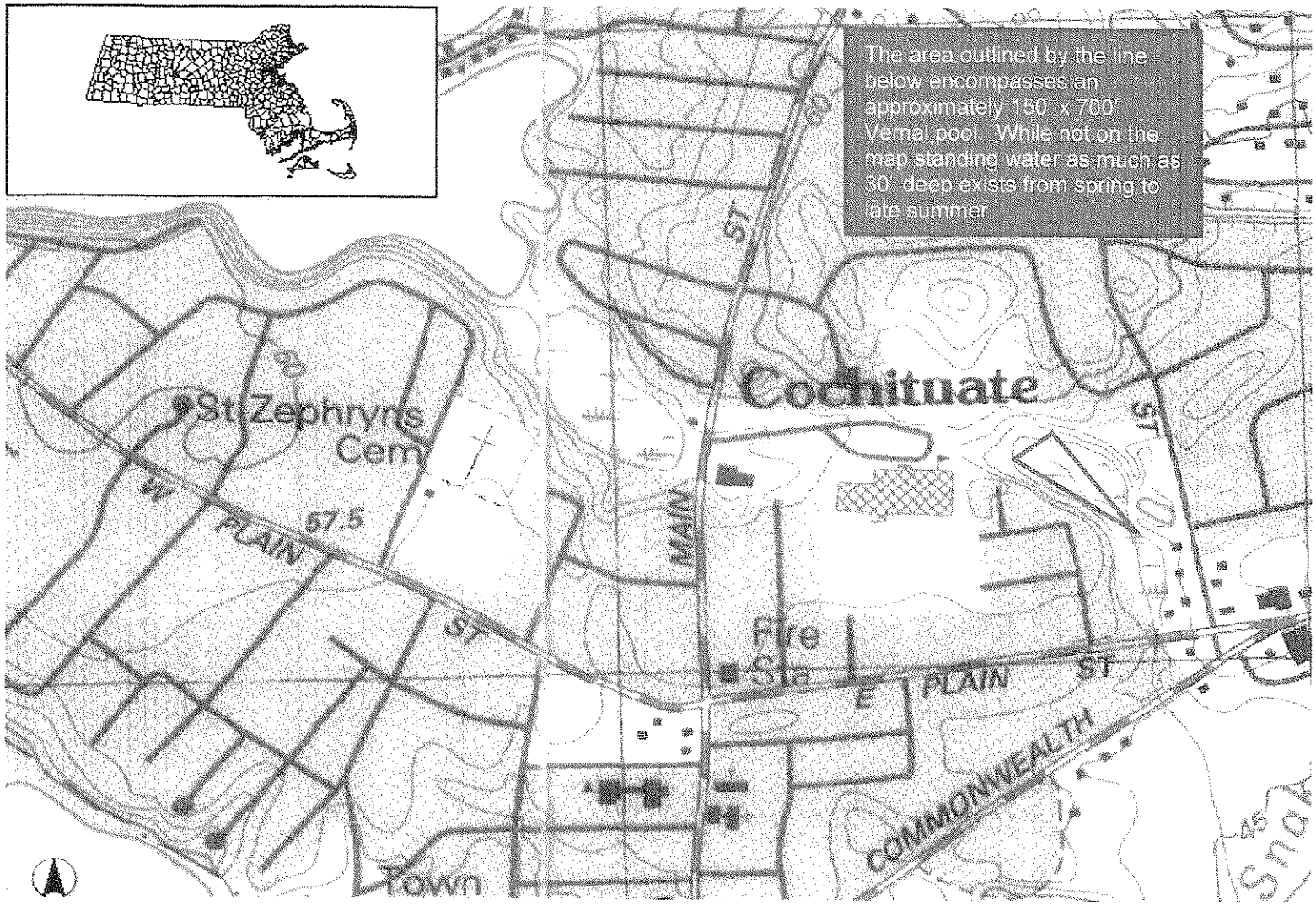
Trails.com



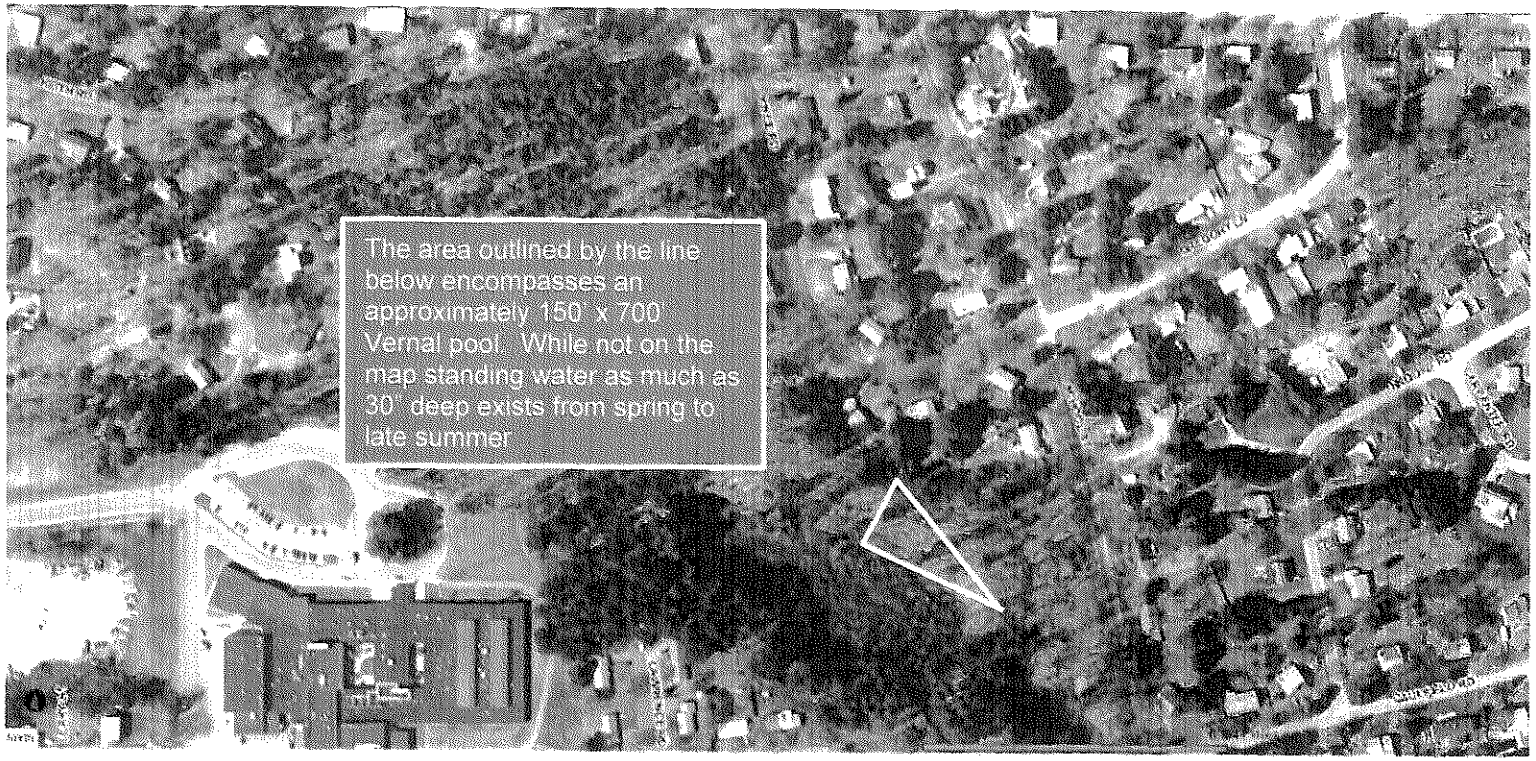
Center: 42.3237°N 71.3571°W
Elevation at center: 190 feet (58 meters)
Quad: USGS Framingham
Org Name: x42071c3
Org Source Scale: 1:25,000

Green Frog
Photographed on 4/19/2011
In the water of the vernal pool

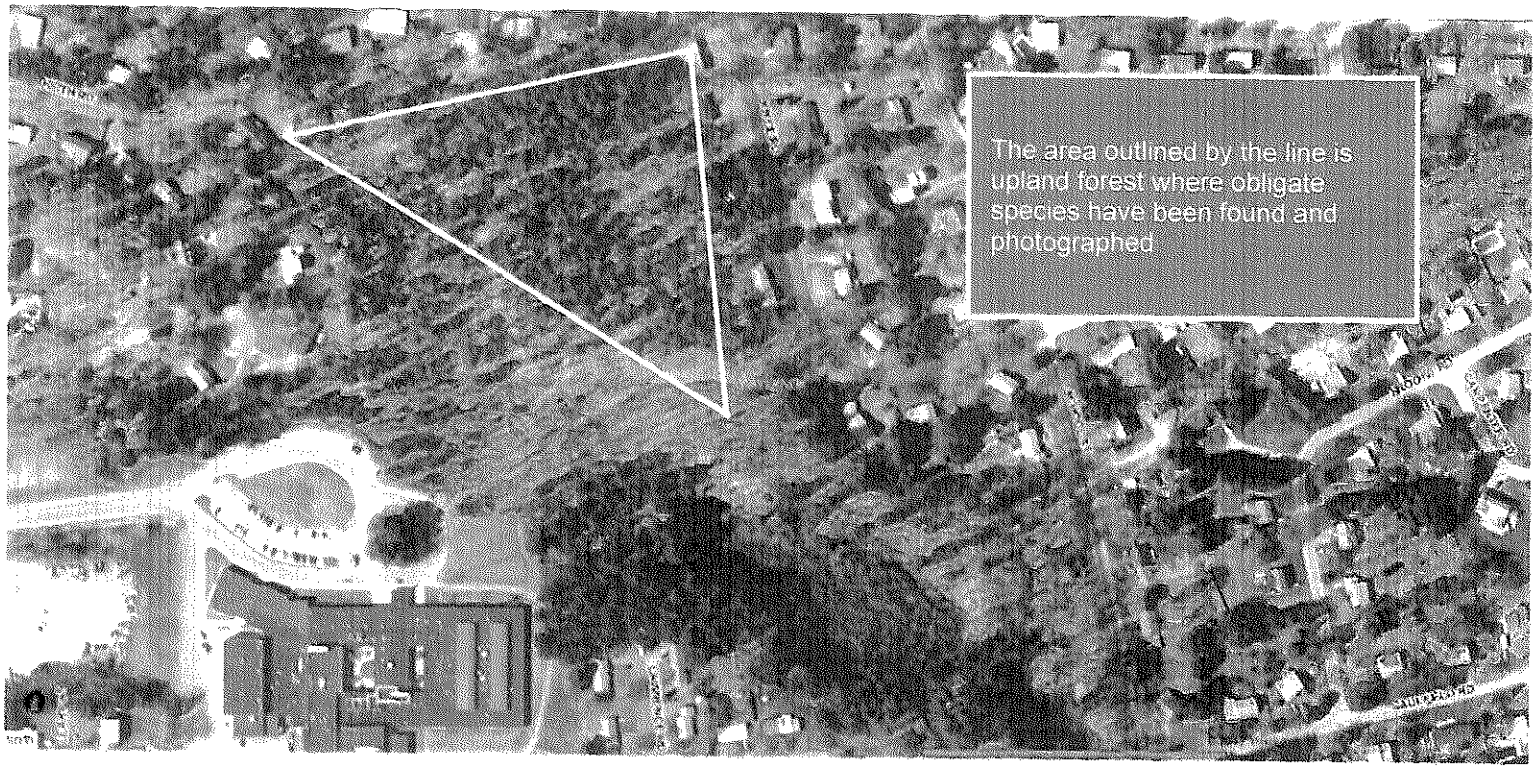
Wayland Middle School Vernal Pool #1



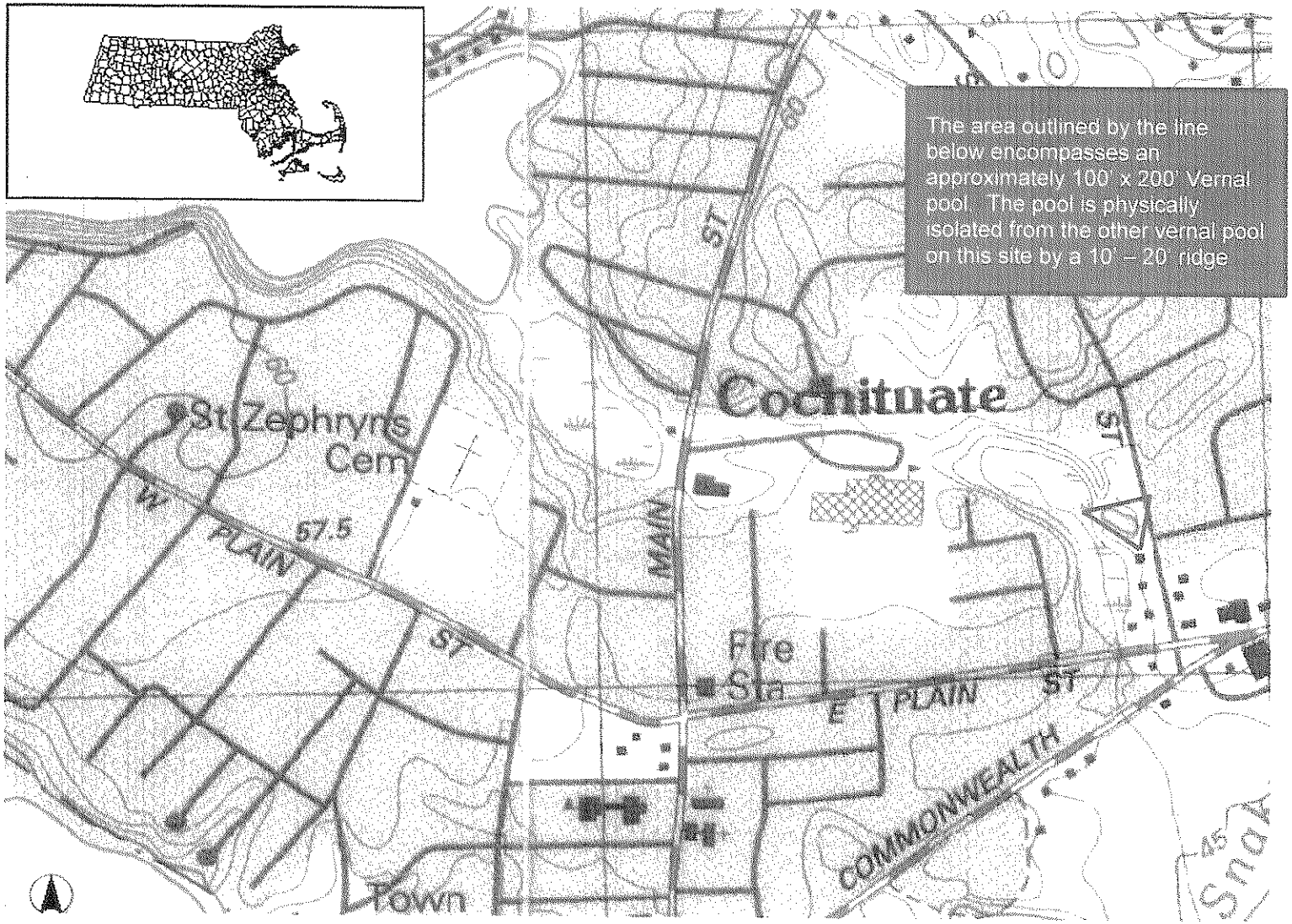
Wayland Middle School Vernal Pool #1



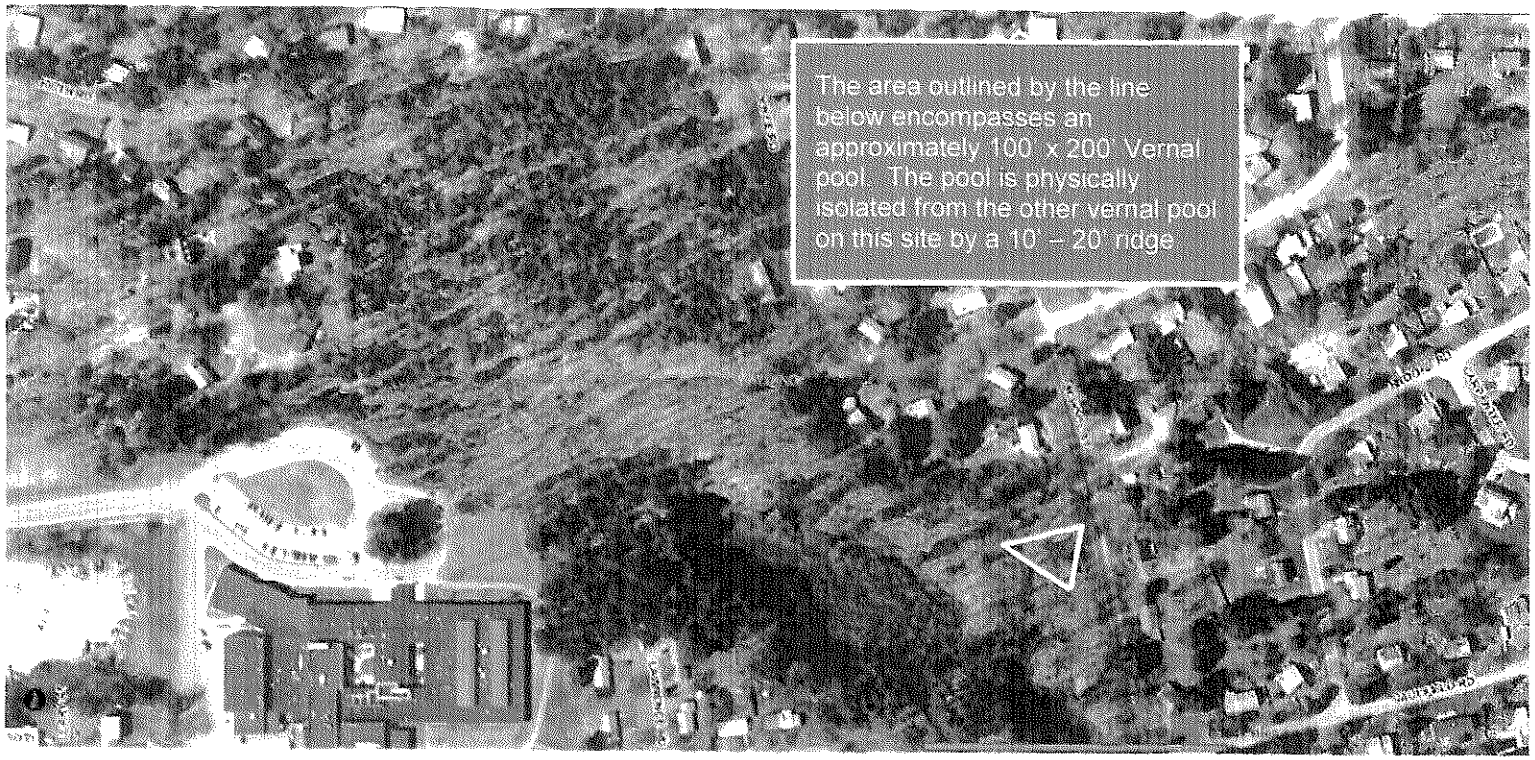
Wayland Middle School Vernal Pool #1



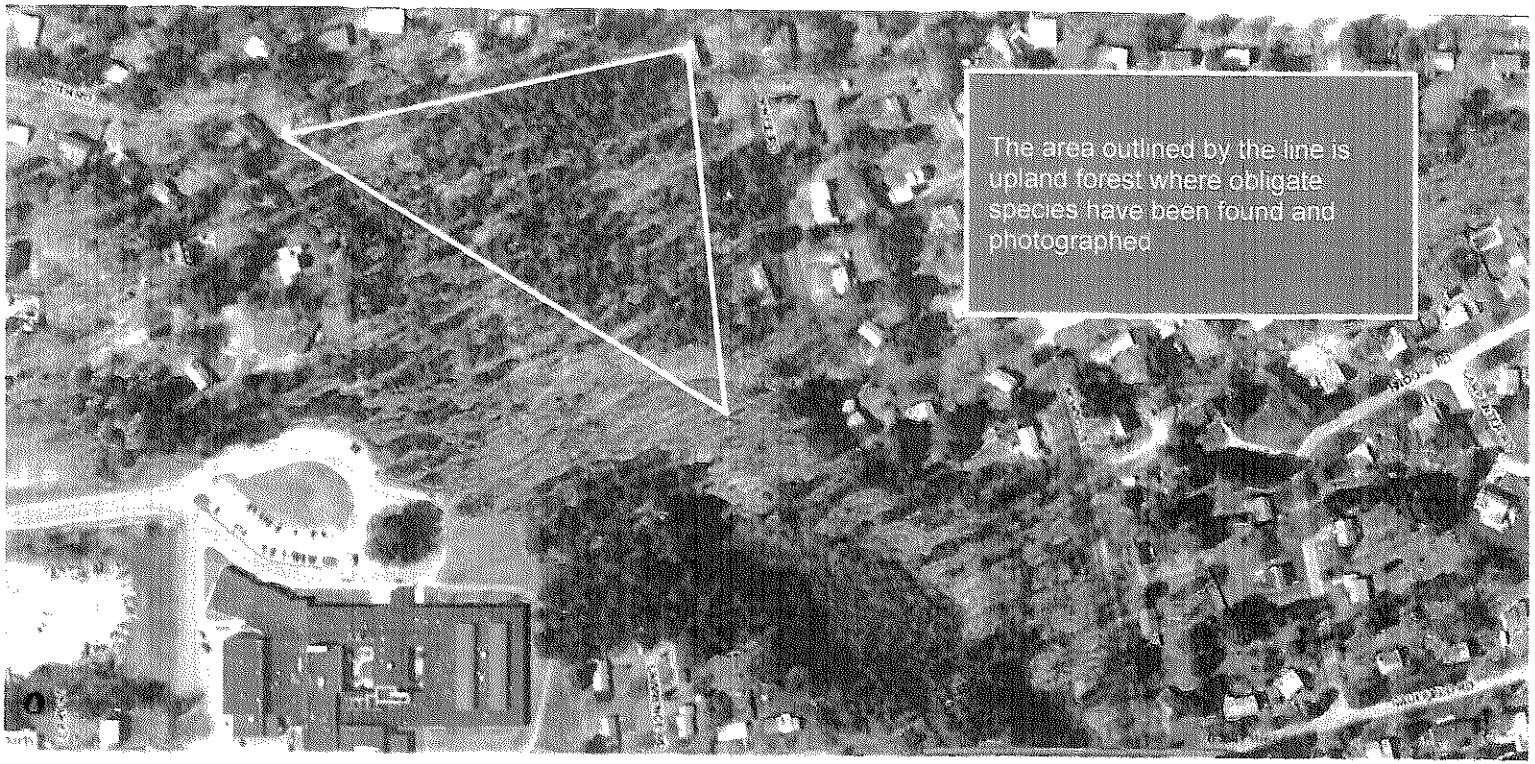
Wayland Middle School Vernal Pool #2



Wayland Middle School Vernal Pool #2



Wayland Middle School Vernal Pool #2



Enclosure 6: 2008 Publication by the Society for the Study of Amphibians and Reptiles

Urban Herpetology, J.C. Mitchell, R.E. Jung Brown, and B. Bartholomew, editors
Herpetological Conservation 3:xxx-xxx.

CHAPTER 3

BREEDING AMPHIBIAN POPULATION DECLINES FOLLOWING LOSS OF UPLAND FOREST HABITAT AROUND VERNAL POOLS IN MASSACHUSETTS, USA

Bryan Windmiller[1], Rebecca N. Homan[2], Jonathan V. Regosin[3], Leslee A. Willitts[4], Daniel L. Wells[5] and J. Michael Reed[6]

Abstract — Rapid urbanization is known to imperil populations of pond-breeding amphibians, in part through loss of terrestrial non-breeding habitat. However, we are aware of no published case studies that document changes in pond-breeding amphibian population size or structure following the loss of significant terrestrial habitat to urbanization. Here, we describe changes in breeding population size of three species of vernal pool-breeding amphibians following destruction of forested upland habitat surrounding vernal pools at two sites in Massachusetts. At the first site, Shopper's World, a small population of *Rana sylvatica* collapsed by the first spring breeding season following loss of 90% of the upland forest surrounding a vernal pool; no evidence of breeding by this species could be found by the third year following habitat alteration. At a second site, Marlboro Road, relatively large breeding populations of *R. sylvatica*, *Ambystoma maculatum*, and *A. laterale-jeffersonianum* hybrids declined sharply after 41% of contiguous upland forest within 300 m of a vernal pool was cleared for residential houses. Breeding populations of the same three species showed lesser changes in size at another vernal pool, separated by <100 m from the altered Marlboro Road pool, but on the other side of a road crossed by relatively few amphibians. Additionally, recapture rates of individually marked *Ambystoma maculatum* at the altered pool were lower following construction than at the relatively unaltered pool. By the third year following construction, breeding population sizes of *A. laterale-jeffersonianum* hybrids, but not of the other two species, had returned to pre-construction levels. Our observations demonstrate that breeding populations of amphibian species at both sites declined as a consequence of anthropogenic habitat loss. We recommend that more such case studies be conducted so that meta-analyses of the resulting data will allow conservationists to better predict the consequences of urbanization-related alterations of terrestrial amphibian habitat.

Key words — *Ambystoma*, Amphibian, Case Study, Habitat Loss, Population Decline, *Rana sylvatica*, Vernal Pool

Several recent studies have described the dependence of pond-breeding amphibian species on adjacent forested terrestrial habitat (Raymond and Hardy 1991; Windmiller 1996; Vasconcelos and Calhoun 2004; Regosin et al. 2005) and the critical importance of protecting such habitat to amphibian conservation efforts (Windmiller 1996; Semlitsch 1998; Calhoun et al. 2005). Among pond-breeding amphibian species in eastern North America, correlational studies have demonstrated that both the abundance and probability of occurrence of several amphibian species are lower in ponds surrounded by relatively little forested area or, conversely, by relatively high proportions of urbanized land cover and roadways (Windmiller 1996; Gibbs 1998; Homan et al. 2004; Rubbo and Kiesecker 2005; Clark et al. 2008).

[1]*Hyla Ecological Services, 65 Arrowhead Road, Concord, Massachusetts 01742, USA*
[2]*Department of Biology, Denison University, Granville, Ohio 43023, USA*
[3]*Natural Heritage and Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, 1 Rabbit Hill Road, Westborough, Massachusetts 01581, USA*
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However, we are not aware of any studies that have compared pond-breeding salamander population structure prior to and following urbanization-related habitat alteration despite the fact that terrestrial habitat loss to urbanization is known to be a substantial threat to amphibian populations in eastern North America (Klemens 1993). Here, we provide data from two case studies that document declines in breeding population sizes of pond-breeding amphibian species following the destruction of forested upland habitat adjacent to vernal pool breeding sites. Additionally, we provide recommendations for conducting similar studies in the future.

Materials and Methods

Species Studied — The species studied, Wood Frog (*Rana sylvatica*), Spotted Salamander (*Ambystoma maculatum*), and mixed-ploidy hybrids of Blue-spotted Salamanders (*A. laterale*) and Jefferson Salamanders (*A. jeffersonianum*), all typically breed in fishless, often temporary ponds and other wetlands (Petranka 1998). In eastern North America, the breeding habitats most commonly associated with these species are often referred to as vernal pools in regulatory and scientific literature (Preisser and Clark 2000). The salamanders that we henceforth refer to as "hybrid Blue-spotted Salamanders" or "*Ambystoma laterale* hybrids" were predominately triploid females of the "*Ambystoma jeffersonianum* complex" (Uzzell 1963), with morphological characters of most individuals resembling those of "LL" triploids (*sensu* Klemens 1993). Measurement of mean erythrocyte areas of a sample of 121 female salamanders from the Marlboro Road site indicated that 75% were polyploid (Homan 2003; R. Homan et al. 2007).

Study Areas and Site Histories — We monitored amphibians in three vernal pools before and after significant adjacent upland habitat loss at two of the pools. The Shopper's World Vernal Pool was located in an urbanized, commercial district in Framingham, Massachusetts (N42° 18.10', W71° 23.55'). The vernal pool was fishless, 0.13 ha in area, and had a seasonal inlet and outlet and dried completely in the summer of some years but not in others. Prior to June 1994, the Shopper's World Vernal Pool was ringed on three sides by heavily trafficked roadways, parking areas, and shopping centers. To the east, however, the vernal pool abutted 6.3 ha of contiguous forested uplands and a larger area of marshland and forested wetland.

In June 1994, 90% of the contiguous upland forest adjoining Shopper's World Vernal Pool was cleared for the construction of a large, multiplex movie cinema and parking area (Fig. 1). The remaining upland forested habitat, totaling 0.6 ha in area, included a 38 m wide buffer zone adjacent to the edge of the vernal pool and two smaller habitat fragments to the north. Pre-construction drainage into the vernal pool from a large adjacent parking area was temporarily interrupted during construction and the vernal pool dried completely at the abnormally early date of 25 June 1995.

The second study site, Marlboro Road, was located in a predominately suburban area in Sudbury, Massachusetts, approximately 28 km west of Boston. The site contained two fishless vernal pools, separated by an undivided two-lane road with moderate vehicular traffic density, and a habitat mosaic of wetlands, forested uplands, and single-family housing surrounding the pools (Figs. 2, 3, see Regosin et al. 2005 for a more detailed description of the site). The two pools, referred to here as North Pool (N42° 24.24', W71° 25.35') and South Pool (N42° 24.20', W71° 25.27'), were, respectively, approximately 0.32 and 0.23 ha in spring-time surface area. During the six-year study period, the North Pool was entirely dry only once for a brief period of time. The South Pool, in contrast, dried completely by late September in most years.

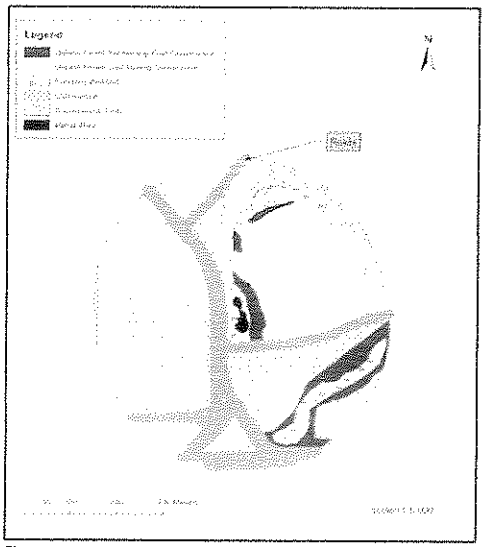

Fig. 1. Land cover changes in a 300 m buffer area drawn around Shopper's World Vernal Pool in Framingham, Massachusetts, that occurred during construction of a cinema complex in summer 1994. Land cover polygons interpreted from MassGIS orthophotos.

In March 1996, a new roadway was cleared to the west and south of the South Pool. During 1997 and 1998, 17 single-family houses were constructed in the vicinity of the South Pool. Land clearing was approximately 15% complete by March 1997 and more than 90% complete by March 1998. In all, residential construction removed 40.7% of the contiguous upland forest cover within 300 m of the South Pool (Fig. 2, Table 1). The North Pool, in contrast, suffered relatively little loss of adjacent contiguous forested habitat during the study period. During the summer of 1998, a single house was constructed northeast of the pool, causing a loss of 8.2% of contiguous upland forest within 300 m of the North Pool (Fig. 3).

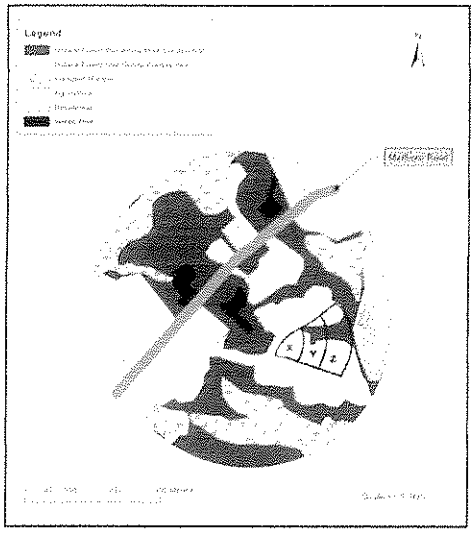

Fig. 2. Land cover changes in a 300 m buffer area drawn around the more impacted South Pool (center point of figure), Marlboro Road site, Sudbury, Massachusetts. The relatively unaltered North Pool lies across Marlboro Road and a third vernal pool, not part of this study, is in the northeastern corner of the figure. Changes in land cover, as shown, occurred during construction of a residential housing subdivision, primarily in the summer of 1997. Land cover polygons were interpreted from MassGIS orthophotos. Location of 1997 drift fence array is shown (curved lines) in the "XYZ Area," an area that had been partially isolated from surrounding forest by road construction prior to the spring of 1997.

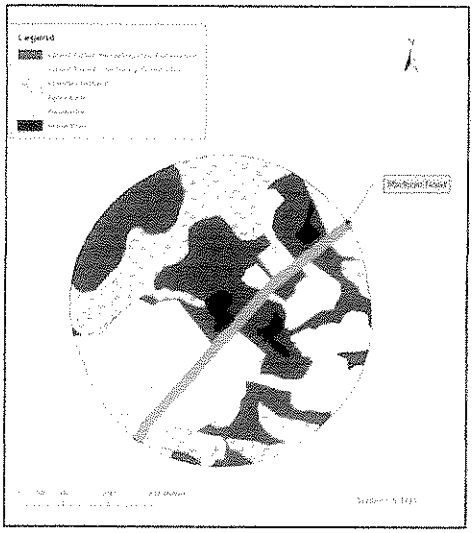

Fig. 3. Land cover changes in a 300 m buffer area drawn around the relatively unaltered North Pool (center point of figure), Marlboro Road site, Sudbury, Massachusetts. The more impacted South Pool lies across Marlboro Road and a third vernal pool, not part of this study, is in the northeastern corner of the figure. Changes in land cover, as shown, occurred during construction of a residential housing subdivision, primarily in the summer of 1997. Land cover polygons were interpreted from MassGIS orthophotos. Area A, as shown, was cleared of forest cover in the summer of 1998.

Data Collection and Analysis at Shopper's World Site — In March 1991, we first observed chorusing *R. sylvatica* in the Shopper's World Vernal Pool and tadpoles of the species were observed in May of that year. In late winter 1992, we installed a drift fence — pitfall trap array around the margins of the Shopper's World Vernal Pool. Drift fences consisted of 0.9 m high plastic siltation fencing suspended from wooden stakes, with the bottom 0.2 m of plastic buried beneath the ground surface. We buried 25 pairs of 19-L plastic buckets on either side of the pond-encircling drift fence, at intervals of approximately 9 m. We checked traps daily from late March until late summer of the years 1992–1997. We closed the traps each summer after two weeks had elapsed since the last capture of a *R. sylvatica* metamorph leaving the pool;

Table 1. Changes in forested area within 300 m of Marlboro Road South and North Pools following construction in summer, 1997. Contiguous forested areas are those not bisected by Marlboro Road, which relatively few amphibians crossed.

Pool	Habitat Type	Pre-Construction Area (ha)	Post-Construction Area (ha)	% Change
South Pool	Total Forest	24.8	19.3	-22.2
	Contiguous Forest	16.2	11.4	-29.5
	Total Upland Forest	17.2	11.8	-31.4
	Contiguous Upland Forest	11.8	7.0	-40.7
North Pool	Total Forest	25.0	21.1	-15.7
	Contiguous Forest	15.1	14.4	-4.9
	Total Upland Forest	16.1	12.4	-23.0
	Contiguous Upland Forest	8.5	7.8	-8.2

gaps were left in the drift fencing to permit free movement of animals during periods when the traps were closed. Captured amphibians and other vertebrates were recorded by trap number, sexed when possible, and released opposite their points of capture. Captured amphibians were not marked during the course of the study. In addition to pitfall trap sampling, we counted *R. sylvatica* egg masses by walking transects through the vernal pool in April of 1995, 1997, and 2003. In 1997 and 2005, we also surveyed the vernal pool for newly hatched *R. sylvatica* tadpoles on the same day as the egg mass count, using numerous dip net sweeps throughout the pool.

To determine whether the number of *R. sylvatica* breeding at the Shopper's World Vernal Pool changed following the clearing of most of the adjacent forest, we divided the study into a "pre-construction" phase (March 1992–June 1994) and a "post-construction" phase (July 1994–August 1997). We then tested the null hypothesis that the total number of emigrating adult and newly metamorphosed *R. sylvatica* captured per year would be the same under pre- and post-construction periods. We compared pre- and post construction total captures of adult and newly metamorphosed *R. sylvatica* using contingency table analysis, with expected values in pre- and post-construction categories dependent upon the proportion of study years in each period. We used the number of adult *R. sylvatica* captured emigrating from the vernal pool each year as the basis of between-year comparisons since, in some years, the traps were not opened early enough to capture all immigrating breeders.

Additionally, we tested the hypothesis that the number of emigrating adult *R. sylvatica* captured in 1995, the spring after construction, was lower than would be expected given the previous years' capture data. To do so, we calculated the expected number of 1995 breeders using *R. sylvatica* demographic parameters provided by Berven (1990) as follows: annual survivorship for adult *R. sylvatica* = 18.4% (mid-point of values given in Berven 1990 for males and females), years to first breeding from metamorphosis = 1 for males and 2 for females (the modal values in Berven 1990), and survivorship from metamorphosis to first breeding = 7.8% for females (at age 2) and 37.9% for males (at age 1). We assumed that the sex ratio among newly metamorphosed *R. sylvatica* was 1:1 (Berven 1990).

Data Collection and Analysis at Marlboro Road Site — Our study commenced in March 1996 and continued until September 2001. For comparative purposes, we divided the study into "pre-construction" (March 1996–June 1997) and "post-construction" (July 1997–September 2001). We captured ambystomatid salamanders and *R. sylvatica* entering and leaving the South and North Pools with pond-encircling drift fence and pitfall arrays similar to those described above for the Shopper's World Vernal Pool. We checked pitfall traps daily during the spring breeding period and at least 3–4 times weekly throughout the summer and autumn months. We usually closed the pitfall traps during the winter months, leaving gaps in the fencing. We identified captured amphibians to species, sexed all adults, and released them on the opposite side of the fence. We weighed and measured samples of captured individuals. In 1996 and 1997, we individually marked all captured *Ambystoma* (990 hybrid *A. laterale* and 506 *A. maculatum*) with toe clips using the system described by Hero (1989). In the spring of 1998, we recorded the 1997 toe clip numbers for approximately the first 1/3 of *Ambystoma* captured that year (37.3% of hybrid *A. laterale* and 33.1% of *A. maculatum*). In 1998, 147 Spotted Salamanders and 262 hybrid Blue-spotted Salamanders were marked individually with subdermally inserted PIT-tags (Ott and Scott 1999). From spring 1998 onwards, most of the remaining captured *Ambystoma* were toe-clipped with batch-marks to indicate the year and nearest breeding pool at which they were first captured. Wood Frogs were generally not marked.

The first drift fence array, constructed in March 1996, enclosed 34% of the perimeter of the South Pool and included 10 pairs of pitfall traps. A partial drift fence also was constructed around 48% of the North Pool perimeter in 1996 but the pitfall traps were open for only a portion of the breeding migration. In early March 1997, the drift fence array was extended to include 82% of the South Pool perimeter using 24 pairs of pitfall traps; the remainder of the South Pool perimeter consisted of lawns and adjacent residential property to which we had no access. At the same time, the North Pool was completely encircled with a drift fence array consisting of 24 pairs of pitfall traps.

Additionally, in March 1997, we installed three parallel arcs of drift fencing across a 1.54 ha patch of upland forest, referred to henceforth as the "XYZ Area" (Fig. 2), that had been partially isolated from contiguous forested areas by newly constructed roadways. The XYZ Area drift fence array originally consisted of 19 pairs of pitfall traps. In the summer of 1997, approximately 67% of the XYZ Area was cleared for houses and lawns, leaving a reduced fragment of 0.50 ha of upland forest. The drift fence system in the XYZ Forest Fragment was reduced accordingly to 9 pairs of pitfall traps for the remainder of the study. In addition to the pond-encircling drift fence around the North Pool, a large array of drift fencing, mostly in arcs parallel to the Pool, was constructed in the upland and wetland forest surrounding the North Pool during 1998 and 1999; the entire array is described in Regosin (2003).

At the Marlboro Road Site, we estimated the breeding population sizes of *R. sylvatica* and *Ambystoma* spp. using pitfall trap captures for each study year at each of the two vernal pools. Breeding population estimates for *Ambystoma* spp., all of which were marked upon first capture, were calculated as: # captures of immigrants + = unmarked individuals among emigrants. For *R. sylvatica*, which were generally not marked, we used total captures of emigrating adults as our estimate of yearly breeding population size since some immigrants reached the breeding pools prior to our opening pitfall traps in at least one of the study years. Since the drift fence array around the South Pool in 1996 was smaller than in subsequent years, we calculated 1996 estimates of breeding population sizes by mul-

tiplying the number of individual amphibians of each species captured in 1996 by the ratio: # pitfall traps in 1997–2001 South Pool array / # pitfall traps in 1996 South Pool array (ratio = 2.4).

To determine whether breeding amphibian population sizes changed following destruction of upland forest habitat adjacent to the South Pool, we compared data from the 2-yr pre-construction and the 4-yr post-construction periods. Additionally, we used breeding population sizes at the relatively unaffected but adjacent North Pool (<100 m from the South Pool) as another point of comparison, asking whether the ratio of South Pool / North Pool captures for each species changed from the pre- to the post-construction period and whether the North Pool breeding populations showed changes similar to those observed in the South Pool following construction. Although forested habitat north and south of Marlboro were connected by amphibian migration and some individual *Ambystoma* metamorphs that emerged from each pool eventually bred in the other pool (J. Regosin unpubl. data), Marlboro Road served as a partial barrier to amphibian movement. In 1997, for example, only 3.5% of all *Ambystoma* individuals leaving the North Pool and 6.4% of all *Ambystoma* leaving the South Pool were captured in pitfall traps facing Marlboro Road and subsequently released on the opposite side of the road. Thus, we suggest that the partial barrier of Marlboro Road likely insulated the amphibian populations breeding in the North Pool from the full consequences of habitat alteration adjacent to the South Pool.

Results

Shopper's World Site — During the three pre-construction years of our study, we captured an average of 16.3 (range = 10–24) adult *R. sylvatica* emigrating from the Shopper's World Vernal Pool per year (Table 2). In sharp contrast, only one *R. sylvatica* was captured leaving the vernal pool in each of the three post-construction study years, a decline of 94% from the pre-construction mean. The 52 total *R. sylvatica* adults captured leaving the Shopper's World Vernal Pool were unequally distributed among the pre- and post-construction periods (chi-square = 41, df = 1, $P < 0.0001$). The sharpest decline in the number of adult *R. sylvatica* captured occurred between 1994 and 1995, the period during which construction occurred. Consistent with this, the number of adults that would have been expected to breed in 1995, given capture data from 1992–1994 and using *R. sylvatica* survivorship parameters presented in Berven (1990), was 10.7; the actual number of emigrating adults captured was one.

As with adults, the number of juvenile *R. sylvatica* captured emigrating from the Shopper's World Vernal Pool was much lower in the four post-construction summer seasons (mean = 13.8, SE = 6.6; Table 2) than in the two pre-construction years (mean = 274, SE = 140.0), a decline of 95%. The 603 total *R. sylvatica* juveniles captured leaving the Shopper's World Vernal Pool were unequally distributed among the pre- and post-construction periods (chi-square = 899, df = 1, $P < 0.0001$). In 1994, the year that construction activities resulted in abnormally early drying of the vernal pool, juvenile recruitment (1.3 juveniles per adult) was approximately 10% of the mean for the five years during which juveniles were captured (mean = 13.1). Searches for *R. sylvatica* egg masses and tadpoles in 1997 failed to detect any evidence of successful breeding and no juveniles were captured leaving the vernal pool in that year. Similarly, in 2003 we could not find a single egg mass or tadpole in the pool.

Marlboro Road Site: Overall Trends in Breeding Population Sizes — All three amphibian species had lower post-construction period (1998–2001) mean breeding population sizes at both vernal pools compared to pre-construction (1996–1997) (Table 3). This reflected the fact that, for all three species at both vernal pools, breeding population size values during the 1997–2001 period were highest in 1997. However, relative declines from 1997 pre-construction values to the post-construction mean values were greater at the South Pool, where more forested habitat was lost, than at the North Pool for all three amphibian species.

Upland forest destruction adjacent to South Pool occurred largely between the 1997 and 1998 breeding period. Notably,

Table 2. Annual totals of *Rana sylvatica* captured in pitfall traps leaving the Shopper's World Vernal Pool. Clearing of adjacent upland forest occurred in June 1994, prior to 1994 metamorph dispersal. Thus, for metamorphs, the pre-construction mean was for the years 1992-1993, and for adults it was 1992-1994. Standard errors are given in parentheses.

Year	# Adults	# Metamorphs	Metamorphs/ Emigrating Adult	Drying Date
1992	15	414	27.6	None
1993	10	134	13.4	July 6
1994	24	32	1.3	June 25
1995	1	11	11.0	July 16
1996	1	12	12.0	None
1997	1	0	0.0	July 2
Pre-Construction	16.3 (± 4.1)	274.0 (± 140.0)	20.5 (± 7.1)	
Post-Construction	1.0 (± 0.0)	13.8 (± 6.6)	8.1 (± 3.2)	

for all three species, the single greatest between-year decline at either vernal pool occurred at the heavily impacted South Pool between 1997 and 1998, with *R. sylvatica* numbers declining at the South Pool by 87%, hybrid *A. laterale* by 51%, and *A. maculatum* by 47% (Table 3). At South Pool, during the four study years following upland forest clearing, numbers of breeding *R. sylvatica* and *A. maculatum* never exceeded 60% of pre-construction values, regardless of whether pre-construction values are defined by the mean of 1996 and 1997 values or by 1997 values alone (Fig. 4, Table 3). Similarly, in the post-construction years, the ratio of South Pool / North Pool breeding population size estimates for *R. sylvatica* and *A. maculatum* never attained their 1997 pre-construction levels (Fig. 5). Hybrid *A. laterale* breeding population size at the South Pool, in contrast, exceeded 60% of the 1996–1997 mean pre-construction values in all post-construction years and exceeded the pre-construction mean in one year (2000). Furthermore, the ratio of hybrid *A. laterale* captured exiting the South Pool vs. the North Pool exceeded the 1997 level during the last two years of the study.

One result of this difference in population trajectories of the two *Ambystoma* species is that the ratio of breeding adult *A. maculatum* to hybrid *A. laterale* at the relatively impacted South Pool decreased sharply after the construction period, from a 1996–1997 mean of 2.46 to near parity (1.18) in the post-construction years. At the relatively undisturbed North Pool, in contrast, hybrid *A. laterale* captures exceeded *A. maculatum* captures in all study years and the mean annual ratio of

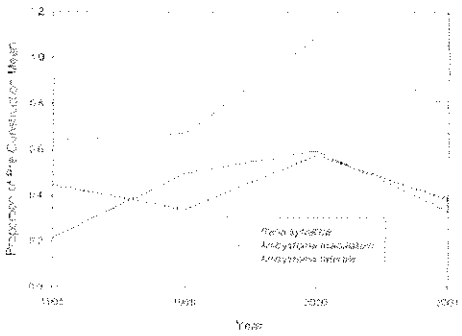

Fig. 4. Number of individual breeding amphibians of three species captured at South Pool in post-construction years, expressed as proportion of the mean number of breeding individuals captured in 1996 and 1997, the pre-construction period.

spotted to hybrid *A. laterale* in post-construction years (0.45) was similar to that observed in 1997 (0.37) and 1996 (0.64) among a sample of 95 total *Ambystoma* captured).

Marlboro Road Site: Trends among Sub-Population Groups — In spring 1998, immediately following the bulk of forest clearing near the South Pool, we observed that a smaller proportion of *A. maculatum* marked at the South Pool in spring 1997 were

Table 3. Breeding population sizes at Marlboro Road vernal pools. Construction – related habitat loss occurred primarily between 1997 and 1998 adjacent to the South Pool; 1996-1997 is the pre-construction period. Data for 1996 at the North Pool were insufficient to derive accurate breeding population size estimates. Standard errors are given in parentheses.

Pond	Year	# *R. sylvatica*	# *A. maculatum*	# *A. laterale* hybrids
South Pool	1996	701	288	81
South Pool	1997	3038	206	151
South Pool	1998	403	110	74
South Pool	1999	932	84	78
South Pool	2000	1115	142	126
South Pool	2001	618	95	91
South Pool Mean Pre-Construction		1869.5 (±1168.5)	247.0 (±41.0)	116.0 (±35.0)
South Pool Mean Post-Construction		767.0 (±158.9)	107.8 (±12.6)	92.2 (±11.8)
South Pool % Change Pre- vs. Post -Construction		-59.0	-56.4	-20.5
South Pool % Change 1997 vs. Post-Construction		-74.8	-47.7	-38.9
North Pool	1997	844	300	839
North Pool	1998	413	295	763
North Pool	1999	442	271	622
North Pool	2000	695	251	582
North Pool	2001	332	200	376
North Pool Mean Post-Construction		470.5 (±78.4)	254.2 (±20.2)	585.8 (±80.0)
North Pool % Change 1997 vs. Post-Construction		-44.3	-15.2	-30.2

recaptured that year (4.9% of a total of 206 marked) than was the case for *A. maculatum* captured at the relatively unaffected North Pool in 1997 (12.7% of a total of 300, Fisher's exact test, two-tailed P = 0.01). There was no significant difference among recapture rates for hybrid *A. laterale* marked at the two vernal pools in 1997 (South and North Pool respective recapture rates of 9.9% of a total of 151 and 12.4% of a total of 839). As noted previously, only approximately the first 1/3 of salamanders captured in 1998 were checked for 1997 toe-clips.

In the XYZ Area, south of the South Pool, which suffered a 67.5% reduction in forest cover between the springs of 1997 and 1998 (Fig. 2), annual per-trap captures of all three study species in the XYZ drift fence array fell sharply after 1997 (Table 4). Compared to 1997, mean annual per-trap captures for the remaining 4 yrs of the study declined by 77% for hybrid *A. laterale*, 84% for *A. maculatum*, and 96% for *R. sylvatica*. Additionally, the proportion of 1997 breeding *A. maculatum* marked in the XYZ area in 1997 that were recaptured in 1998 was 79% lower than the recapture rate of *A. maculatum* captured in all other traps in 1997, though the difference was not statistically significant (Fisher's exact test, two-tailed P = 0.11, Table 4). In contrast, the proportion of hybrid *A. laterale* captured in the XYZ array in 1997 that were observed among 1998 captures (12.2%) was almost identical to the recapture proportion of hybrid hybrid *A. laterale* first captured in all other traps in 1997 (12.0%, Fisher's exact test, two-tailed P = 1.0).

Discussion

Impacts of Upland Forest Destruction — Results of our studies at both the Shopper's World and Marlboro Road sites do not constitute an experimental study as they lack replication and true control. These data therefore cannot confirm a causal link between the large-scale habitat alterations that occurred adjacent to vernal pools and the subsequent changes that we observed in vernal pool-breeding amphibian populations. Nevertheless, we find that the data show sharp declines in breeding population sizes of amphibian species occurring immediately following destruction of upland forest surrounding two vernal pools, and comparatively little change at a relatively unaffected third pool. At the Shopper's World site, destruction of 90% of the upland forest patch adjacent to a vernal pool was followed by a 94% decline in the numbers of adult *R. sylvatica* captured relative to the three-year pre-construction study period. Indeed, in each of the three post-construction study years, only a single *R. sylvatica* adult was captured leaving the vernal pool. By 1997, three years after the upland forest clearing, we were unable to locate either *R. sylvatica* eggs or tadpoles in the pool. No metamorphs were captured leaving the pool that summer. Six years later, in 2003, we were still unable to find any *R. sylvatica* egg masses or tadpoles in the Shopper's World Vernal Pool.

Rana sylvatica populations are characterized by high between-year variability in numbers of breeding adults (Berven and Grudzien 1990; Berven 1995), and we cannot exclude the possibility that the dramatic change we observed in *R. sylvatica* captures at the Shopper's World Vernal Pool was the result of natural fluctuations. However, in reviewing available multi-year data on *R. sylvatica* breeding population sizes (Berven and Grudzien 1990; Berven 1995; B. Windmiller unpubl. data), we have yet to observe an instance of a sustained decline in a *R. sylvatica* population of similar magnitude to the 94% decline that we observed for three years at the Shopper's World Vernal Pool relative to the three pre-construction study years. Berven and Grudzien (1990), for example, provide 7 yrs of data on *R. sylvatica* breeding population sizes at six different ponds in a national forest in Virginia. Among 24 possible within-pond comparisons of two-year periods to preceding

Table 4. Total annual captures of adult amphibians per pitfall trap and between-year recapture rates for the XYZ Area, a 1.64 ha forested fragment of which 67.5% was cleared in summer 1997. Recapture rates are percentages of the cohort of 1997 — breeding individual *Ambystoma* that were recaptured in a sample of 1998 — breeders; the 1997 cohort is civided here between those individuals captured in 1997 in the XYZ Area pitfall traps and those 1997 — breeders captured elsewhere on the site.

	Year	*A. laterale* Hybrids	*A. maculatum*	*R. sylvatica*
	1997	3.00	3.53	35.37
	1998	0.67	0.33	2.00
XYZ Area	1999	0.67	0.44	2.29
per-Trap Captures	2000	1.00	0.55	1.14
	2001	0.44	0.89	0.14
Mean Post-Construction		0.69	0.56	1.39
% Change 1997 vs. Post-Construction		-77.0%	-84.1%	-96.1%
XYZ Recapture Rate	1997 - 1998	12.2%	2.1%	n.a.
	(N)	(41)	(47)	
All Other Trap Recaptures	1997 - 1998	12.0%	10.2%	n.a.
	(N)	(949)	(459)	

two-year periods, the largest observed decline for a Wood Frog breeding population was 83%. Among the 5 yrs of *R. sylvatica* breeding population data reported here for the relatively undisturbed North Pool in Sudbury, Massachusetts, the greatest between-year decline in *R. sylvatica* breeding numbers was 49%. Additionally, at the Marlboro Road Site, less than 12 km from the Shopper's World Site and thus sharing similar annual precipitation patterns, *R. sylvatica* populations were high in 1996 and 1997, two years during which the Shopper's World Vernal Pool *R. sylvatica* population was near extirpation.

Our data suggest that clearing of most of the adjacent Shopper's World upland forest in June 1994 caused exceedingly high mortality rates among *R. sylvatica* adults and juveniles in the period between forest clearing and breeding in March 1995, a conclusion supported by our calculation of predicted 1995 *R. sylvatica* captures using stage-specific demographic data from Berven and Grudzien (1990). Since, in northeastern North America, few *R. sylvatica* occur in dry upland forest during June (Regosin et al. 2003), it is unlikely that many *R. sylvatica* were directly killed during the forest clearing operations. Instead, the observations of Regosin et al. (2003) suggest that upland forest, particularly areas within 100 m of vernal pool breeding sites, is critical to *R. sylvatica* populations during the winter months. Perhaps, deprived of adequate overwintering sites, the *R. sylvatica* of the Shopper's World population experienced unusually high winter mortality rates during the winter of 1994–1995.

The effects of apparently low survivorship among *R. sylvatica* in the terrestrial environment during the year between March 1994 and March 1995 were compounded by the very low rate of juvenile recruitment during the summer of 1994, an event probably caused by the unusually early drying of the vernal pool as a consequence of construction activities. With little suitable upland forest remaining, the relatively few newly metamorphosed *R. sylvatica* that emerged from the vernal pool in 1995 and 1996 were apparently unable to survive to maturity in numbers sufficient to revive the population, which was small at the outset of the study. Surrounded by heavily trafficked roadways and extensive urbanization, the Shoppers' World *R. sylvatica* population was cut off from rescue through recolonization (cf. deMaynadier and Hunter 2000) and declined to extirpation.

In contrast to Shopper's World, the magnitude of post-construction declines observed in three vernal pool-breeding amphibian species studied at the Marlboro Road South Pool are within the range of reported natural variation in yearly breeding population sizes reported for *R. sylvatica* (Berven and Grudzien 1990; Berven 1995) and Spotted Salamanders (Husting 1965; Seeton et al. 1986). Moreover, all three species also showed declines at the relatively undisturbed North Pool relative to pre-construction conditions in 1997. The fact that mean annual breeding population sizes of all three study species were lower at the South Pool in the four year post-construction period than in the two year pre-construction period is not, in of itself, convincing evidence that the observed declines were the result of construction-related changes in land cover.

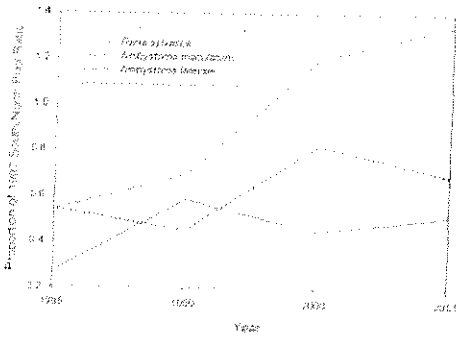

Fig. 5. Ratio of the number of individual breeding amphibians of three species captured at South Pool / North Pool post-construction years, expressed as proportion of the 1997 pre-construction ratio of South / North Pool captures of the same species.

However, taken as a whole, data comparing pre- and post-construction amphibian population structure at the South and North Pools strongly suggest that the loss of forested upland habitat during construction near the South Pool in 1997 caused increased mortality of resident *R. sylvatica* and *Ambystoma* populations and subsequent declines in the numbers of all three species. First, the 6 yrs of available breeding population data for the South Pool and 5 yrs of data for the North Pool provide nine between-year comparisons for each of the three species. For all three species, the single greatest between-year decline was recorded at the South Pool between 1997 and 1998, the primary period of habitat alteration. Second, although breeding population size data for the North Pool does not serve as a true experimental control for data recorded at the South Pool, these two adjacent vernal pools shared nearly identical climatic conditions. Additionally, *A. maculatum* egg mass count data from successive years suggest that variability in breeding effort for this species may be correlated among ponds within a region extending over tens of kilometers (Ruth et al. 1993; Windmiller 1996; B. Windmiller unpubl.data). Thus, it is notable that in the North Pool, <100 m from the South Pool, breeding population numbers for both species of *Ambystoma* showed little change between 1997 and 1998, and the greatest between-year decline for all three species at the North Pool was between 2000 and 2001, a period during which population size data declined sharply for all three species at both pools. Moreover, the ratio of breeding individuals at the South vs. North Pools declined sharply from 1997 to 1998 for all three species (> 45% decline for each species, Fig. 5) and, compared to 1997, remained depressed by >50% for all three species during the 1999 breeding season. In the 4-yr post-construction period, only hybrid *A. laterale* ever regained the 1997 ratio of North vs. South Pool captures.

Unlike the fate of the small *R. sylvatica* population at the Shopper's World Vernal Pool, the relatively large pre-construction populations of *R. sylvatica*, hybrid *A. laterale*, and *A. maculatum* at the South Pool persisted after alteration of much of the surrounding upland forest habitat. The breeding population sizes of all three species, however, declined sharply over the two years following construction and, for *A. maculatum* and *R. sylvatica*, remained at less than 60% of their pre-construction levels throughout our 4 yr post-construction monitoring period. Only the hybrid *A. laterale* population recovered to pre-construction breeding values. Recapture data for individually-marked *A. maculatum* suggest that mortality rates were higher for individuals that had resided in the altered South Pool vicinity during the construction period compared to those that had been last captured near the relatively unaffected North Pool. Although we cannot surmise the cause of increased mortality among South Pool-breeding amphibians during and following clearing of 41% of upland forest around their breeding pool, our frequent checks of the relatively sparsely trafficked subdivision roadways suggest that road-kill was not a primary factor.

Conservation Implications — Extirpation of the Shopper's World *R. sylvatica* population occurred even though all Federal, state, and local wetlands protection measures were applied to their fullest extent. Not only were all wetland areas untouched by construction, the Town of Framingham Conservation Commission required the developer of the site to leave a 38 m-wide wooded buffer area around the wetland boundary intact. Similarly, the Town of Sudbury Conservation Commission required the developers of the housing subdivision adjacent to the South Pool to leave intact all wetland areas on the sites, as well as a 30.5 m-wide forested buffer zone around the vernal pool. Additionally, because of the presence of a state-protected species, *Ambystoma laterale* complex (Species of Special Concern, as listed by the Massachusetts Division of Fisheries and Wildlife), the developers were further required to spare several patches of upland forest as far as 220 m from the South Pool. In our experience in Massachusetts, few construction projects near vernal pools in Massachusetts are as tightly regulated as those described here; most such projects are permitted to clear upland forest areas to within 10 m or less of the wetland boundaries. Our case studies at Shopper's World and Marlboro Road therefore support the conclusion, reached by others as well, that wetland protection regulations are inadequate tools to protect populations of amphibian species that depend upon both wetland and upland habitats from anthropogenic habitat alteration (Windmiller 1990; Semlitsch 1998; Calhoun and Klemens 2002; Homan et al. 2004).

The fate of the Shopper's World Wood Frog population represents a fairly extreme case of urbanization-related destruction of critical terrestrial habitat for vernal pool-breeding amphibians. Even in the densely settled northeastern United States, relatively few vernal pools remain within a setting as heavily urbanized as the Shopper's World Vernal Pool (Gibbs 1998). Additionally, relatively few construction projects adjacent to vernal pool breeding sites result in the conversion of as much as 90% of all surrounding upland forest habitat into buildings and paved surfaces, as was the case at Shopper's World. However, levels of upland forest destruction around vernal pools similar to or greater than those observed at the Marlboro Road site are common in the rapidly urbanizing northeastern United States (B.Windmiller pers. obs.), suggesting that anthropogenic amphibian population declines comparable to those that we observed at the South Pool are widespread. Furthermore, data from the XYZ Area, where per-trap amphibian capture rates declined much more than the proportionate reduction in forested area, indicate that leaving small patches of forest surrounded by houses, lawns, and roads is of dubious value to the conservation of vernal pool-breeding amphibians.

Finally, our data suggest the seemingly paradoxical conclusion that hybrid *A. laterale*, the only one of the three taxa studied that is protected as a rare species in Massachusetts, may be the most resistant of the species to the scale of upland forest destruction that occurred at the Marlboro Road study site. If this is generally true, possible explanations may include a greater ability by *A. laterale*-complex salamanders to use forest edge or wetland habitats (B. Windmiller unpubl. data) and the release of hybrid *A. laterale* from interspecific competition with *A. maculatum* if the latter species is reduced in number by habitat loss. However, urbanization may pose a particular threat to populations of hybrid *A. laterale-A. jeffersonianum*. Rebecca Homan et al. (2007) observed that the ratio of female to male hybrid *A. laterale* at the North Pool averaged 28.3:1 and increased over the course of the study. If the relatively few males present in such populations are particularly vulnerable to habitat destruction, urbanization may imperil populations of hybrid *Ambystoma* through removing opportunities for females to breed successfully, whether through gynogenesis or sexual reproduction (Klemens 1993). Future studies comparing the responses of these two species to habitat alteration should note the ploidy and genotypic make-up of *A. laterale-A. jeffersonianum* complex salamanders that are studied (Lowcock et al. 1987).

Recommendation for Future Studies — Regulators and conservationists would benefit greatly from an increased understanding of the specific responses of vernal pool-breeding amphibian species to urbanization. Correlational studies are able to provide considerable insight into the regional-scale trends in relationships between urbanization and amphibian abundance and distribution. Yet regulators are frequently called upon to make decisions of considerable economic importance on a much smaller site-specific scale. Studies such as the ones described here may allow regulators to optimize conservation outcomes by distinguishing between projects that are likely to cause only temporary increases in amphibian mortality versus those that carry a significant risk of causing permanent declines or extirpations. Additionally, data on the abilities of different amphibian species to survive in and move through an urbanized habitat

matrix would allow regulators to more confidently choose between various site development alternatives.

Because it is inherently difficult to conduct controlled and replicated studies that involve large-scale conversion of natural habitat into urban land cover, we believe that it is important to maximize the knowledge gained from case studies such as ours. Meta-analyses of many well-conceived case studies that compare pre- and post-construction patterns in amphibian demography and habitat use might offer an excellent means of elucidating the responses of amphibian populations to urbanization. This would be particularly true if unpublished studies, perhaps from local consulting projects, could be compiled to reduce problems associated with publication biases (e.g., Sterne et al. 2000). Based on our experience with the studies reported here, we offer the following recommendations for the design of pre- vs. post-construction case studies of amphibian populations: (1) Maximize pre-construction data collection by beginning the study as soon as possible after the opportunity arises and initiating all study components at the outset; (2) Establish similar study protocols at nearby research areas that will be unaffected by the proposed construction; (3) Individually mark as many amphibians as possible during the pre-construction period, using marking systems such as PIT-tags (Orr and Scott 1999) or visible implanted elastomers (Bailey 2004) that allow identification over the lifetime of the amphibian; and (4) Track the movements and fates of individual amphibians through the pre- and post-construction landscape using radiotelemetry (Madison 1997), concentric drift fence arrays (Windmiller 1996; Regosin 2003), or direct observation. We recognize, however, that logistical considerations, timing of the permitting and construction process, and land ownership patterns will greatly affect the eventual study design.

The costs for pre- vs. post-construction case studies are most appropriately borne by developers seeking permits to alter wetlands, vernal pools, or other regulated habitat areas, with maximum study costs capped at a fixed percentage of estimated project costs. To reduce the possibility for conflicts of interest, we recommend that funding for the study be transferred from the developers to conservation agencies, which would, in turn, contract suitable researchers.

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Uses of WMS Woods by students

Our Wellness program (formerly Physical Education) uses the land that would include the rerouted path for its archery course. They also have students ski and snowshoe on trails through the wooded areas that would become fields.

As for science, the grade and course that uses the natural area most is seventh grade Life Science. Each year the course begins with a survey of the organisms in our local ecosystem. Students spend five full class periods studying organisms in the woods. The lab is extensive as it requires them to learn and use many different data collection methods on the biotic and abiotic factors within the ecosystem. Students perform tests on the soil, measure air temperature, and document and describe everything they see. In recent years the MS has invested in new technology to bring data collection methods up to date.

Funds provided by the Wayland Public School Foundation have purchased digital cameras so every lab group can capture authentic images of their findings. Another WPSF grant has funded GPS devices which allow students to pinpoint the location of each organism they find. New Vernier brand LabQuest units allow for digital data collection of temperature and light. Not only do students emerge with authentic skills of a field biologist, but they also develop awareness of and appreciation for their natural surroundings. Only after this first step can they themselves become stewards of the environment in the spirit of Rachel Carson, the seventh grade house mentor.

The science department recently had professional development in which an outside consultant trained teachers to use the GPS data and digital photographs students collect with GIS software such as GoogleEarth to compile data in a database that they will contribute to annually (assuming they still have access to the habitat they have been studying for the past couple of decades). Teachers have met with the town GIS coordinator to plan collaboration in which he could post middle school generated data as part of the town's ecological data. This fits nicely with the initiative of the Middle and High School's professional development theme this year of exploring ways for students to benefit from Web 2.0 tools where they become contributors to the information on the internet rather than just consumers.

The English teachers have also used the woods as outdoor classroom space. Over the years 6th grade English teachers have used to use the woods for journaling and preparation for the Walden trip.

Art teachers also use the woods, bringing the students there for observational drawing.

Finally, last year during the winter carnival, students participated in a hike in the woods.

It is clear that the middle school teachers and students use the woods as outdoor learning space. If the proposed fields project comes to fruition, our students and our teachers will lose this valuable natural learning space. It will negatively impact the learning experience at the middle school.