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Woodstock, Vermont

Biological Inventory of Amphibians and Reptiles at the Marsh-Billings-Rockefeller National Historical Park and Adjacent Lands

Technical Report NPS/NER/NRTR—2005/008

ON THE COVER
Jefferson Salamander: *Ambystoma jeffersonianum*
Painted Turtles (*Chrysemys picta*) at the Pogue
Photographs by: Vermont Institute of Natural Science and Tom Lautzenheiser

Biological Inventory of Amphibians and Reptiles at the Marsh-Billings-Rockefeller National Historical Park and Adjacent Lands

Technical Report NPS/NER/NRTR—2005/008

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U.S. Department of the Interior
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Northeast Region
Marsh-Billings-Rockefeller National Historical Park
Woodstock, Vermont

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Abstract

In June, 1996, the 555-acre Marsh-Billings-Rockefeller National Historical Park was established to interpret conservation history and the evolving nature of land stewardship in America. In order to help guide the development of a forest management plan, a biological inventory of the amphibian and reptiles within the park and adjacent lands was conducted in 1999 and 2000. A variety of field techniques were used to document the composition and distribution of amphibian and reptiles in the park, and assess relative abundance and species richness across three main habitat types – hardwood forest, hemlock/hardwood forest, and conifer plantations. A total of 13 amphibian species (6 salamanders, 7 frogs) and 5 reptiles (3 snakes, 2 turtles) were documented in the park. Significant breeding populations of the rare Jefferson Salamander, along with more common vernal pool-breeding species, were found in 6 of 10 temporary pools. Both relative abundance and species richness were higher in hardwood and mixed stands than in softwood stands and conifer plantations. Although Red-backed Salamanders were the most widely distributed species, visual encounter surveys showed significantly fewer individuals in conifer stands than in hardwood/mixed wood forests. In addition, an artificial cover board experiment revealed significantly higher counts of adult Red-backed Salamanders in hardwood and mixed wood stands than in a conifer plantation. Recommendations for forest management and long-term monitoring are discussed.

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Background and Purpose

The Marsh-Billings-Rockefeller National Historical Park (MABI) is the only national park to focus on conservation history and the evolving nature of land stewardship in America. Opened in June of 1996, Vermont's first national park preserves and interprets the historic 555-acre Marsh-Billings-Rockefeller property located in Woodstock, Windsor County, Vermont. The National Park Service (NPS) plans to operate the forest as a working landscape with educational forestry demonstrations, exhibits, and sustainable forestry practices. To attain these goals, a forest management plan is being developed for the park. In order to help guide the development of this plan, park managers require comprehensive information about the biological resources that occur within the park and how management practices might affect the status and distribution of these resources. To that end, the first in a series of biological inventories was conducted during 1996 when the vascular plants occurring at MABI were surveyed (Hughes and Cass 1997). That was followed by this study in 1999 and 2000 to inventory the reptiles and amphibians of the park.

Recent data indicate that amphibians and reptiles are critical components of both terrestrial and wetland ecosystems (Werner and McCune 1979, Gibbons 1988). Due to their extremely low energy requirements, the biomass of many amphibian and reptile species may exceed that of nearly all other vertebrates within an ecosystem, making them extremely important in energy flow and nutrient cycling (Burton and Likens 1975, Pough 1980, Bury 1988). Additionally, both groups are excellent indicators of environmental degradation – amphibians due to their aquatic/terrestrial life cycle and permeable skin – and reptiles due to their high trophic level positioning.

The relative abundance and distribution of many amphibian and reptile populations are strongly influenced by microclimate, soil moisture and pH, vegetation, and the presence of leaf litter and coarse woody debris on the forest floor. Therefore, management practices that alter these habitat characteristics may have negative, long-term effects on populations. Research suggests that while the long-term effects of forest harvesting on amphibians are variable, they can be mitigated for many species by leaving adequate microhabitat structure intact (deMaynadier and Hunter 1995). Wyman and Jancola (1992) demonstrated that hardwood forest stands tend to have a higher density and diversity of amphibian species compared to coniferous forests, but this may vary geographically or between stands depending on soil chemistry (Wyman 1988). In addition, amphibian populations may be significantly limited in conifer plantations due to the loss of understory structure, hardwood litter and forest floor microhabitats (deMaynadier and Hunter 1995).

Through a cooperative agreement with the Vermont Institute of Natural Science, a quantitative assessment of amphibian and reptile populations of the Marsh-Billings-Rockefeller NHP and adjacent lands was conducted during 1999 and 2000. The broad goal of the inventory was to provide park managers with the baseline data necessary to help develop an ecologically sound

forest management plan, and formulate effective monitoring strategies for the future. The specific objectives were to:

1. Document the composition, distribution, and status of amphibians and reptiles in the study area;
2. Evaluate species richness and relative abundance within the 3 primary forested habitats (hardwoods, mixed stands, and conifer plantations);
3. Identify ecologically sensitive and/or critical areas (e.g., vernal pools or other breeding sites, hibernaculums, migration corridors etc.) where forest management may be restricted;
4. Describe the distribution and relative abundance of any state and/or federally-listed Endangered and Threatened species, species of Special Concern, and/or exotics occurring within the park; and
5. Provide information necessary to develop a general monitoring strategy and design, tailored to specific threats and resource issues of the park, which can be implemented following the inventory.

This report details the results of this study, and makes recommendations for management and monitoring.

Study Area

The 555-acre Marsh-Billings-Rockefeller National Historical Park ranges from approximately 700 to 1,450 feet in elevation, and is dominated by northern hardwood forest, primarily American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and yellow birch (*Betula lutea*). Some stands however, contain a significant component of Eastern hemlock (*Tsuga canadensis*), particularly along the stream in the eastern half of the park, and in pockets to the east and north of the 15-acre pond, known locally as the Pogue (Fig.1). In addition, there are several conifer plantations of various sizes and species composition, including red pine (*Pinus resinosa*), Scotch pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), European larch (*Larix decidua*), and white pine (*Pinus strobus*). To the east and south of the Pogue there are several hayfields, totaling 33 acres. The park contains an extensive network of hiking trails and carriage roads that are groomed for cross-country skiing in winter, and open to foot and horse traffic at other times of the year. In addition, the park contains several wetlands and vernal pools used by amphibians for breeding. Adjacent to the park's southeastern corner is a 122-acre parcel owned by the town of Woodstock and managed as a Town Park. Largely forested, this land supports a cliff/rocky outcrop community, two vernal pools, and is connected to MABI by several trails and carriage roads. Directly south of MABI is the King Farm, a 156-acre parcel owned by the Vermont Land Trust. This land supports mature northern hardwood and mixed forests, conifer plantations, and open fields, as well as three vernal pools, and also shares several hiking/ski trails with MABI.

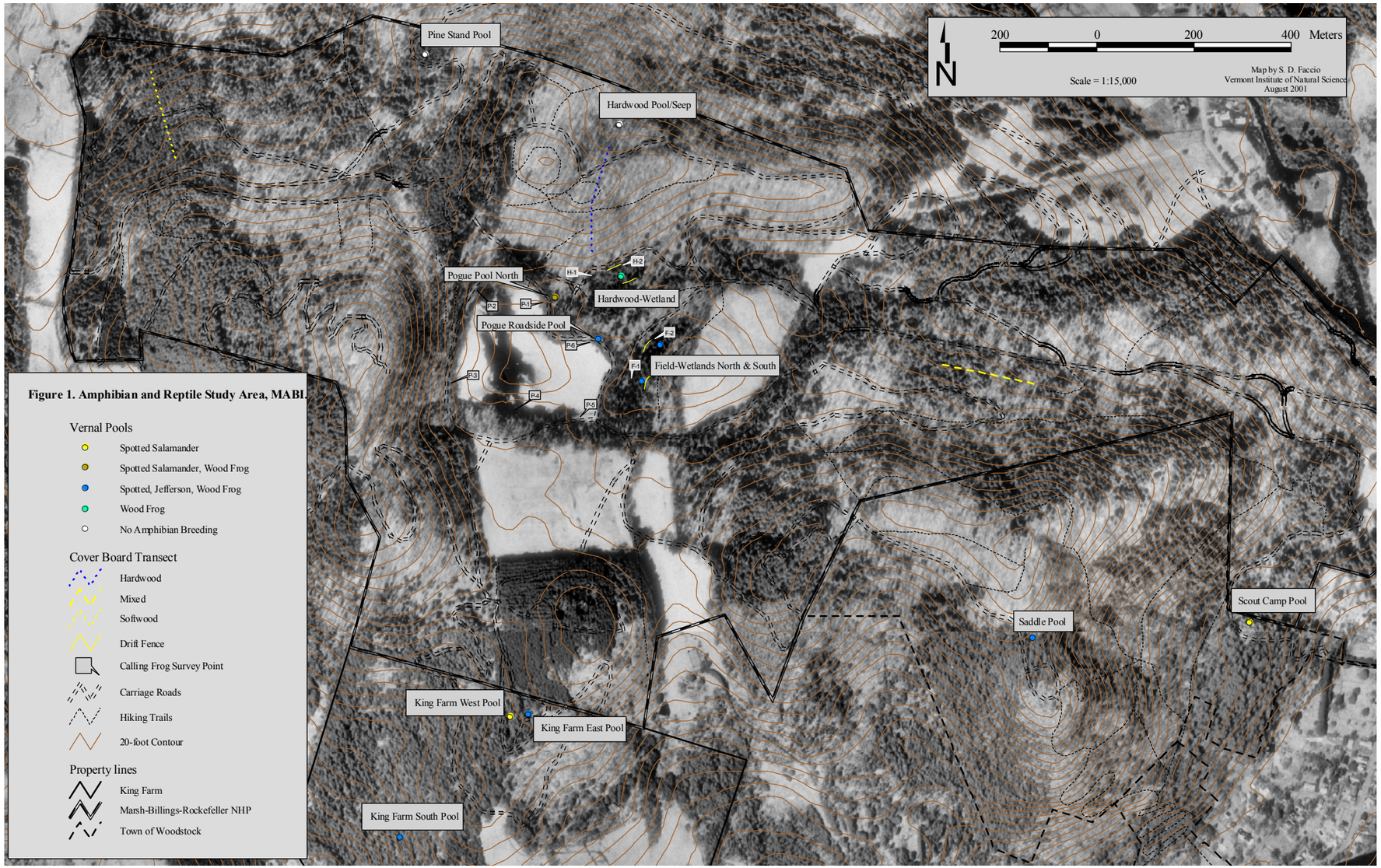


Figure 1. Amphibian and Reptile Study Area, MABI

Methods

Survey Techniques

Due to the diverse life histories, habitat requirements, and generally shy nature of the target organisms, six different inventory methods were employed during this project – drift fences with pitfall traps, minnow traps, egg mass counts, nocturnal calling frog surveys, artificial cover board arrays, and time-constrained visual encounter surveys. All amphibians and reptiles captured were identified to species, sexed (if possible), snout to vent length (S-V) and/or total length measured (or in some cases placed into a size class), checked for reproductive condition, and released at point of capture. In addition, all adult Spotted Salamanders captured were individually identified based on their unique spot patterns, a technique developed by the principle investigator. Photographic vouchers were made for all species encountered within the range of photographic equipment.

Drift Fences

Prior to the start of the 1999 amphibian breeding season, four, 30.5-meter long drift fences, each with 8 pitfall traps (consisting of two #10 cans attached end to end) buried along their length, were established at two different forested wetlands – the Hardwood-Wetland (HW), and the Field-Wetland (FW) (Fig. 1). Pitfall traps were typically opened on rainy days or when rain was expected overnight, and then checked the following morning. These two wetlands were targeted for drift fence sampling because of their relatively large size (ca. 1-acre each), their central location within the park, and their accumulations of *sphagnum* mosses and raised hummocks. These characteristics identified them as potential breeding habitats for several amphibian species including the rare and secretive Four-toed Salamander (*Hemidactylium scutatum*), a species listed as one of Special Concern in Vermont.

Minnow Traps and Egg Mass Counts

To determine the presence/absence of vernal pool-breeding amphibians, commercially available minnow traps were used at 12 potential breeding pools. As soon as the ice cover receded on breeding pools, and continuing through the spring season, up to 5 traps were placed along the shoreline, 5-10 meters apart, in water deep enough to cover the funnel openings, but not deep enough to cover the entire trap. Traps were generally left overnight and checked the following morning. All potential breeding pools on the three properties were sampled with minnow traps during the study.

In addition, these 12 pools were searched for the presence/absence of egg masses of ambystomatid salamanders, and Wood Frogs during the spring breeding season to provide an index of each species' relative abundance and the potential productivity of each pool.

Nocturnal Calling Frog Surveys

To inventory frogs, a protocol established for the Vermont Calling Frog Survey was modified and used to sample the Pogue, the Field-Wetland, and the Hardwood-Wetland. A total of 10 listening stations were established; 6 around the Pogue, and 2 at each of the wetlands (Fig. 1). Systematic aural surveys of calling frogs occurred on rainy or humid nights throughout the spring and summer. At each station, all frogs heard calling during a 10-minute period were identified to species and their relative abundance estimated based upon the following codes:

Code 1: Can clearly hear all individuals of a species and can count them easily – there is ample space (time) between calling individuals.

Code 2: There is some overlap of calls between individuals of a species, but not so much as to make an accurate count impossible.

Code 3: A full chorus. Calls for a species are constant, continuous, and overlapping.

Artificial Cover Boards

To compare the distribution and relative abundance of Red-backed Salamanders within 3 different forest cover types, cover board transects were established during early April 1999 in a northern hardwood stand, a hardwood/hemlock stand, and a red pine plantation (Fig. 1). Following the protocol to monitor terrestrial salamanders established by the North American Amphibian Monitoring Program (Droege et al. 1997), within each study site 40 white pine cover boards (measuring 25 x 25 x 2.5 cm) were laid out in pairs, 0.5 m apart. Each pair of boards was spaced approximately 10 m apart and, to reduce forest edge effects, at least 50 m from the forest edge.

Cover boards were checked approximately each week between April and November during the two-year study, but were not checked during misty or rainy weather when salamanders were more likely to be out foraging in the leaf litter (Jaeger 1979, 1980). Individual salamanders encountered under each board were tallied and handling of salamanders was avoided as much as possible. All Red-backed Salamanders were placed into one of the following size classes: Adult (> 40 mm S-V), Sub-adult (30 – 40 mm S-V), and Juvenile (< 30 mm S-V) (Sayler 1966). During 2000, most adult Redbacks were sexed by visually noting the shape of the snout (squared in males, rounded in females) (Hunter, et. al. 1999).

Habitat Sampling

To evaluate and compare habitat variables within the 3 forest stands, vegetation metrics were sampled at seven plots centered on every third pair of cover boards at both the hardwood and hardwood/hemlock study sites in 1999, and at the softwood plot in 2000 (Table 1). Habitat variables were chosen based on their relevance to forest management and terrestrial amphibians, primarily Red-backed Salamanders.

Table 1. Habitat variables measured at three cover board transects.

Habitat Variable	Transformations
Ground Cover [a]	
Total green cover below 50 cm	log
Shrubs	none
Ferns	none
Grass/sedge	none
Forbs	log (x+1)
Moss	none
Leaf litter	none
Downed logs > 12 cm diameter	none
Bare ground	$\log_{10}$ (x+1)
Standing water	none
Canopy Closure [b]	none
Canopy height	log
Shrub/sapling density [c]	$\log_{10}$ (x+1)
Canopy trees [d]	none
Litter depth [e]	none
Plot aspect	none
Plot slope	square root
Soil pH	log

[a] Based on visual estimates of percent cover within 5 m radius.
[b] Ten views through a sighting tube at 1 m intervals along each cardinal compass direction (40 total).
[c] Two perpendicular strip transects (2 m wide) intersecting at plot center and oriented along cardinal compass directions.
[d] Identify and measure (dbh) of all trees using a 10-factor prism.
[e] Measure the organic layer at 3 locations, 1.5 m apart, along each cardinal compass direction (12 total).

Time-constrained Visual Encounter Surveys

Each of the major habitat types were actively and systematically surveyed for amphibian and reptiles during spring, summer, and autumn using Visual Encounter Surveys (VES), yielding the number of individuals of each species encountered per person-hour (Heyer et al. 1994). Particular microhabitats were targeted during these searches to increase the chances of encountering certain species. These microhabitats included streams and seeps, rocky/cliff areas, stone walls and abandoned foundations, in and around vernal pools, and beneath rocks, logs, accumulations of leaf litter, and other debris. During all VES, overturned cover objects were returned to their original position to minimize habitat disturbance. Aspects of seasonal, temporal, and weather effects on animal detectability was considered during these searches (e.g., rainy spring evenings for amphibian breeding assemblages, warm sunny days for basking turtles and snakes, etc).

Paired Visual Encounter Surveys

In order to compare the abundance and distribution of amphibians in hardwood-dominated stands with those in pine plantations and conifer-dominated stands, paired VES were conducted in which a hardwood/mixed forest (hardwood/hemlock) stand was searched on the same day and with the same amount of effort as a softwood stand or conifer plantation. During these searches, efforts were made to select paired sites with similar aspects, slopes, relative sizes, and other physiographic features, in order to limit the variables that could influence amphibian abundance and distribution.

Data Analysis

For cover board transects, counts of Red-backed Salamanders by year were analyzed using a Mann-Whitney U test. The distribution of salamander counts by size class and habitat was compared using Kruskal-Wallis and Mann-Whitney U tests. To examine the relative importance of habitat variables to the abundance of adult Red-backed Salamanders at cover board transects, multiple regression was used. Models were constructed using backward, stepwise regression methods, using a subset of 10 variables that were not highly intercorrelated ($r<0.80$), and with t values greater than 2.0 and tolerance values greater than 0.1. The relationship between visual encounter survey effort, relative abundance and species richness was evaluated using simple linear regression. The number of Red-backed Salamanders and the number of all amphibians observed during paired visual encounter surveys was compared among hardwood and softwood sites using Wilcoxon Signed Rank tests. All Statistical analysis were performed using the Systat package (SYSTAT 8.0, SPSS, 1998).

To compare the relative importance of the major natural community types of the park, species richness, diversity, and relative abundance were evaluated using the VES data. I used the Shannon diversity index (H), which accounts for species richness, abundance and evenness. In the formula below, s represents richness and p is the proportionate representation of species i among the total number of individuals.

$$\mathrm{H} = -\sum_{i=1}^{s} (p_i)(\ln p_i)$$

Results

A total of 13 amphibian species (6 salamanders, 7 frogs) and 5 reptiles species (2 turtles, 3 snakes) were documented in the park during the 2-year study (Table 2). Of these, 11 amphibian species (6 salamanders, 5 frogs) were confirmed to have breeding populations in the park, and although not confirmed, all the reptiles are suspected to breed within the study area.

Table 2. Species of amphibians and reptiles encountered at MABI during 1999-2000.

Species	Number Encountered [a]	Notes on Distribution and Relative Abundance within MABI and Adjacent Lands
Salamanders		
Jefferson Salamander *(Ambystoma jeffersonium)*	189	Several metapopulations; limited distribution; locally common; breeds in 6 of 10 pools
Spotted Salamander *(Ambystoma maculatum)*	244	Several metapopulations; more widely distributed than Jefferson Salamander; locally common; breeds in 9 of 10 pools
Dusky Salamander *(Desmognathus fuscus)*	27	Breeding population in stream and adjacent seeps; uncommon
Northern Two-lined Salamander *(Eurycea bislineata)*	267	Breeding population in stream; common
Red-spotted Newt *(Notophthalmus viridescens)*	45	Breed in Pogue and Field-Wetland; locally common
Red-backed Salamander *(Plethodon cinereus)*	1,479	Widely distributed; most abundant in hardwood/mixed stands and around both the Field-Wetland and Hardwood-Wetland
Frogs		
American Toad *(Bufo americanus)*	55 [b]	Breeding population in Pogue; common
Spring Peeper *(Pseudacris crucifer)*	16 [b]	Breeding population in Pogue and Field-Wetland; common
Bullfrog *(Rana catesbiana)*	1	No evidence of a breeding population
Green Frog *(Rana clamitans)*	16 [b]	Breeding population in Pogue and Field-Wetland; common
Pickerel Frog *(Rana palustris)*	3 [b]	Breeding population in Pogue; uncommon
Northern Leopard Frog *(Rana pipiens)*	1 [c]	No breeding population
Wood Frog *(Rana sylvatica)*	983	Several metapopulations; widely distributed; locally common; breeds in 8 of 10 pools
Turtles		
Snapping Turtle *(Chelydra serpentina)*	2	Breeding population in Pogue likely; relative abundance unknown
Painted Turtle *(Chrysemys picta)*	35	Breeding population in Pogue; common
Snakes		
Milk Snake *(Lampropeltis triangulum)*	1	Status unknown
Redbelly Snake *(Storeia occipitomaculata)*	1	Status unknown
Common Garter Snake *(Thamnophis sirtalis)*	5	Status unknown, but likely to be widely distributed

[a] Represents number captured in pitfall or minnow traps, and/or observed during area searches; except for Spotted Salamander, may include multiple counts of some individuals.

[b] Does not include estimates of individuals heard in breeding choruses during Calling Frog Survey.

[c] Represents one unconfirmed individual heard on Calling Frog Survey.

Rare Species

Significant breeding populations of Jefferson Salamander were documented on each of the three land parcels surveyed in this study. Of these 3 populations, the largest occurred at MABI, centered around the breeding pools north and east of the Pogue (Fig. 1). Under a cooperative agreement with the U.S. Fish and Wildlife Service, this population, along with the syntopic Spotted Salamander population, was studied with radio telemetry between May and November 2000 to better understand the specific forest stands and habitats utilized (Faccio 2001). The Jefferson Salamander is considered a "Species of Special Concern" by the Nongame and Natural Heritage Program of the Vermont Fish and Wildlife Department (VT-listed as S2). In addition, the Northeast Endangered Species Technical Committee recently listed the Jefferson Salamander as a species of regional conservation concern, indicating that; a) the species is at high risk of extirpation from the region, b) few data exist with which to address conservation concerns, and c) a significant portion of the species range occurs in the Northeast and that without conservation attention, the global population could be at risk (Therres 1999).

Drift Fences

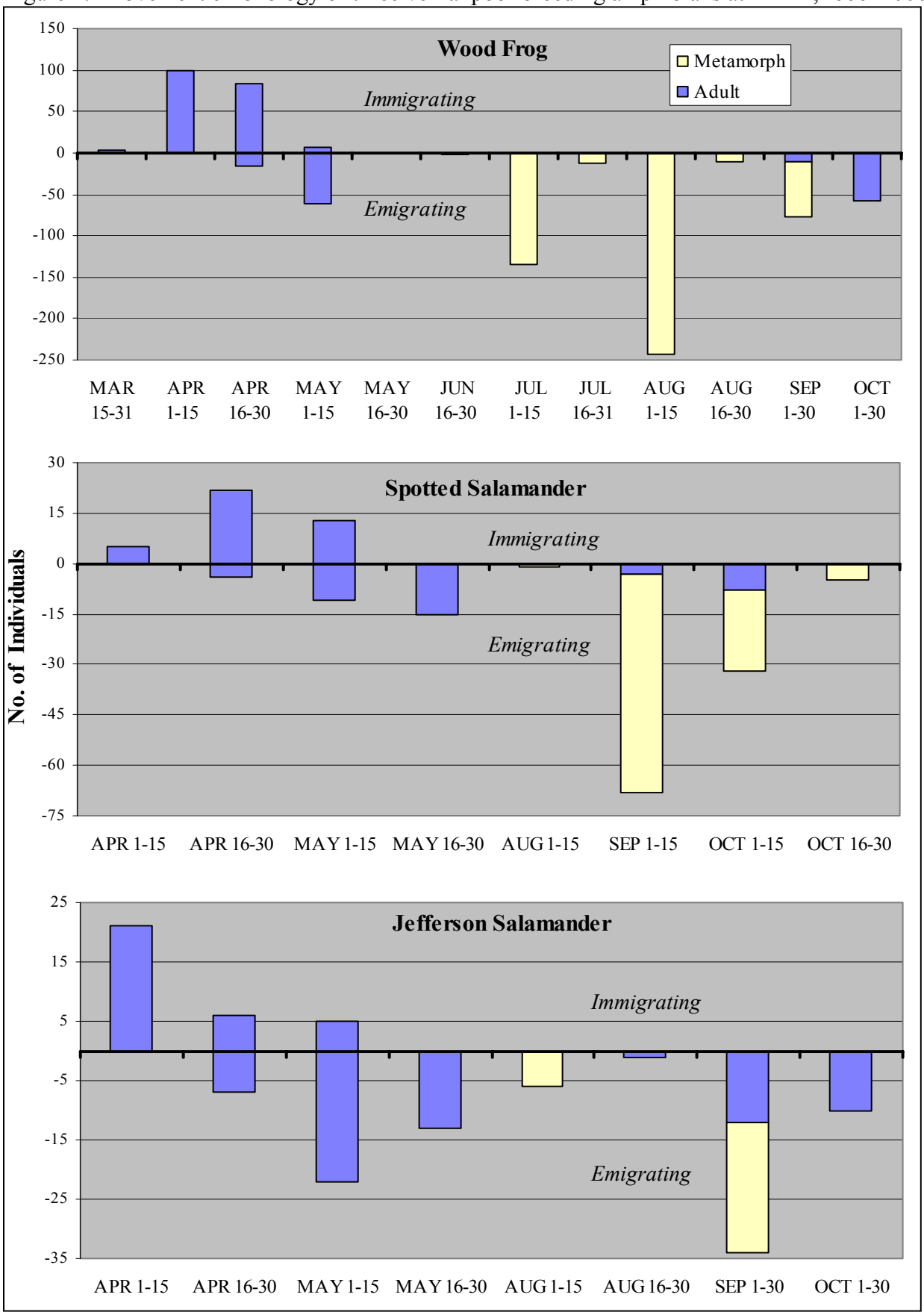
Drift fence/pitfall traps were operated on 58 different occasions for a total of 208 trap-nights (trap-nights = the number of fences opened x the number of nights operated). A total of 2,043 amphibians of 11 different species were captured in drift fence/pitfall traps (Table 3). Of these, 4 species – Wood Frog, Jefferson, Spotted, and Red-backed salamanders – made up 96.5% of all captures. Seasonal variations in both species captured and their relative abundance was closely tied to breeding phenology and weather. Lack of rainfall during June and July 1999 limited trapping effort during that period, while above normal rainfall occurred during the same period in 2000. As expected, early vernal pool breeding amphibians such as Wood Frogs, and Jefferson and Spotted salamanders, showed peak activity in April and May, with another period of activity between July and October when adults and metamorphs emigrated away from breeding and summering sites (Fig. 2). The terrestrial breeding Red-backed Salamander, which was found in high densities around the drift fence study sites (probably due to the moist microclimate in the area), also showed activity peaks in May and again in late summer (Aug./Sept.).

Wood Frogs and Spotted Salamander populations showed distinct male-biased sex ratios of approximately 2:1 and 2.6:1 respectively, while captures of adult Jefferson Salamanders showed a slightly female-biased sex ratio of 1.4:1 (Table 3, Fig. 3). Drift fence captures by age class revealed insights into the productivity of the breeding pools and use of the area by adult and juvenile amphibians (Fig. 4). A total of 622 metamorphs were captured, of which 483 were Wood Frogs, followed by Spotted Salamanders (96 individuals), Jefferson Salamanders (28), Red-spotted Newts and Spring Peepers (7 each), and Red-backed Salamander (1). In addition, a high number of juvenile Red-backed Salamanders (87 individuals), Wood Frogs (59), and American Toads (34) were captured in drift fences, compared with relatively few Green Frogs (5), Red-spotted Newts (2), and Spotted Salamanders (1).

Table 3. Drift fence/pitfall trap captures by species and sex, 1999-2000.

Species	Adult Males	Adult Females	Unknown Sex	Metamorph	Total
Amphibians					
Jefferson Salamander	46	62	14	28	150
Spotted Salamander	70	27	6	96	199
Red-backed Salamander	215	194	276	1	685
Red-spotted Newt	2		9	7	18
Two-lined Salamander			3		3
Wood Frog	254	117	59	483	937
American Toad	3	3	39		45
Bullfrog	1	0	0		1
Green Frog	1	5	7		13
Pickerel Frog			2		2
Spring Peeper	3	4		7	14
Amphibian Total	**595**	**412**	**414**	**622**	**2,043**
Mammals					
Meadow Vole			50		
Short-tailed Shrew			105		
Masked Shrew			127		
Smokey Shrew			7		
Unknown Shrew			1		
Peromyscus spp.			33		
Woodland Jumping Mouse			4		
Star-nosed Mole			1		
Hairy-tailed Mole			1		
Mammal Total			**329**		

Figure 2. Movement chronology of three vernal pool-breeding amphibians at MABI, 1999-2000.



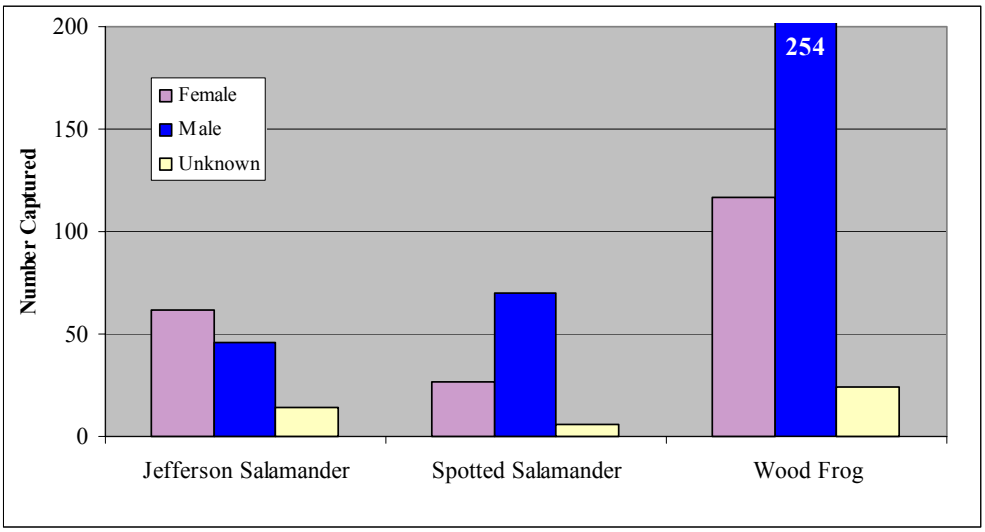


Figure 3 Adult sex ratio of three vernal pool-breeding amphibians captured in drift fences at MABI, 1999-2000.

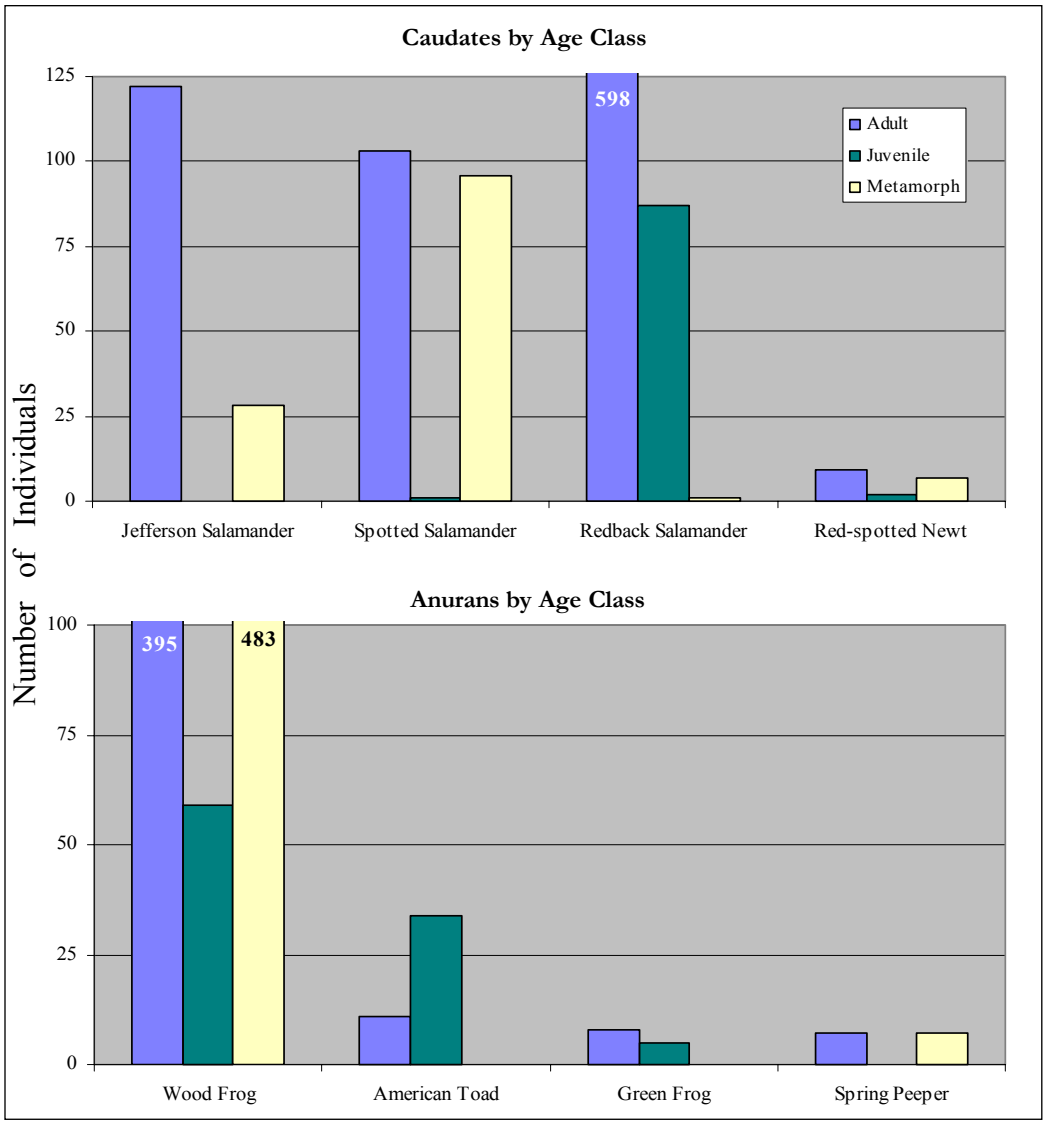


Figure 4. Drift fence captures of caudate and anuran amphibians by age class at MABI, 1999-2000.

Recaptures

At least 7 Spotted Salamanders (5M, 2F) identified by their unique spot pattern, and 1 unknown sex Jefferson Salamander (identified by a uniquely shaped tail) were recaptured in drift fences subsequent to their original capture. Only one individual was captured during both years of the study. This animal, a female Spotted Salamander, was first encountered entering the Field-Wetland North on 5 May 1999, and was recaptured in an adjacent pitfall trap of the same drift fence on 2 May 2000. This low number of recaptures was insufficient to permit population estimates using mark/recapture statistics.

In addition to amphibians, 329 small mammals of 8 species were captured in drift fence/pitfall traps (Table 3). Of these, 3 species, Meadow Vole, Masked Shrew, and Short-tailed Shrew, made up 85.7% of all mammal captures.

Minnow Trapping/Egg Mass Counts

To sample vernal pool breeding amphibians, minnow trapping was conducted at 12 potential breeding pools between 9 and 28 April, 1999 and 29 March and 21 April, 2000. As many as 5 minnow traps were placed in each pool during 14 trapping sessions for a total of 1,571 trap-hours (trap-hours = # of traps x total hours in pool). One hundred and thirteen individuals of 4 species (Jefferson, and Spotted salamanders, Red-spotted Newt, and Wood Frog) were captured in minnow traps at 8 different pools (Table 4). Of these 8 pools, 4 had eggs of Wood Frog, and Jefferson and Spotted salamanders present, 2 pools had Spotted Salamander and Wood Frog eggs, and 1 pool had just Spotted Salamander eggs. In addition, at the King Farm West and Hardwood-Wetland pools, where minnow trapping was unsuccessful, in 1999 four Spotted Salamander egg masses were observed at the former, and fifteen Wood Frog egg masses were observed at the latter. Finally, minnow trapping and egg mass counts at 2 small pools – the Pine Stand Pool, and the Hardwood Pool/Seep – revealed no sign of use by breeding amphibians (Table 5).

Table 4. Minnow trap captures by species and sex, 1999-2000.

Species	Adult Males	Adult Females	Unknown Sex	Total
Jefferson Salamander	34	1	0	35
Spotted Salamander	30	7	1	38
Red-spotted Newt	1		1	2
Wood Frog	29	2	7	38

Table 5. Presence/absence data for 12 pools monitored with minnow traps and egg mass counts, 1999-2000.

Pool Name	Total Minnow Trapping-hours	Species Captured in Minnow Traps	Species Egg Masses Observed
Field-Wetland North	72.0	Jefferson & Spotted Salamanders, Wood Frog	Jefferson & Spotted Salamanders, Wood Frog
Field-Wetland South	178.0	Jefferson & Spotted Salamanders, Red-spotted Newt, Wood Frog	Jefferson & Spotted Salamanders, Wood Frog
Hardwood-Wetland	39.0		Wood Frog
Pogue Roadside Pool	225.0	Jefferson Salamander, Wood Frog	Jefferson & Spotted Salamanders, Wood Frog
Pogue Pool North	344.5	Spotted Salamander, Red-spotted Newt	Spotted Salamander, Wood Frog
Saddle Pool	216.0	Jefferson & Spotted Salamanders, Wood Frog	Jefferson & Spotted Salamanders, Wood Frog
King Farm East	264.75	Spotted Salamander	Jefferson & Spotted Salamanders, Wood Frog
King Farm West	20.5		Spotted Salamander
King Farm South	69.75	Jefferson Salamander, Wood Frog	Jefferson & Spotted Salamanders, Wood Frog
Scout Camp Pool	33.5	Spotted Salamander	Spotted Salamander
Hardwood Pool/Seep	54.0		
Pine Stand Pool	54.0		
Total	1,571.0		

Nocturnal Calling Frog Surveys

Seven calling frog surveys were conducted each year for a total of fourteen survey nights. During 1999, surveys were conducted on 6, 16, and 28 May, 2, 17, and 25 June, and 1 July, while in 2000, surveys occurred on 6, 20, and 31 May, 13 and 28 June, and 17 and 31 July. At least one species of frog were detected during each survey.

The Pogue

A total of 5 frog species were identified at the Pogue during calling frog surveys; American Toad, Pickerel Frog, Green Frog, Spring Peeper, and Northern Leopard Frog (Table 6). All but the Northern Leopard Frog appear to have significant breeding populations in the Pogue. Green Frog and Spring Peeper were the most abundant and widespread species, and were detected at all 6 Pogue listening stations in addition to both Field-Wetland pools. Green Frogs were heard on 11 of 14 survey nights (78.6%) as early as 16 May and as late as 31 July. Spring Peepers were heard during 9 of 14 survey nights (64.3%) between 6 May and 17 June. Pickerel Frog and American Toad were less numerous and less widespread. Pickerel Frogs occurred at all 6 Pogue stations on 7 of 14 survey nights (50%) between 6 May and 2 June, while American Toads were heard at 5 Pogue stations on 3 survey nights (21.4%) between 16 and 31 May.

Table 6. Results of Calling Frog Surveys at MABI, 1999-2000. Call intensity codes given are as follows: Code 1 = all calling individuals can be clearly heard and counted, ample time between calls; Code 2 = some overlap of calls between individuals of a species; Code 3 = full chorus; species calls are constant, and overlapping.

		LISTENING STATION a									
SPECIES	**DATE**	**P-1** Pogue N side near vernal pool	**P-2** Pogue NW corner	**P-3** Pogue SW corner at Cattails	**P-4** Pogue S side at Cattails	**P-5** Pogue SE corner at outlet	**P-6** Pogue NE at road side pool	**F-1** Field-Wetland South pool	**F-2** Field-Wetland North pool	**H-1** Hardwood Wetland south end	**H-2** Hardwood Wetland north end
American Toad	5/16/99		1	1	1						
	5/28/99				1		1				
	5/31/00		3	3	3	2					
Wood Frog	5/6/00							1	1		
Green Frog	5/16/99						1	1			
	5/28/99	1			1		1				
	6/2/99	3	3	3	3	3	3				
	6/17/99	1		1	1		1				
	6/25/99	1	1	1	1	1	1				
	7/1/99	1	1	1	1	1	1				
	5/31/00	1		1	1		1				
	6/13/00	1		1	1		1				
	6/28/00	1	1	1	1		1				
	7/17/00	1			1		2		1		
	7/31/00				1		1				
N. Leopard Frog	5/16/99		1								
Pickerel Frog	5/6/99		1				1				
	5/16/99		1	1		1					
	5/28/99		1								
	6/2/99		3		3						
	5/6/00	1			1		1				
	5/20/00					1	1				
	5/31/00						1				
Spring Peeper	5/6/99	1	3	2	3	3	1	1	3		
	5/16/99	1	3	2			1	3	2		
	5/28/99		2		2			3	2		
	6/2/99		3		3			3	3		
	6/17/99										
	5/6/00	3	3	3	3			2	3		
	5/20/00	2	2	3	3		1	2	2		
	5/31/00	1	1	2	2		1		1		
	6/13/00	1	2	2	2		1		2		

[a] See Figure 1 for location of Listening Stations.

The single record for Northern Leopard Frog occurred on 16 May, 1999 at the northwest corner of the Pogue. Three other frog species were heard at the same time – American Toad, a full chorus of Spring Peepers, and Pickerel Frog, whose snore-like call is similar to that of the Leopard Frog. Given that the distribution of the Leopard Frog in Vermont is limited primarily to the Champlain Valley, with documented records from just 2 towns in the Connecticut River Valley (Andrews 2000), it seems possible that the call heard in this study could have been that of an aberrant Pickerel Frog rather than a Northern Leopard Frog.

Field-Wetland

Calling frog surveys at both the north and south pools of the Field-Wetland detected 3 frog species; Wood Frog, Green Frog, and Spring Peeper (Table 6). No frogs were heard during call surveys at the Hardwood-Wetland, although Wood Frog breeding was documented there during egg mass counts.

Two species that were expected to breed in the park, Bullfrog and Gray Treefrog (*Hyla versicolor*), were not detected during the calling surveys or active searches in 1999 or 2000. However, a single adult, male Bullfrog (85mm S-V) was captured in a drift fence on 5 May 1999 on the south side of the Hardwood Wetland.

Artificial Cover Boards

On average, cover boards were checked 2.8 times per month between 13 April and 24 November. Although all 3 transects were surveyed on the same day on 37 occasions (93.3%), the hardwood plot (HA) was checked a total of 41 times, the hardwood/hemlock plot (MI) 40 times, and the softwood plot (SO) was surveyed a total of 38 times. A total of 390 Red-backed Salamanders and 1 Red-spotted Newt were encountered under cover boards. Among the Red-backed salamanders, 26.9% were adult, 56.9% were sub-adult, and 16.4% were juvenile (Table 7). Within these three size classes, there was a significant difference in the distribution of adults between the three study plots (Kruskal-Wallis test = 6.053, $P = 0.048$) but not for sub-adult or juveniles. When compared to the SO transect, adults were significantly more abundant at both the HA (Mann-Whitney U test = 258.00, $P = 0.025$) and MI (Mann-Whitney U test = 233.00, $P = 0.029$) study plots.

Numbers of Red-backed Salamanders observed under cover boards differed significantly by year (Mann-Whitney U test = 677.500, $P = 0.002$), with 106 observed in 1999 and 284 in 2000 (Table 7, Fig. 5). Monthly Red-backed Salamanders counts per survey varied considerably from lows of 1.0 in April and August 1999, to a high of 20.3 in September 2000 (Fig. 5). In general, counts of Red-backed Salamanders were highest in the spring and fall, and lowest in summer.

Table 7. Number of Red-backed Salamanders observed under cover boards by plot, year, and size class, 1999-2000.

Plot	Size Class	1999	2000	Total
Hardwood	Adult	12	32	44
	Sub-adult	31	43	74
	Juvenile	5	17	22
Mixed Wood	Adult	10	29	39
	Sub-adult	22	60	82
	Juvenile	7	24	31
Softwood	Adult	4	18	22
	Sub-adult	14	51	65
	Juvenile	1	10	11
Total		106	284	390

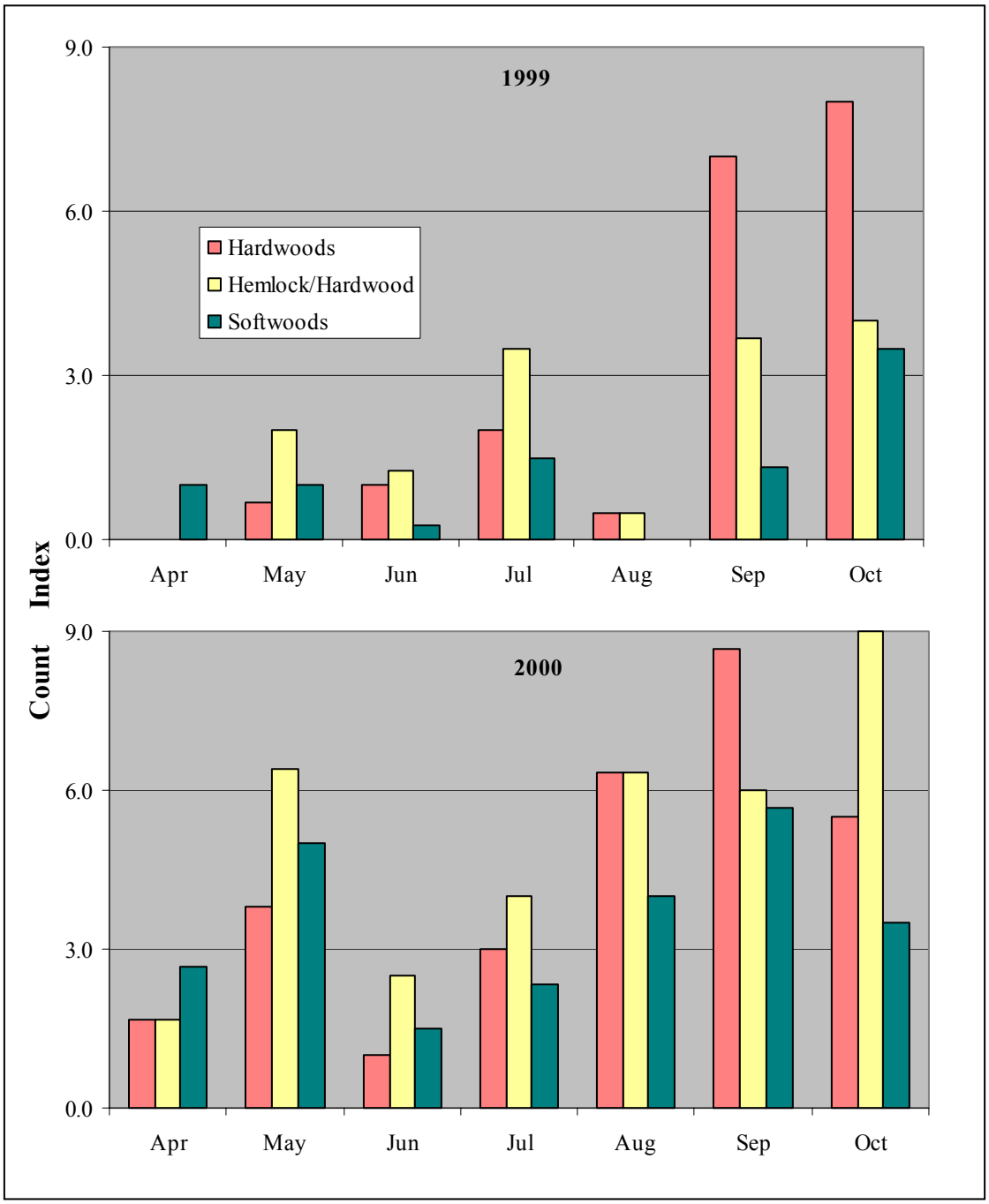


Figure 5. Monthly Red-backed Salamander counts/survey at three coverboard transects by year.

The relationship between habitat characteristics and the distribution and abundance of adult Red-backed Salamanders among the 3 cover types was analyzed by means of correlation and regression analyses on a subset of 10 uncorrelated ($r<0.80$) habitat variables (Table 1). The three best univariate associations and the best multivariate model (based on maximum adjusted r^2) are presented in Table 8.

Significant positive relationships were found between adult Red-backed Salamander abundance and soil pH, percent forbs, canopy height, and canopy closure. Several studies have shown that soil/humus pH can limit the distribution and abundance of Red-backed Salamanders and other amphibians (Wyman and Hawksey-Lescault 1987, Wyman 1988, Wyman and Jancola 1992). In this study, cover boards with the highest counts of adult salamanders had a mean soil pH of 5.60 (range = 4.80 – 6.40), while boards with the lowest counts had a mean pH of 5.04 (range = 4.60 – 6.00). Overall, the softwood transect had a lower mean pH (5.17) than either the mixed (5.37) or hardwood sites (5.33). In contrast to the results of others (Heatwole 1962, deMaynadier and Hunter 1998, Messere and Ducey 1998), percent leaf litter was negatively correlated with salamander abundance, possibly due to the thick, complete needle layer present in the SO plot and the fact that I did not distinguish between percent hardwood litter and percent conifer litter within the habitat plots.

Table 8. Summary of regression analyses for adult Red-backed Salamander-habitat relationships at cover board transects in three different forest cover types, 1999-2000.

Model Variables	**Correlation**	r^2 **(adjusted)**	***P***
Soil pH	+	0.225	0.020
Percent forbs	+	0.177	0.037
Percent litter	–	0.098	0.097
Soil pH, canopy height, canopy cover, % litter, % forbs, % green cover	+, +, +, –, +, –	0.421	0.034

Time-constrained Visual Encounter Surveys

Major habitat types were actively and systematically searched for reptiles and amphibians during 45 sessions on 27 days between 21 April 1999 and 16 September 2000. Most VES were conducted by 1 to 3 people, but parties of 4, 5, 7, and 10 individuals conducted surveys occasionally. A total of 748 individuals of 12 species were encountered during 103.26 person-hours of searching (7.25 animals/person-hour) (Table 9).

Table 9. Species and number of individuals encountered per person-hour of searching during time-constrained visual encounter surveys in 8 different habitat types, 1999-2000. Person-hours searched in each habitat type is given in parenthesis.

	Number Encountered/Person-hour [a]								
SPECIES	**Hardwood Forest** (23.0)	**Hayfield** (14.1)	**Hemlock Forest** (3.25)	**Mixed Forest** (9.25)	**Softwood Forest** (4.25)	**Pine Plantation** (6.75)	**Stream** (38.66)	**Forested Wetland** (4.0)	**Total** (103.26)
American Toad	0.22	0.36							0.10
Green Frog							0.08		0.03
Wood Frog	0.13		0.31	0.54				1.75	0.16
Spring Peeper	0.04							0.25	0.02
Spotted Salamander	0.04		0.31	0.11		0.15			0.04
Jefferson Salamander				0.22					0.02
Red-backed Salamander	10.13		4.00	10.27	1.65	3.41	0.05	2.00	3.69
Red-spotted Newt	0.39		0.62	0.54		1.04		0.50	0.24
Two-lined Salamander							6.84		2.56
Dusky Salamander							0.54	1.50	0.26
Unkn. plethodontid larvae							0.34		0.13
Snapping Turtle								0.25	0.01
Red-bellied Snake				0.11					0.01
Total	10.95	0.43	5.24	11.79	1.65	4.59	7.85	6.25	7.25

[a] *Person-hours = number of hours searched x number of persons searching*

To test if relative abundance and species richness was simply due to the amount of time spent searching within a particular habitat, the total hours searched was compared with the number of individuals per person-hour and the number of species encountered (Fig. 6). Within each habitat, both the number of individuals ($r^2 = 0.123$, $P = 0.392$) and the number species found ($r^2 = 0.074$, $P = 0.515$) was not influenced by the time spent searching indicating that VES can be used to compare both relative abundance and species richness between habitats. Two species, Red-backed and Two-lined salamanders, accounted for the majority of individuals counted (50.9% and 35.3% respectively). Across all habitats except hayfield, an average of 3.7 Red-backed Salamanders were found per person-hour of searching, while in favorable cover types, roughly 10 individuals were encountered per person-hour, compared to low counts of 1.7 to 2.0 individuals per person-hour in less favorable habitats (Table 9).

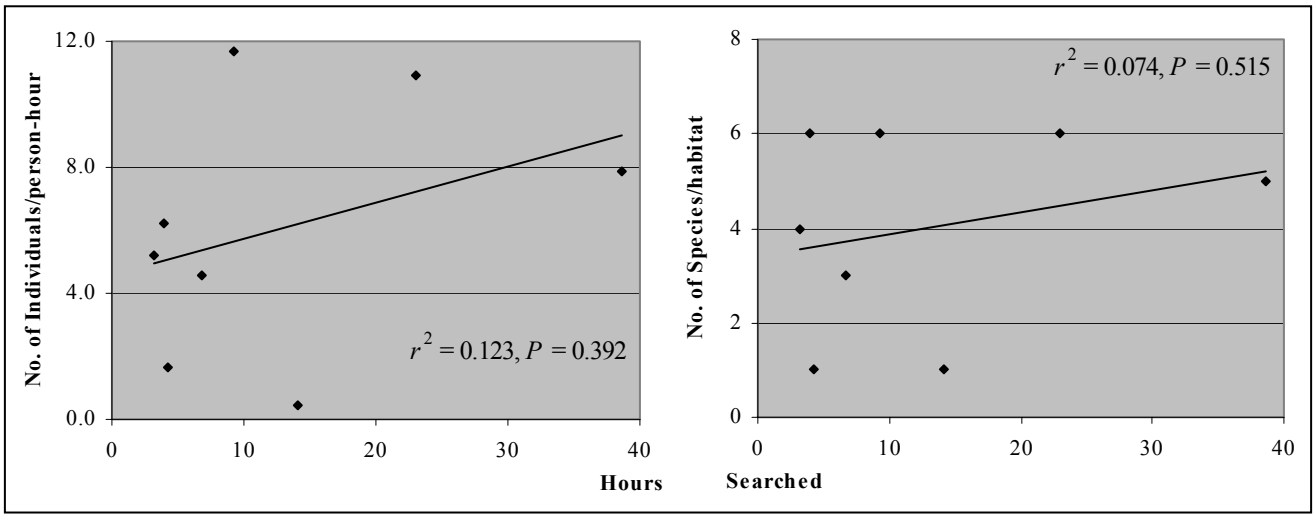


Figure 6. The relationship between visual encounter survey effort, and relative abundance (left) and species richness (right), 1999-2000.

Species Richness, Diversity, and Relative Abundance

Among the 8 major habitat types within the park, the highest species richness was encountered in those with suitable microclimates associated with closed canopied, deciduous-dominated forest stands, and wet sites (Table 10; Fig. 7). Habitats with the fewest number of species present were those with generally poor microclimates, low vegetative structure (conifer stands and plantations, and hayfields) and a history of habitat disturbance (conifer plantations and hayfields). Shannon diversity indices for each habitat are presented in Figure 7 and Table 10. Diversity accounts for the number of species in each habitat as well as the number of individuals per species (evenness). Among terrestrial habitats, hardwood/hemlock forests had the highest relative abundance of reptiles and amphibians (11.79), followed by hardwood stands (10.95), and forested wetlands (6.25), while those with the lowest were pine plantations (4.59) and hayfields (0.43) (Table 10; Fig. 7).

Table 10. Species richness, relative abundance, and Shannon diversity indices based on 45 visual encounter surveys for 8 major habitat types at MABI. Relative abundance and diversity ranks appear in parentheses.

Habitat Type	Species Richness	Relative abundance [a]	Diversity Index
Forested Wetland	6	6.25 (4)	1.181 (1)
Hardwood/hemlock Forest	6	11.79 (1)	0.564 (3)
Hardwood Forest	6	10.95 (2)	0.366 (5)
Stream	5	7.85 (3)	0.334 (6)
Hemlock Forest	4	5.24 (5)	0.790 (2)
Pine Plantation	3	4.59 (6)	0.447 (4)
Hayfield	2	0.43 (8)	0.000 (7)
Conifer Forest	1	1.65 (7)	0.000 (7)

[a] Number of individuals encountered/person-hour

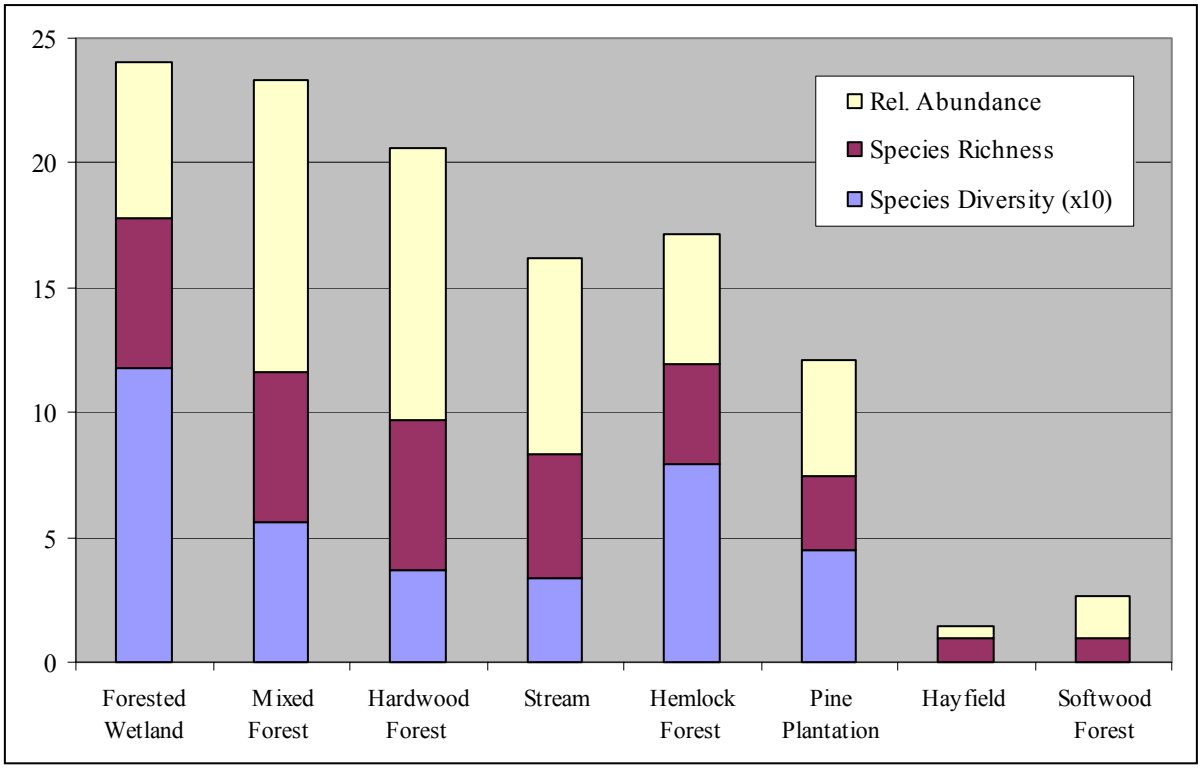


Figure 7. Relative abundance, species richness, and diversity by habitat based on visual encounter surveys, 1999-2000. (n=45)

Paired Visual Encounter Surveys

In order to more effectively compare the abundance and distribution of amphibians in hardwood-dominated stands with pine plantations and conifer-dominated stands, paired VES were conducted within these habitat types on 12 occasions between 13 May 1999 and 17 August 2000 for a total of 30.5 person-hours. A total of 326 individual amphibians of 6 species were encountered, although the majority (88%) were Red-backed Salamanders (Table 11). When counts of all species were summed, significantly more individuals were found in hardwood/mixed forest stands than in plantations/conifer stands (Wilcoxon Signed Rank Test = 2.936, P = 0.003). Red-backed Salamanders were also more abundant in hardwood stands (Wilcoxon Signed Rank Test = 2.943, P = 0.003).

Table 11. Counts of amphibians observed in paired visual encounter surveys within hardwood/mixed stands and conifer stands, 1999-2000. (n=12)

Species	**Hardwood/Mixed Forests**	**Conifer Forests/ Plantations**
American Toad	5	0
Wood Frog	7	1
Spring Peeper	1	0
Red-backed Salamander	244	43
Red-spotted Newt	13	9
Spotted Salamander	1	2
Total	271	55

Notes on Amphibian Breeding Pools

Twelve potential breeding pools were monitored for amphibian use during the 1999 and 2000 spring/summer seasons (Fig. 1; Table 5) and notes were kept on the hydrological cycle of each pool. Two of these pools (Saddle Pool and Pogue Pool North) were included in a state-wide study of vernal pools being conducted by the Biomonitoring and Aquatic Studies Section of the Vermont Department of Environmental Conservation's (DEC) Water Quality Division. The project, led by biologist Jim Kellogg, evaluated the macroinvertebrates, amphibians, vegetation, and water chemistry of vernal pools located in different physiographic regions of the state to get an idea of the biological variability associated with temporary pools.

Rainfall between April and August varied significantly between the two years, with an average of 2.03 inches during the 5-month period in 1999 compared to 4.90 inches during the same period in 2000 (Woodstock Village Cooperative Weather Station, National Weather Service Webpage, http://www.nws.noaa.gov/er/btv/). During 1999, all 11 pools were completely dry by 11 July, with drying dates ranging from 28 April to 11 July. Jefferson and Spotted salamander larvae apparently suffered high mortality rates at most or all pools during the 1999 breeding season as no metamorphs were observed or captured in drift fences. Wood Frog larvae may have had a higher survival rate as 10 juveniles (avg. size = 19.4 mm) were captured in drift fences on 27 August, and metamorphs were observed on several occasions around the Field-Wetland. During 2000, only 3 pools dried completely – the Scout Camp Pool dried by 11 July, the Pogue Roadside Pool by 6 July, and the Pogue Pool North dried by 25 August. Amphibian productivity improved noticeably in 2000 with 124 Ambystomatid salamander metamorphs and 483 metamorph Wood Frogs captured in drift fences (Figs. 2 and 4). In addition, Ambystomatid metamorphs were observed during active searches at 3 pools that were not monitored with drift fences.

Field-Wetland – North and South Pools

Located to the east of the Pogue and just west of a large hayfield/cattle pasture at an elevation of 1,150 feet, the Field-Wetland (FW) consists of 2 distinct breeding pools in a shallow, shrub-dominated, mossy wetland within a hemlock/hardwood canopy. The 2 FW breeding pools are not contiguous, but are separated by a narrow, 20 m long, seasonal seep that was mostly dry during 1999. During periods of high water, the north pool (FWN) drains slowly northeastward through a seep, while the south pool (FWS) drains slowly to the south through a seep. Drift fence #1 bordered the eastern edge of the FWS and drift fence #2 bordered the western edge of the FWN. Both pools are well-shaded by a nearly closed canopy.

Both pools have substantial breeding populations of amphibians, including Jefferson and Spotted salamanders, Wood Frogs, Spring Peepers, and Red-spotted Newts. Large numbers of egg masses of both salamander species and Wood Frogs were observed in the pools during April and May in both years. Maximum counts included 133 Jefferson Salamander egg masses on 18 May 2000, and 57 Spotted Salamander egg masses on 16 May 1999 in the FWN, and 58 Wood Frog egg masses in the FWS on 20 April 2000. Among the several other breeding pools in this area of

the park, the 2 Field-Wetland pools appear to be the most important to breeding populations of amphibians, particularly Ambystomatid salamanders and Wood Frogs. In addition, on 1 May 2001, a juvenile Painted Turtle (carapace length = 5.0 cm) was found basking in the FWN, suggesting this site may provide important overwintering conditions for young turtles. Moss mats and hummocks were actively searched on 22 April 1999 for the presence of Four-toed Salamanders but none were encountered. Although conditions look suitable for this rare species, the elevation may be limiting as they have not been found breeding above 1,000 feet in Maine or Massachusetts (A. Richmond, personal communication).

Hardwood-Wetland

Located approximately 200 m northwest of the Field-Wetland, the Hardwood-Wetland (HW) is a shallow, shrub-dominated wetland in a hardwood-dominated forest, at an elevation 1,150 feet. This site has many grassy hummocks, less moss than the FW, and little open water available for breeding amphibians. One small breeding pool (ca. 2 x 3.5 m) was located on the south-central side of the wetland. Drift fence #s 3 and 4 flank the north and south sides of the HW.

Use of the HW for egg laying by pool-breeding amphibians appears to be limited to a small population of Wood Frogs. On 21 April 1999, actively calling Wood Frogs and about 15 egg masses were present in the small pool mentioned above. Wood Frog metamorphs were captured in drift fences at the HW suggesting successful metamorphosis probably occurred. Although both Jefferson and Spotted salamanders were captured in drift fences 3 and 4, no evidence (e.g. spermatophores, egg masses, etc.) was found to indicate that either species used the HW for breeding. Recaptures of 2 Spotted Salamander individuals suggest that salamanders may pass through the HW enroute to the FW for breeding. However, the moist microclimate of this wetland may provide important summer habitat for many amphibian species, particularly in drought years.

In addition, based on the two following observations, a Snapping Turtle apparently used the HW as a hibernaculum during the winters of 1998-99 and 2000-2001. On 21 April 1999, while searching the HW for presence of amphibians, an adult Snapping Turtle (carapace length = 35 – 40 cm) was observed basking in shallow water next to a large (ca. 60 x 90 cm) hummock. As the turtle was approached it submerged beneath a log. Probing with a stick, the turtle's carapace could be felt about 50 cm beneath the log and hummock. On 1 May 2001, an adult Snapping Turtle, with a carapace measuring 37 cm, was encountered moving across a park carriage road between the HW and the Pogue. The turtle continued without stopping and entered the Pogue. Because of the proximity of this wetland to the Pogue (ca. 75 m) it may be an important over-wintering site for Snapping and Painted turtles as well some amphibian species.

Pogue Roadside Pool

The Pogue Roadside Pool appears to have been artificially created when the carriage road around the Pogue was constructed. Located near the northeast corner of the Pogue, the pool is surrounded to the north by hardwood forest and to the south by a carriage road and the Pogue.

This lack of forest cover to the south exposes the small, shallow pool to a high level of solar radiation, increasing water temperature and evaporation. The pool was monitored with minnow traps, and visually by egg mass counts and observations.

At least 3 species of amphibians laid eggs in the Roadside Pool. Maximum counts of egg masses for these 3 species were; 8 Jefferson Salamander, 11 Spotted Salamander, and 12 Wood Frog. However, it doesn't appear that any larvae transformed before the pool dried up on 22 June, 1999, and 6 July 2000.

Pogue Pool North

The Pogue Pool North is a small, shallow vernal pool approximately 100 m northwest of the Pogue Roadside Pool. Located in a hardwood forest with a partially closed canopy, the pool is in close proximity to the Pogue (ca. 25 m) and 2 carriage roads. This pool is 1 of 2 in the study area that is included in a state-wide investigation of vernal pools being conducted by the Vermont DEC. Amphibian use of the pool was monitored by minnow trapping, egg mass counts, and observations.

At least 2 species of amphibians laid eggs in the Pogue Pool North; with maximum counts of 19 Spotted Salamander egg masses and 7 Wood Frog eggs. No amphibian larvae survived to metamorphosis in 1999 due to the rapid loss of water. Even though the pool did not dry completely until late August 2000, the water level was very low by 5 July, and no metamorphs could be confirmed in the area surrounding the pool.

Saddle Pool

The Saddle Pool is a small, ridge-top vernal pool of medium depth, located in a saddle at an elevation of 1,200 feet just south of the summit of Mt. Tom, on land adjacent to MABI and owned by the Town of Woodstock. The well-shaded pool is surrounded by hemlock/conifer forest to the south, and hardwood forest to the north. The area just east of the pool is steep and rocky with exposed cliffs and many large boulders. Immediately west of the pool is a carriage road leading to a scenic vista. Of all the pools monitored, the Saddle Pool was the last to lose ice cover (it was still 90% ice-covered on 9 April 1999 when 1 female Jefferson Salamander was captured in a minnow trap), and routinely had water temperatures 3-9 degrees F lower than other pools. Accordingly, the Saddle Pool held water until 6 July 1999, longer than all other pools except the Field-Wetland, and it never dried completely in 2000. The Saddle Pool, in addition to the Pogue Pool North, is included in a state-wide vernal pool study being conducted by the Vermont DEC. The Saddle Pool was monitored with minnow traps, and visually by egg mass counts and observations.

The Saddle Pool has a significant population of breeding amphibians, including Jefferson and Spotted salamanders, and Wood Frogs. In May 1999, 66 Jefferson Salamander egg masses and

36 Spotted Salamander masses were counted in this relatively small pool. In contrast, only 3 Wood Frog egg masses were found. Successful productivity at the Saddle Pool was unlikely in 1999 due to dry weather conditions, but both Spotted and Jefferson metamorphs were found during searches around the pool's perimeter in July and August 2000. This site appears to be especially important to Jefferson Salamanders, and represents the only likely breeding site for this metapopulation.

Scout Camp Pool

Located approximately 450 m east of the Saddle Pool, the Scout Camp Pool is a small vernal pool in a mixed, white pine/hardwood forest at an elevation of 800 feet. The pool is adjacent to a boy scout camp building on Town of Woodstock property, and is in close proximity to the MABI southeastern boundary. The Scout Camp Pool had wide fluctuations in water level during a short period in 1999 that may or may not be related to the pool's proximity to the scout building. The pool was found to be nearly dry on 29 April, then full on 6 May; then completely dry on 17 May, and full 2 days later on 19 May. It was completely dry again on 11 and 18 June. During 2000, the water level was found to be very low on 1 and 16 June, and then dry on 6 July.

Monitored with minnow traps, and visually by egg mass counts and observations, only Spotted Salamanders were found breeding in the Scout Camp Pool, with 16 egg masses counted on 16 May 2000. It is unknown what effect the widely fluctuating water level had on the egg masses and/or larvae in the Scout Camp Pool, but it seems unlikely that any larvae survived to metamorphosis in either year.

King Farm – East, West and South Pools

Adjacent to the Park's southwestern border is the King Farm Property of the Vermont Land Trust. Three small pools were located here – the East and West Pools located near the northeastern boundary of the property, and the South Pool located about 400 m southwest in a hemlock-dominated stand. All 3 pools were monitored with minnow traps, and visually by egg mass counts and observations.

East Pool

The King Farm East pool, located within a northern hardwood/hemlock stand at an elevation of 1,200 feet, is similar to the Saddle Pool in size and depth. During 1999 the pool was dry by mid-June, and although the level was noted as "low" in late-May 2000, it held never dried completely. The East pool contains breeding populations of Wood Frogs, Jefferson, and Spotted salamanders, although only the latter of these appears sizeable. Egg mass counts revealed 2 Wood Frog, 6 Jefferson Salamander, and 26 Spotted Salamander egg masses. No metamorphs were documented here although a suitable hydroperiod occurred in 2000.

West Pool

Located just 40 m west of the East pool in a hemlock-dominated stand, the King Farm West pool is shallow and provides only marginal amphibian breeding habitat. The water level was very low on 16 June 1999 and completely dry by 4 July 1999. Breeding evidence consisted of just 4 Spotted Salamander egg masses in 1999, but none were present in 2000.

South Pool

The King Farm South pool was not discovered until October 1999. Located along a topographic "bench" on a relatively steep, southwest-facing slope at an elevation of 1,100, this small pool was surprisingly productive for salamanders. Twenty-nine Jefferson and 18 Spotted salamander egg masses were counted on 6 May 2000, along with 2 Wood Frog eggs. Metamorphs of all three species were found during a search in late-July. The water level of this pool did not drop during the 2000 season until late-August. The King Farm South pool appears to be especially important to Jefferson Salamanders, and like the Saddle Pool represents the only significant breeding site for this metapopulation.

Hardwood Pool/Seep

The Hardwood Pool/Seep is a shallow seep that was originally thought to be a vernal pool. It is located about 400 m north of the Pogue at an elevation of 1,200 feet in a hardwood stand, near the end of the Hardwood cover board transect. It was monitored for signs of breeding activity with minnow traps and observations but none was noted. This site does not appear to provide the necessary water depth or hydroperiod for breeding, but it may serve as an important "stepping stone" pool allowing dispersing juveniles to reach more suitable breeding sites.

Pine Stand Pool

The Pine Stand Pool is located at an elevation of 1,100 feet in a Scots Pine plantation near the northwestern boundary of the Park. The pool was monitored with minnow traps and was visited several times with no signs of breeding activity. It was found to be completely dry on 28 April 1999 and does not appear to provide the necessary conditions for breeding amphibians. Like the Hardwood Pool/Seep however, it may be an effective "stepping stone" pool for dispersing amphibians.

Discussion

In general, the herptofauna of the Marsh-Billings-Rockefeller National Historical Park was found to be typical for the park's location, size, and habitat types. Of the 20 species that were either expected or known to exist in the park prior to this study, only 2 were not confirmed as present; Gray Treefrog and Smooth Green Snake (*Opheodrys vernalis*). Despite targeted searches, the reticent Smooth Green Snake likely exists at MABI, particularly around the fields and the old ski hill on the adjacent property to the north. No federal or state endangered or threatened species were encountered during the 2-year inventory. The breeding populations of the rare (VT- S2) Jefferson Salamander are significant however. Populations of this area-sensitive species have declined in southern New England as a result of habitat fragmentation due to development, while populations of its congeners, the Blue-spotted (*Ambystoma laterale*) and Spotted salamanders, have increased or remained stable (Bodin 2001). Forest management in the areas of the MABI and adjacent parcels where this species is found should be avoided or kept to a minimum (see Forest Management Recommendations).

Distribution

The distribution of amphibian and reptile species within the MABI is dependant on life history traits, habitat requirements, and other factors.

Vernal Pool Breeders

Populations of the 3 species that are dependant on temporary woodland pools for breeding (Jefferson and Spotted salamanders, and Wood Frog) are concentrated in wooded habitats around those breeding sites (Fig. 1; Tables 2, 5). Results from my radio telemetry study at MABI (Faccio 2001) and from other studies with these species (Madison 1997, Semlitsch 1998, Kleeberger and Werner 1983), indicate that most Jefferson and Spotted salamanders remain within a 150 to 250 m radius of the breeding pool throughout the year, while Wood Frogs may disperse up to 600 m from a pool (P. deMaynadier, personal communication).

Stream Salamanders

The two species of stream salamander – Two-lined and Northern Dusky – breed only in the stream, its larger tributaries, and possibly adjacent seeps (Table 2). One clutch of Two-lined Salamanders eggs were discovered attached to the bottom of a rock in the stream channel near the northeast corner of the "summer pasture." Among these two species, the Two-lined Salamander is the more widely distributed, being found along the entire length of the stream, up several of its tributaries, and rarely captured in drift fences during extensive wet periods. The distribution of the Northern Dusky Salamander is limited primarily to the lower stream, northeast of "summer pasture," where the substrate is more gravelly, with less silt than up closer to the Pogue. Several Dusky Salamanders were found in mossy seeps adjacent to the stream along the steep hemlock ravine near the park's northeastern border. Numerous larvae, most of which

could not be identified to species, were encountered during stream searches suggesting that suitable productivity is occurring.

Pogue Breeders

The distribution of the 4 frog species that breed in the Pogue is quite variable (Tables 2, 6). Among them, the Pickerel Frog appears most limited in terms of its distribution and relative abundance. This species was found breeding only in the Pogue, two were captured in drift fences, and several were observed in grassy areas around the Pogue. Although several sources indicate that the post-breeding movements of Pickerel Frogs take them away from their breeding sites to meadows and damp woods, no data exist about emigration distances (Hunter et al. 1999, Klemens 1993). Breeding choruses of American Toads were also limited to the Pogue. Assemblages of hundreds of toad larvae were observed often along the dike at the Pogue's southeast end, and numerous metamorphs were encountered around the Pogue in late summer. In addition, 45 toads were captured in drift fences, and several adults were encountered in other areas of the park, suggesting their wide tolerance of habitats and environmental conditions enable them to be more widely distributed. Both Green Frog and Spring Peeper were found breeding in the Pogue and the Field-Wetland. While they are probably most abundant in the forested areas and field edges immediately surrounding these breeding sites, both species were found in the eastern half of MABI on several occasions. Adult Spring Peepers were found in a hardwood stand approximately 1 km east of the Pogue, and in a Norway Spruce seep near Route 12 north of the mansion. During stream searches, 3 adult Green Frogs were encountered along the stream in the hemlock gorge. Recent radio telemetry work in New York indicate that Green Frogs have the ability to make extensive movements (up to 560 m) away from breeding sites and may depend on streams and seeps as overwintering sites (Lamoureux and Madison 1999).

Red-backed Salamander

Results from both the artificial cover board transects and VES indicate that the terrestrial Red-backed Salamander is widely distributed throughout the park. However, while individuals were found in all forested habitats, their relative abundance was higher in hardwood and hardwood/hemlock stands than in pine and spruce forests and plantations. Significantly more Red-backed Salamanders were found in hardwood/mixed stands compared to coniferous stands in paired VES. Among the cover board experiment, significantly more adults were found in hardwood and mixed wood transects compared to the softwood site, while no difference in the distribution of sub-adult and juvenile salamanders among treatment classes was detected. This may indicate that adults are selecting and defending territories within hardwood/mixed stands, while younger, nonbreeding "floaters" are competitively excluded to less favorable conifer stands. In a Maine study, deMaynadier and Hunter (1998) found a higher proportion of immature Red-backed Salamanders in recently harvested areas adjacent to mature forest stands and postulated that these open-canopied sites may serve as sink habitats for nonbreeding animals. Experimental studies in natural habitats by Mathis (1990) and Gabor (1995) revealed significant correlations between Red-backed Salamander size and both the size of cover objects and the quality and quantity of prey within defended territories. My results indicate that homogeneous conifer stands and plantations offer less favorable habitat for Red-backed Salamanders and

possibly other terrestrial amphibians. In addition, the only Red-backed Salamander nest found during many person-hours of turning cover objects, was located under a rock (~ 40 cm^2 in size) on 28 July 2000 within a mature hardwood stand, 30-40 m west of the hardwood cover board transect. The clutch contained 8-10 embryos and 2 adult Red-backs were present.

My analyses of habitat variables among the cover board sites revealed several positive and negative associations that may have contributed to the lower abundance of Red-backed Salamanders in softwood stands. Several of these variables have been found to influence this species' distribution and abundance in other studies, including soil pH, canopy closure, and understory vegetation. Wyman and Hawksley-Lescault (1987) studied the effect of soil pH on the density and distribution of Red-backed Salamanders in New York. They showed that Red-backs avoided sites with high acidity and that their abundance was dramatically reduced on sites with a pH below 3.8. In general, needle-dominated organic layers are more acidic than deciduous litter (Wyman and Jancola 1992), which is supported by this study. deMaynadier and Hunter (1998) found a strong relationship between canopy closure and Red-backed Salamander abundance along forest edges in Maine. My results support these findings as well. Although red pine plantations often have completely closed canopies, the stand selected for the cover board transect contained several canopy gaps due to windthrows and tree harvests. The understories within these canopy gaps were regenerating with hardwood species, and may have contributed to the negative association with percent total green vegetation in the habitat analysis.

Turtles

As expected, only Painted and Snapping turtles were encountered within the park and adjacent lands (Table 2). Both species are largely confined to the Pogue, although observations indicate that the Hardwood- and Field-Wetlands may serve as important overwintering sites for some individuals. Although direct evidence of breeding was not confirmed, a juvenile Painted Turtle was found basking in the Field-Wetland, indicating that breeding has occurred. In addition, J. Wiggin (personal communication) has encountered Snapping Turtles laying eggs along the Pogue dike, and a Painted Turtle was observed laying eggs at the hilltop overlook, 200 m west of the Pogue, during July 2001 (T. Lautzenheiser, personal communication).

Snakes

Three snake species were documented at MABI during the study period – Eastern Garter Snake, Milk Snake, and Northern Redbelly Snake (Table 2). A fourth species, Smooth Green Snake, is likely to exist on the property but was not found. Due to their secretive nature, very few individual snakes were encountered, making it is impossible to accurately describe their distribution within the study area. However, inferences can be made about their distribution based on knowledge of their habitat associations both from experience and the literature. Although all 3 species are habitat generalists, the Garter Snake is likely to be the most abundant and widely distributed. This is supported simply by the proportion of Garter Snakes to other snakes (5:1) that were encountered during all phases of field work. The Redbelly Snake is likely to have the most specialized habitat requirements of the three species. Although they frequent a

wide variety of upland habitats, including deciduous forests, conifer woods, bogs, powerline cuts, and occasionally meadows and yards, Redbelly Snakes appear to prefer moist conditions, and especially moist woodlands (Klemens 1993, DeGraaf and Rudis 1986). The only specimen found during this study was located on 6 July 1999 under a piece of flaking bark on a large rotten hemlock log along the stream/meadow edge, 50 m downstream from the Pogue. Milk Snakes tolerate a wide variety of habitats, including dry and moist woodlands, rocky hillsides, old fields, and are often found in and around outbuildings, barns, and abandoned foundations (Klemens 1993, DeGraaf and Rudis 1986). The single individual documented during the inventory was found in the empty swimming pool near the mansion (K. Jones, personal communication).

Management Recommendations

MABI has a long history of forest management dating back more than 100 years. Recent management practices have served multiple uses, from increasing recreational opportunities, to enhancing aesthetic and wildlife values, and production of forest products through timber harvesting (Wiggin 1993). Semlitsch (2000) reasoned that if a resource manager's goal is to maintain or enhance amphibian diversity, the following critical elements must be incorporated into management plans:

- Maintenance or restoration of temporary wetlands with a diverse array of hydroperiods;
- Protection of terrestrial buffer zones of natural vegetation and associated habitats to protect core breeding sites (wetlands and streams);
- Protection of amphibian communities from invasion by fish predators (both native and exotic);
- Protection of the integrity of ecological connectivity (i.e., stepping stone ponds with corridors of natural vegetation) among wetlands in the landscape;
- Restriction of chemical use (salt, oil, fire retardants, vegetation growth retardants, herbicides, pesticides) on site, but especially near ditches, streams, or wetlands;
- Prohibition of release of any captive-raised or maintained amphibians, whether native or exotic;
- Identify and resolve conflict between current management practices and those necessary for amphibians.

While it is unknown how past management practices at MABI have affected the herptile community, the following recommendations are intended to guide the development of an ecologically sound management plan that will promote biodiversity while maintaining the educational, aesthetic, and recreational values of the land.

Vernal Pools and Surrounding Terrestrial Habitat

A total of 10 temporary amphibian breeding pools were documented during this study – 5 on MABI, 2 on land owned and managed by the Town of Woodstock, and 3 on the King Farm property of the Vermont Land Trust (Fig.1; Table 5). While these pools are vital in maintaining breeding populations of several amphibian species, the surrounding forested habitats are equally important since all the species that utilize the pools for breeding live in the surrounding forest (usually within 200 m; Madison 1997, Semlitsch 1998, Faccio 2001) during the non-breeding season (≥ 11 months). Any management plan that focuses only on protecting the pool itself will probably fail to maintain viable amphibian breeding populations, therefore, identifying and protecting critical terrestrial habitat should be a priority (Marsh and Trenham 2001).

In identifying critical terrestrial habitat, it is important to consider amphibian metapopulation dynamics. A metapopulation is a set of local populations among which gene flow, extinction, and colonization may occur (Semlitsch 2000). Amphibian aggregations at individual breeding

pools rarely represent distinct populations. Instead, regular dispersal between ponds commonly occurs, particularly among juveniles. Two primary factors have been identified in controlling amphibian metapopulation dynamics: the number of individuals dispersing, and the dispersal distance and probability of successfully reaching ponds (Hanski and Gilpin 1991, Gibbs 1993). A recent study in Maine indicates that open, clear-cut areas are avoided by dispersing juveniles of vernal pool-breeding species (deMaynadier and Hunter 1999). Since clusters of vernal pools exist on each of the three properties in the study area, several metapopulations of Wood Frog, and Jefferson and Spotted salamanders inhabit each property. Therefore, conservation of these amphibian assemblages would be best-achieved by considering groups of pools as the management unit rather than individual pools. In addition, maintenance of forested habitats adjacent to ponds and between neighboring ponds will help maintain source-sink dynamics.

Specific Management Recommendations

The following management guidelines are recommended within a 200 m amphibian buffer zone surrounding each breeding pool cluster (Fig. 8).

- Avoid timber harvests, and agricultural activities (e.g., food plots, mowing, herbicide/pesticide use).
- Encourage coarse woody debris (cwd) on the forest floor by:
    - Discontinuing the policy of removing and/or chipping roadside slash and cwd;
    - Allow fallen limbs, trees, and other cwd to remain;
    - Leave large diameter snags and den trees;
    - Leave long-lived trees such as hemlock, spruce, pine, oak, and northern hardwoods as recruitment for future snags and cwd.
- Consider allowing the western portion of the 9-acre "summer pasture," and the eastern section of the 33-acre hayfield to regenerate into natural forest cover (Fig. 8). This will provide dispersal corridors between MABI breeding pools and those on adjacent lands, which may be particularly important to maintaining viable Jefferson Salamander metapopulations.

Riparian Zone

The single permanent stream, along with its associated seeps, provides the only breeding habitat for populations of Two-lined and Northern Dusky salamanders. It may also serve as important overwintering habitat for Green Frogs (Lamoureux and Madison 1999), and possibly other ranid species. Maintenance of a well-shaded riparian zone that is free from excessive erosion and siltation is required for the persistence of these amphibian populations.

Establishing a buffer zone necessary to maintain a functioning riparian ecosystem is dependant on many factors, including local climatic conditions, topography, geology, and vegetation. Many researchers have investigated the effects of riparian buffer zones on ecosystem processes.

These studies include the role of root strength on slope stability (Burroughs and Thomas 1977, Sidle et al. 1985), shade (Beschta et al. 1987, Takentat 1988), water quality (Lynch et al. 1985, Castelle et al. 1992) and wildlife (Erman et al. 1977, Rudolph and Dickson 1990, McComb et al. 1993). While, most of these studies indicate that a minimum buffer width of 30 m is necessary to avoid significant impacts on riparian environments, buffers up to 100 m are often recommended. Rudolph and Dickson (1990) found that reptile and amphibian populations were significantly lower in stream side habitats with narrow buffer widths (≤ 30 m) than those with wider buffer strips due to changes in air, soil, and water temperatures, relative humidity, and soil moisture resulting from increased solar penetration.

Specific Management Recommendations

With the exception of the hayfields near the Pogue and the old Mt. Tom ski hill at the park's northeast border, much of the stream is covered by a closed, hemlock-dominated canopy. Maintenance of this well-shaded environment is critical to the health of the stream community. At a minimum, a 60 m buffer on either side of the stream should be maintained (Fig. 8), within which the following management guidelines are recommended.

- Avoid timber harvests and herbicide/pesticide use.
- Encourage coarse woody debris (cwd) on the forest floor by:
    - Discontinuing the policy of removing and/or chipping roadside slash and cwd;
    - Allow fallen limbs, trees, and other cwd to remain;
    - Leave large diameter snags and den trees;
    - Leave long-lived trees such as hemlock, spruce, pine, oak, and northern hardwoods as recruitment for future snags and cwd.
- Avoid activities that will increase erosion and sedimentation of the stream channel (e.g., trail or carriage road construction, etc.).
- Divert carriage road drainage away from riparian zone.

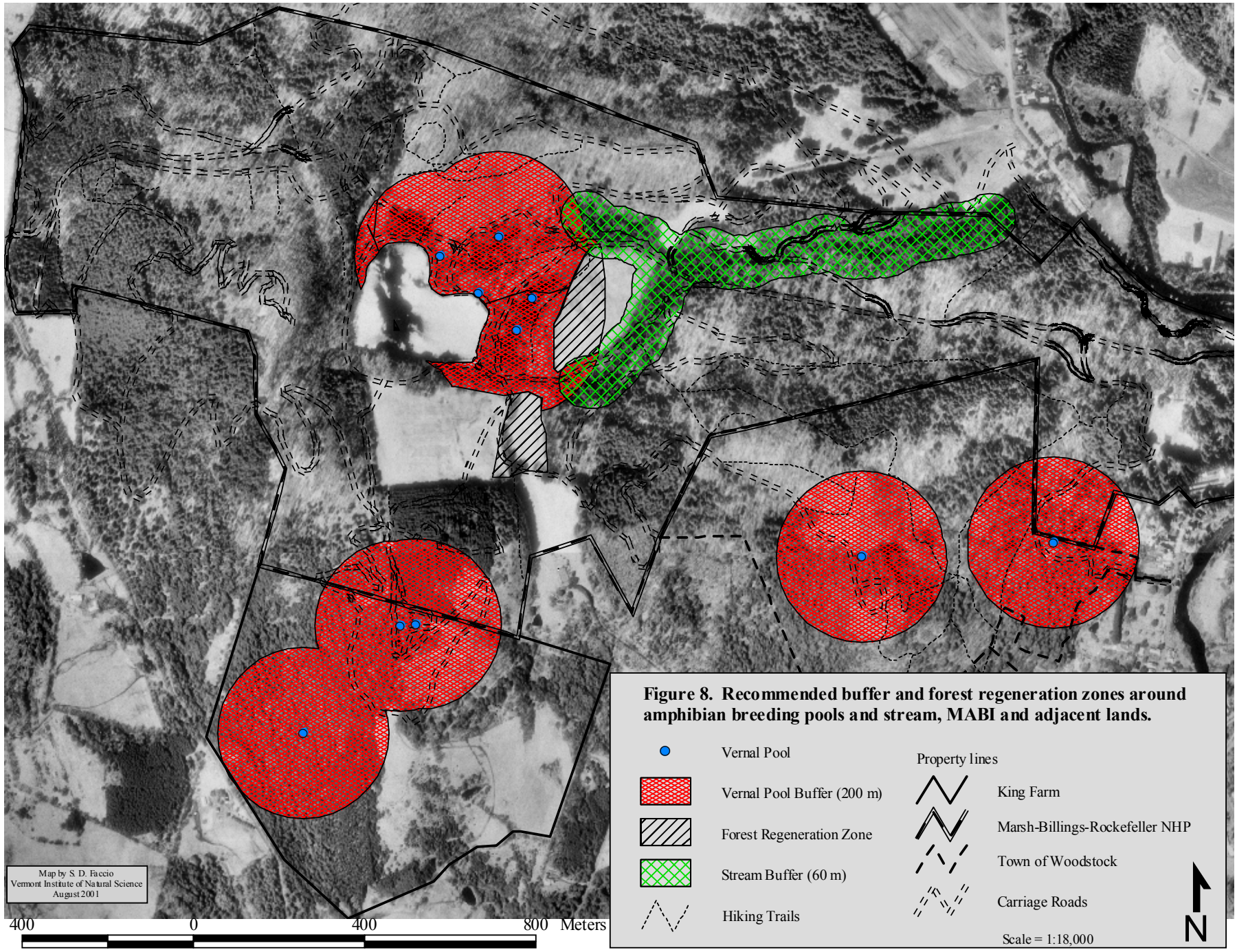


Figure 8. Recommended buffer and forest regeneration zones around amphibian breeding pools and stream, MABI and adjacent lands.

Conifer Plantations

Results from this study indicate that amphibian relative abundance, and species richness and diversity are lower in conifer plantations than in some natural forest cover types. This may be due to a variety of factors, including loss of understory structure, hardwood litter, and changes in other forest floor microhabitat variables. Wyman and Jancola (1992) found significantly lower species richness (2.0-2.8 versus 7.7 species) and density (0.08 m^2 versus 0.48 m^2) of amphibians in coniferous forests than in American beech forests in New York, and speculated that homogeneously low soil/humus pH in the conifer stands created a toxic microhabitat disruptive to amphibian sodium balance. Other studies have indicated that long-term effects on amphibians can be significant in conifer plantations, which are usually associated with intensive site preparations and stand management practices that modify levels of cwd and other microhabitats (deMaynadier and Hunter 1995).

Specific Management Goal

Slowly convert plantations in the western half of MABI (e.g., the red pine plantation south of the Pogue, and the red and Scotch pine, and spruce plantations north and west of the Pogue out to Prosper Rd.) to northern hardwoods over time (~30-50 years). Pursue specific management recommendations from a consulting forester that will encourage natural regeneration of northern hardwood species while conifer plantation species (e.g., red and Scotch Pine, and Norway spruce) are removed.

Monitoring Recommendations

Results from this, and other biological inventories at MABI, will help provide a framework upon which an ecologically sound management plan can be developed. In addition, a equally sound monitoring strategy should be implemented to assess ecological changes that may occur over time. These changes may be the result of stressors – physical, chemical, or biological entities that cause an adverse ecological effect (Lowrance and Vellidis 1995) – which disrupt ecological integrity and threaten ecosystem processes and stability (Karr 1996). Although it may be desirable to monitor all the plants and animals in a given study area or region, it is impractical due to financial and logistical constraints. Therefore, it makes sense to find species or groups of species who changes in abundance are likely to fluctuate with changes in the system, but that are reasonably easy, cost-effective, and statistically appropriate to monitor (Welsh and Droege 2001).

Amphibians are widely recognized as sensitive bioindicators of environmental change due their complex life histories, thin permeable skin which is in constant contact with their environment, and susceptibility to temperature extremes and drought. In the Northeast, most amphibians occur syntopically with many other small forest plants and animals, are often numerous, can be easily and inexpensively sampled, are positioned at mid-levels in the food web, and are highly sensitive to a variety of ecological stressors. Therefore, I propose the following three monitoring techniques, targeted to detect varying degrees of change among 3 different amphibian habitats; artificial coverboard transects, calling frog surveys, and vernal pool egg mass counts.

Artificial Coverboard Transects

Woodland amphibians, particularly plethodontid salamanders such as the Red-backs, have been shown to be excellent candidates for monitoring forest ecosystems. Welsh and Droege (2001) presented ecological, life history, and statistical data showing that salamanders in the genus *Plethodon* offer a logical, cost-effective metric for monitoring ecosystem integrity. Since the Red-backed Salamander is abundant and widespread within MABI, it would be a good indicator species for long-term monitoring.

Using input values (mean count and standard deviation) derived from data collected during the artificial coverboard (ACO) experiment in this study, I used the program *MONITOR* (Gibbs 1995, Eagle, et al. 2000) to determine the number of ACO plots needed to detect a declining trend of 3% per year with at least 90% power (Fig. 9). These results indicate that a minimum of 5 or 6 ACO transects would be needed to monitor relatively slight (3% or greater) changes in salamander abundance over 10 years. With 3 transects already established at MABI, an additional 2 or 3 transects would be required.

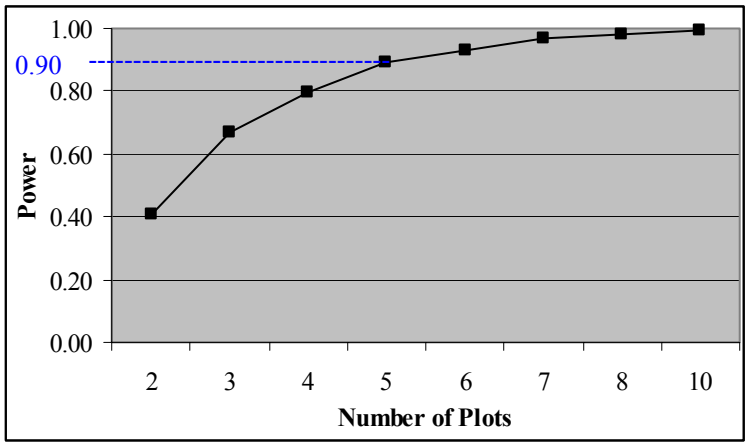


Figure 9. Number of artificial cover board plots and their power to detect an existing decline of 3% per year, assuming a 10-year survey, and 5 counts per year.

I propose the following protocol for monitoring abundance of Red-backed Salamanders at MABI.

- Establish 3 additional ACO transects, 1 each in a hardwood, hemlock/hardwood, and conifer stand using board size, spacing, wood type, and number of boards as described in Methods section above.
- Allow new ACOs to "weather" for 1 year prior to beginning surveys.
- At each of the 6 ACO transects, conduct 5 surveys per year – 2 during May, and 3 during Sept/Oct (these months coincide with the periods of highest abundance, see Figure 5).

Calling Frog Survey

Calling frog surveys are a cost-effective method for monitoring relative abundance of calling anurans in a given area. While continuing the survey already established at MABI would only be capable of detecting relatively large-scale trends with sufficient power, it would document presence/absence, and confirm new or lost species over time. This could be most useful for species such as Bullfrog, which were found in the park but not confirmed as a breeder, or for species that have the potential to breed but were not discovered, such as Gray Treefrog. In addition, this technique would be effective at documenting loss of relatively small breeding choruses, such as Pickerel Frog, over time.

I recommend following the protocol that was established for, and used in this study, and consulting with the Vermont Calling Frog Survey Coordinator to determine the best dates and survey conditions for conducting counts.

Vernal Pool Egg Mass Counts

Conducting time-constrained visual encounter surveys (VES) for egg masses are an effective method for monitoring relative abundance and presence/absence of vernal pool-breeding species (Heyer et. al. 1994). In this case, VES would be used to monitor 3 species, Wood Frog, and Jefferson and spotted salamanders. Because of the regional concern about the conservation of Jefferson Salamander in the Northeast, I suggest that egg mass counts occur at 3 of the pools in which this species was confirmed breeding, as well as 2 pools where they were absent. Because the breeding phenologies of these species are dependant upon weather suitable for migration to pools, two surveys at each pond should be conducted each year; the first survey between 15 and 30 April, and the second between 15 and 30 May.

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