VERNAL POOL ASSESSMENT

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WILDLIFE DIVISION

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ENDANGERED AND THREATENED SPECIES WILDLIFE GROUP

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INTRODUCTION

Vernal pools are currently defined by the Maine Department of Inland Fisheries and Wildlife (MDIFW) as naturally-occurring, seasonal to permanent bodies of water occurring in shallow depressions that fill during the spring and fall and may dry during the summer. Vernal pools do not support permanent or predatory fish populations[1]. They provide the primary breeding habitat for one or more of Maine's four vernal pool indicator species—spotted and blue-spotted salamanders (*Ambystoma maculatum* and *A. laterale*), wood frogs (*Rana sylvatica)*, and fairy shrimp (*Eubranchipus* spp). In addition to the indicators, vernal pools also provide habitat for other wildlife species including several native amphibians (Table 1) and Endangered and Threatened species in Maine.

Vernal pools may be classified as a variety of wetland classes (after Cowardin et al. 1979); unvegetated pools (PUB, POW), marshes and wet meadows (PEM), shrub swamps (PSS), and forested wetlands (PFO) may all provide potential breeding habitat for vernal pool indicator species. They occur in a variety of landscape settings including bottomlands associated with rivers, wetland complexes, and as isolated depressions in an upland landscape.

In some instances, these pools may be permanent or semi-permanent (rarely drying); but most often there is no permanent inlet or outlet. Fish populations may be

[1] Vernal pool indicator species have been known to successfully breed in the presence of some smaller fish species including minnows (Cyprinidae) and sticklebacks (Gasterosteidae).

Table 1. Maine's amphibian species and their use of vernal pool habitats.

Species	**Vernal Pool Habitat Use**
SALAMANDERS (CAUDATA)	
Common Mudpuppy (*Necturus maculosus*)	
Blue-spotted Salamander * (*Ambystoma laterale*)	Preferred Breeding
Spotted Salamander * (*Ambystoma maculatum*)	Preferred Breeding
Red-spotted Newt (*Notophthlamus v. viridescens*)	Facultative Breeding, Foraging, Dispersal
Northern Dusky Salamander (*Desmognathus fuscus*)	
Northern Two-lined Salamander (*Eurycea bislineata*)	
Northern Spring Salamander (*Gyrinophilus p. porphyriticus*)	
Four-toed Salamander (*Hemidactylium scutatum*)	Facultative Breeding
Northern Redback Salamander (*Plethodon cinereus*)	
FROGS and TOADS (ANURA)	
American Toad (*Bufo americanus*)	Facultative Breeding
Gray Treefrog (*Hyla versicolor*)	Facultative Breeding
Northern Spring Peeper (*Pseudacris c. crucifer*)	Facultative Breeding
Bullfrog (*Rana catesbeiana*)	Foraging, Dispersal
Green Frog (*Rana clamitans melanota*)	Facultative Breeding, Foraging, Dispersal
Pickerel Frog (*Rana palustris*)	Facultative Breeding, Foraging, Dispersal
Northern Leopard Frog (*Rana pipiens*)	Facultative Breeding, Foraging, Dispersal
Mink Frog (*Rana septentrionalis*)	
Wood Frog * (*Rana sylvatica*)	Preferred Breeding

* Vernal pool indicator species.

excluded from permanent breeding pools that are isolated hydrologically or shallow enough to become anoxic by summer's end and/or by completely freezing in winter. In Maine, pools are generally less than 2 acres and commonly as small as 0.1 acre. These special features, particularly the lack of predatory fish, make vernal pools extremely important habitat for several species of wildlife.

Amphibians may spend most of their lives closely associated with aquatic systems (e.g., bull frogs, *Rana catesbeiana*; green frogs, *Rana clamitans*; spring salamanders, *Gyrinophilus porphyriticus*; mudpuppies, *Necturus maculosus*) or they may be largely terrestrial (e.g., redback salamanders, *Plethodon cinereus*; four-toed salamanders, *Hemidactylium scutatum*; gray tree frogs, *Hyla versicolor*). Some species, such as the red-spotted newt (*Notophthalmus viridescens*), spend significant periods of time in both aquatic and terrestrial habitats. This assessment will deal primarily with the three amphibian species largely dependent on seasonal wetlands for optimal breeding habitat (Table 1). These species breed in wetlands over a period of up to two weeks and then return to forested habitats for the rest of the year. Fishless pools are optimal breeding habitat for the ambystomatid salamanders (known as "mole" salamanders because of their habit of living in small, underground burrows during the non-breeding season) and wood frogs. The spotted salamander, blue-spotted salamander, and wood frog are considered indicator species for vernal pools in Maine. The egg masses of wood frogs do not have the mechanical or physiological barriers to predation that characterize egg masses of many aquatic amphibians that regularly breed in permanent pools with fish (Brodie et al. 1987; Henrikson 1990; Crossland 1998). The spotted and blue-spotted salamanders have an outer gelatinous envelope around the eggs that provides some protection from fish predation, however, the larval stages are vulnerable to predation (Kats et al. 1988, Hecnar and M'Closkey 1997). While the indicator species may breed in other wetlands, survival and recruitment of juveniles is reduced in wetlands with predatory fish (Petranka 1998). Other amphibian species (including green frogs, red-spotted newts, spring peepers [*Pseudacris crucifer]*, gray tree frogs, and American toads [*Bufo americanus*]) may also use these wetlands for breeding (depending on the water regime), foraging, or resting. These species are often referred to as facultative users of vernal pools (Table 1).

Although none of the vernal pool indicator species in Maine is currently state-listed, both global and regional population declines (Baringa 1990, Wyman 1990, Wake 1991, Griffiths and Beebee 1992), and increased reports of local amphibian mortality events, have sparked interest in defining habitat requirements and understanding the ecology of vernal-pool breeding species (see *Past and Current Population)*. The wood frog and eastern newt (often associated with seasonal and semi-permanent wetlands) are reported to be disappearing from ecological reserves in developed landscapes of southern New England (C. Raithel, R.I. Dept. of Environmental Management, pers. comm, 1999). The blue-spotted salamander is listed as a Species of Special Concern in Vermont and Massachusetts and is listed as Threatened in Connecticut (Hunter et al. 1999). Causes of declines are unclear, and research to identify causal factors is needed in many geographic regions. Although some herpetologists suggest that amphibian population declines result from global phenomena (acid rain, UV radiation), many population declines may be attributable to local phenomena, particularly habitat loss and fragmentation (Blaustein et al. 1994).

"Significant vernal pools" are currently listed in the Natural Resources Protection Act (NRPA 1996) as Significant Wildlife Habitat, along with deer wintering areas, seabird nesting islands, Atlantic salmon spawning areas, shorebird nesting and feeding areas, waterfowl and wading bird habitats, and Endangered and Threatened species habitats. However, the additional protection afforded by this status is not available until MDIFW develops a regulation defining "significant vernal pools" and a method is developed for pre-identifying pools eligible for protection. The purpose of this assessment is to review the current scientific knowledge of the ecology of vernal pools, outline the natural history of their indicator species, and to assess this information in the context of potential management strategies.

NATURAL HISTORY

Vernal Pool Ecology

The word “vernal” means “spring”, and, indeed, vernal pools generally fill in the spring with snowmelt and spring run-off. Researchers refer to these habitats as seasonal pools, or seasonally-ponded wetlands because the hydrology of pools is so variable. For example, some pools fill in the autumn while others are permanently ponded. Regardless, these habitats are distinguished by seasonal to semi-permanent water regimes that provide specialized breeding habitat for fish-intolerant species: they either dry completely or experience sufficient reduction in water levels as the growing season progresses to exclude adult fish populations. The faunal composition of vernal pools is dictated by hydrology -- different vertebrate and invertebrate species are associated with different water regimes and water sources (and hence differences in water chemistry) -- and landscape setting (the complex relationships between hydrology and species assemblages have not been well-documented to date). All pools have a detrital food base. Leaves and other organic substrates fall into pools providing carbon and nutrients for a suite of shredders and decomposers (invertebrates, bacteria, and fungi) that in turn provide food for fauna in higher trophic levels such as diving beetles, dragonflies, amphibians, turtles, snakes, and birds. Significant oxidation of organic matter (particularly in the truly ephemeral pools) occurs after the pool dries, preventing the accumulation of deep organic deposits typical of peatlands. These periods of oxidation allow for release of nutrients from the litter for the next cycle. This nutrient cycle results in extremely high productivity.

Vernal Pools as Habitat for Invertebrate and Vertebrate Species

Vernal pools support macroinvertebrates commonly found in other low-flow or static aquatic systems including beetles (Coleoptera), dragonflies and damselflies (Odonata), stoneflies (Plecoptera), mayflies (Ephemeroptera), caddisflies (Trichoptera), leeches, crustaceans, and mollusks. Differences in hydrology and water sources seem to influence the presence or absence of certain species of macroinvertebrates, particularly Plecoptera (stoneflies) and Ephemeroptera (mayflies) (Colburn, in prep.); however, more research is needed to elucidate these relationships. Recent studies of factors explaining the distribution and abundance of the seasonal- pool macroinvertebrates have suggested that hydroperiod (the length of time a pool has standing water) and biotic-interactions probably have the greatest influence on community composition (Schneider and Frost 1996; Higgins and Merritt 1999; Schneider 1999; Wissinger et al. 1999). In a study of seven seasonal pools in Wisconsin, for example, Schneider and Frost (1996) concluded that hydroperiod was the most significant factor explaining patterns of presence/absence of macroinvertebrate species among pools. Biotic interactions (competition and predation) appeared to influence patterns of relative abundance rather than species distribution. In contrast, Wissinger et al. (1999) showed that predation by *Ambystoma* (mole salamanders) was the primary factor controlling presence/absence and the relative abundance of macroinvertebrate species among a diverse group of seasonal pools in the Rocky Mountains. Consequently, hydroperiod affected the distribution of *Ambystoma* and many of their macroinvertebrate prey. Similarly, invertebrate species may directly influence reproductive success of pool-breeding amphibians. Leeches and *Ptilostomis* caddisflies may be significant egg-mass predators (Calhoun, personal observation). Predation by *Ptilostomis postica* larvae resulted in up to 100 percent mortality in salamander egg masses in one Pennsylvania study and accounted for 34% of overall spotted salamander mortality in laboratory experiments (Rowe et al. 1994). Some key predators on vernal pool amphibian larvae include adult and larval dytiscid (diving) and gyrinid (whirligig) beetles.

In Maine, the fairy shrimp (Order Anostraca, Family Chirocephalidae) is the only invertebrate family that has been documented thus far to be obligately dependent upon vernal pools. Fairy shrimp persist exclusively in fishless waters with seasonal or semi-permanent water regimes. The characteristics of a vernal pool that provide suitable habitat for fairy shrimp have not been well-defined. Several other crustaceans specialized for life in seasonal waters include clam shrimp (Branchipoda, Conchostraca), fingernail clams, cladocerans (Branchipoda), copepods, and ostracods (Wiggins et al. 1980).

A significant proportion of the animal species diversity and biomass present in vernal pools is contributed by insects. Caddisflies, beetles, true bugs, damselflies and dragonflies, and flies (particularly mosquitoes) may be the most abundant animals in seasonal pools. Fishless wetlands, including isolated ponds or vernal pools, host several insect species that are not characteristically found in pools supporting fish predators. For example, a recent MDIFW invertebrate survey (P. deMaynadier, MDIFW memo, 23 July 1999) of two fishless ponds, Beaver Pond (Somerset Co., Forsythe Twp.) and Lily Pond (Piscataquis Co., Monson Twp), documented the presence of two

(*Enallagma boreale* and *E. aspersum*) of three northeastern damselfly species generally restricted to fishless conditions (Westfall and May 1996, McPeek 1998). P. deMaynadier (MDIFW memo, 23 July 1999) also reports the presence of Notonectids ("Backswimmers") from the genus *Buenoa spp*., and larvae of the dytiscid beetle *Graphoderus spp*., genera that he identifies as restricted to fishless habitats because of their active, diurnal water column behavior (Ward 1992, C. Gibbs, University of Maine, pers. comm). The ringed boghaunter dragonfly (*Williamsonia lintneri*), a state Endangered species, is often associated with acidic, sphagnum-dominated vernal pools in southern Maine. Other species, including caddisflies and mayflies, may be restricted to vernal pools; however, little research has focused on invertebrate populations in these habitats (Huryn and Harris 2000, C. Gibbs, University of Maine, pers. comm.).

Seasonal wetlands, potentially isolated from fish populations since the last glaciation, are important habitats to invertebrates beyond those species that are of conservation concern. Fishless ponds, including vernal pools, may host invertebrate taxa with unique behavioral and genetic adaptations (e.g. diurnal water column activity; deMaynadier 1999). Introduction of predatory fish into historically fishless systems has had dramatic and potentially irreversible effects on both amphibian (e.g. local extirpation or population declines; Hecnar and M'Closkey 1996, Larson 1998) and aquatic invertebrate communities (e.g. food web restructuring; Johnson et al. 1996, McPeek 1998; Evans 1988). Species composition, relative abundance, and behavior of invertebrate assemblages in fishless habitats are unique to these systems (deMaynadier 1999).

Vernal pools provide seasonal resting and foraging habitat for a variety of vertebrate taxa including birds (e.g., dabbling ducks, wading birds, flycatchers), reptiles (e.g., painted turtles [*Chrysemys picta*], wood turtles [*Clemmys insculpta*], garter snakes [*Thamnophis sirtalis*]), mammals (e.g., raccoons [*Procyon lotor*], striped skunks [*Mephitis mephitis nigra*], shrews [*Sorex spp*.]), and amphibians (e.g., bull frogs, green frogs, spring peepers). Many animals use these wetlands as stepping-stones to other wetlands (similar to travel corridors) or as rich foraging grounds. Four-toed salamanders (State Special Concern), whose population and distribution may be underestimated in the state, have recently been documented breeding in sphagnum moss overhanging vernal pools (Hunter et al. 1999). Blanding's turtles (*Emdoidea blandingii*; State Endangered), eastern ribbon snakes (*Thamnophis sauritus sauritus*; State Special Concern) and spotted turtles *(Clemmys guttata*; State Threatened) use vernal pools extensively in southern Maine (Joyal 1996). Wood turtles (State Special Concern) use vernal pools in riparian areas extensively for feeding (Compton 1997) during spring and summer months. Small mammals observed foraging in vernal pools include raccoons, striped skunks, short-tailed shrews (*Blarina brevicauda*), and pine voles (*Pitymys pinetorum*). However, no quantitative studies in the glaciated northeast have been published regarding vernal pool visitation frequency and foraging behavior of small mammals (Colburn, in prep.). Adult spotted salamanders occupied small mammal burrows, particularly those of short-tailed shrews and pine voles, in one Massachusetts vernal pool study (Windmiller 1996). Shrews and voles are commonly captured in pitfall traps around vernal pools as well (P. deMaynadier, Maine Department of Inland Fisheries and Wildlife, pers. comm.; L. Lichko, University of Maine, pers. comm.).

Endangered, threatened, and rare species

Although none of the vernal pool indicator amphibians in Maine is currently state or federally listed, many pool-breeding species in southern New England are at risk Tables 2 and 3).

Table 2. State conservation status of vernal pool obligate or indicator species* (threatened [T] or special concern [SC]).

	RI	CT	MA	NH	VT	ME
Wood frog	x	x	x	x	x	x
Spotted salamander	x	x	x	x	x	x
Blue-spotted salamander	-	T	SC		SC	x
Jefferson salamander	x	SC	SC	x	SC	-
Marbled salamander	x	x	T	SC	x	-
Fairy shrimp	x	x	SC**	x	x	x

* The indicator and obligate status designation is preliminary for all states except Maine.
** Intricate Fairy Shrimp (*Eubranchipus intricatus*)

Table 3. Conservation status of other species associated with New England vernal pools (E=endangered; T=threatened; SC=special concern).

	RI	CT	MA	NH	VT	ME
Western chorus frog	-				E	x
Eastern spadefoot	T	E	T		x	x
Spotted turtle	-	-	SC	SC	T	T
Blanding's turtle			T	SC		T
Wood turtle						SC
Four toed salamander	x	x	SC	x	SC	SC
Intricate fairy shrimp	x	x	SC	x	x	x
Spatterdock darner			E			SC
Ringed boghaunter dragonfly						E
Northern spring amphipod			SC			
Agassiz's clam shrimp*			E			
American clam shrimp			SC			
Piedmont groundwater amphipod		SC	SC			
Clam shrimp**		SC				
Coastal swamp amphipod			SC			

* endemic
** *Eulimnadia stoningtonensis*

As our knowledge regarding invertebrate populations increases, species associated strongly or exclusively with vernal pools may be discovered. Little attention has been given to invertebrate surveys of this habitat in Maine. As Maine experiences the developmental pressures that states to the south have undergone, the state may find seasonal pool species similarly threatened unless proactive measures are put in place.

Vernal Pool Vegetation

Vegetation associated with vernal pools in Maine is generally not specific to vernal pool habitats. To date, only featherfoil (*Hottonia inflata*; State Endangered) has been considered a potential obligate vernal pool species in southern Maine (Cutko 1998). Vernal pool habitats occur in a variety of wetland classes from open water wetlands to forested wetlands; hence, plant species characteristic of a variety of Maine wetlands may be associated with vernal pools.

Vernal Pools in the Landscape

Vernal pools as landscape features

Vernal pools occur in a variety of landscape settings including bottomlands associated with rivers, wetland complexes (particularly forested wetlands), and as isolated wetlands or depressions in an upland landscape. Vernal pools and other small wetlands (<10 acres) are dominant features in many landscapes as they may be one of the more common wetlands in Maine. No comprehensive studies evaluating patterns of spatial distribution and density have been undertaken in New England, however results from related studies suggest distribution and density of vernal pools may be patchy and variable. Densities in two Massachusetts and one Maine study were less than two pools per km^2, and one study in southern Maine reported a density of 13.5 pools per km^2 (Table 4). Vernal pools located in mixed or evergreen forest are difficult to locate using even large scale aerial photography (Stone 1992; Calhoun et al., in prep.) further complicating evaluation of spatial patterns on the landscape.

Artificial pools, such as gravel pits, quarry ponds, roadside ditches, borrow pits, and farm ponds, may provide additional breeding habitat for vernal pool species. Although human-made pools may enhance breeding opportunities, they may also function as biological sinks (that is, as suboptimal habitat that does not support successful reproduction) for vernal pool species owing to inadequate water regimes among other factors (Dimauro 1999).

Gibbs (1993) simulated the loss of small wetlands in a 600 m^2area of Maine to evaluate how the loss of small wetlands affected populations of wetland-associated animals. His model revealed that local populations of turtles, small birds, and small mammals faced a significant risk of site-based extinction if small wetlands were lost. Semlitsch and Brodie (1998) reviewed the literature on seasonal or small depressional wetlands in the United States. They suggest that the loss of vernal pools and other small wetlands may affect the ability of amphibians from one area to disperse to other

Table 4. Density of Vernal Pools in Maine and Massachusetts

Study Location	Total Area Covered (ha)	Density (pools km^2)	Transect Area Covered (km^2)	Density (pools km^2)
York, ME (Calhoun 1997)	3642	13.5	1.9	49.5
Edinburg, ME (Calhoun 1997)	1880	1.4[2]	0.5[3]	23.1
Edinburg, Twp 32, ME (DiMauro 1998)	na	na	1	40[4]
Amherst, MA (Stone 1992)	7187[5]	1.9	na	na
Quabbin, MA (Brooks 1993)	3880	1.1	na	na

suitable breeding sites as distances between pools increase. They also reported that small wetlands contribute greatly to local biodiversity. Small wetlands and vernal pools support a myriad of plant, invertebrate, and vertebrate taxa (particularly amphibians) that otherwise would not occur in a local area.

Vernal pool linkages to surrounding ecosystems

Vernal pools contribute significant amounts of amphibian and invertebrate biomass (and hence food) to adjacent ecosystems. As ectotherms (cold-blooded animals), larval amphibians do not expend energy for heat production thus enabling them to channel their energy resources into growth and biomass accumulation (Pough 1983). In this fashion, vernal pool amphibians efficiently assimilate the rich supply of nutrients available in pools and export them to the surrounding uplands. After leaving the vernal pool, invertebrates and pool-breeding amphibians provide easy prey to a

[2] Of the 26 pools surveyed, 19 were anthropogenic
[3] Of the 12 pools discovered, 7 were anthropogenic
[4] Part of DiMauro's study area overlapped with Calhoun's study area; 9 natural pools and 31 anthropogenic pools
[5] Stone's study area is largely developed so the pool density estimate is artificially low

wide variety of forest animals including snakes, turtles, birds, predatory insects, small mammals, raccoons, striped skunks, (Wilbur 1980; Pough 1983; Ernst and Barbour 1989), coyote *(Canis latrans*), and red fox (*Vulpes vulpes*) (Windmiller 1990). These species also may forage directly in vernal pools. Windmiller (1990) found vernal-pool breeding amphibian biomass in the upland habitat surrounding a pool to be greater than the collective biomass of all breeding birds and small mammals in the 53 acre forest surrounding his study pool in Massachusetts. He concluded that vernal pool amphibians are a powerful influence on the ecology of the surrounding forests, up to several hundred meters from the pool edge. Amphibians are a key link in food webs and nutrient cycles because they are predators on forest invertebrates involved in litter decomposition, thereby indirectly influencing rates of decomposition in the forest floor (Wyman 1998).

Biologists have wondered why small vernal pool depressions have not filled since the last glaciation (as many bogs, fens, and ponds have done). One theory is that hundreds of pounds of detritus entering the pool each fall is converted to migrating animal biomass the next spring. Thus, in some landscapes, vernal pools are an integral cog in forest ecosystem dynamics.

Landuse practices and the ecology of vernal pools

Most studies of factors explaining the distribution and relative abundance of seasonal-pool fauna have focused on the effects of hydrology and biotic interactions on amphibian distribution patterns without regard to land use history. The success of vernal pool breeding fauna is dependent on *both* the physical and biological properties of breeding pools and the quality of the surrounding landscape. It is the terrestrial habitat that supports pool-breeding amphibians for all but a relatively short breeding period (Semlitsch 1998). Although much of amphibian terrestrial life history is still unknown, researchers have documented juvenile emigration distances of wood frogs and adult mole salamanders (Windmiller 1996; Dodd and Cade 1998; Semlitsch 1998). For example, juvenile wood frogs may disperse over a mile (1.6 km) from natal pools while adult ambystomatid salamanders may travel an average of 750 feet (228 m).

Salamanders, and to a lesser degree wood frogs, are especially sensitive to desiccation and temperature extremes (Shoop 1974; Stebbins and Cohen 1995). DeMaynadier and Hunter (1998; 1999) found that both juvenile and adult wood frogs and spotted salamanders selected closed-canopy forests during migratory movements through managed landscapes. Specifically, pool-breeding amphibians need upland habitats characterized by areas of deep, uncompacted forest litter, ample moderate to well-decomposed coarse woody debris, and patches of canopy shade for maintaining a cool, moist, forest floor environment that enables dispersal, migration, foraging, and hibernation (deMaynadier and Hunter 1995; DiMauro 1998). Therefore, disturbances that affect the forest floor environment or create barriers to movement may affect amphibian populations by hindering emigration from and travel to breeding pools. This dependence on the surrounding landscape for both individual survival and integrity of metapopulations (locally interacting subpopulations) of pool-breeding amphibians has prompted Semlitsch (1998) to recommend substituting the term “life zone” for buffer zone when referring to adjacent terrestrial forest habitat. …Conserving the upland landscape around vernal pools is necessary to conserve the ecological value of these critical breeding habitats for amphibians and other wildlife associated with vernal pools.

Land-use practices around vernal pools may influence species assemblages in pools (Laan and Verboom 1990). Batzer and Sion (1999) showed that seasonal pools in old-growth forests in western New York supported different assemblages of macroinvertebrate fauna than were present in pools in forests that had been clearcut (even though clearcutting may have occurred many decades earlier). These results were attributed to differences in the ability of the soils to maintain sufficient moisture in the pool basin to allow taxa that are not desiccation resistant to survive periods without standing water. Although admittedly preliminary, the study of Batzer and Sion (1999) is of particular significance because it suggests the importance of landscape history – rather than pool-specific factors – on the species composition of seasonal-pool fauna. Research on the effects of forest management on amphibian use of vernal pools is still poorly understood and has been identified as an area requiring further investigation (deMaynadier and Hunter 1995). However, limited results suggest that forest harvesting around vernal pools can have important effects on the wildlife values associated with vernal pools. Following a clearcut harvest over 500 ft (152 m) from the edge of a study pool in Louisiana, Raymond and Hardy (1991) reported decreased adult survivorship and upland displacement of a population of mole salamanders (Ambystoma talpoideum). Similarly, deMaynadier and Hunter (1999) demonstrate that landscape disturbances that significantly alter the structural integrity of the forest (understory and overstory canopy structure) can reduce the functional value of the surrounding habitat for movements of pool-breeding amphibians in Maine.

Forest canopy disturbances from agriculture, and commercial and residential development may threaten vernal pool species in suburban landscapes. Windmiller (1996) predicted that future loss of 1/3 of existing upland forest to suburban development or other disturbances within approximately 900 ft (274 m) of 17 breeding pools in Concord, Massachusetts, would reduce the combined population size among five spotted salamander populations by 75%. Research on the effects of development around vernal pools is ongoing (Windmiller, unpub. data). Future research on landuse-amphibian relationships surrounding vernal pools could help forest managers design harvest methods that minimize conflicts with these important amphibian breeding sites and guide development strategies around vernal pools in urbanizing landscapes.

For a summary of recent studies on the ecology of vernal pools in Maine, see "HABITAT ASSESSMENT; Current Habitat."

Research Gaps

A recent monograph , "Vernal pools in the glaciated northeastern United States: a community profile," (Colburn, in prep.), reviews the status of vernal pool research and conservation initiatives. The following key research needs were highlighted:

- Interactions between seasonal pools and their watersheds, particularly with respect to water quality and hydrologic functions;
- Patterns in hydrologic variation in pools: are there predictable patterns based on water sources, condition of the watershed, and pool characteristics?;
- Relationship between hydrologic regime and success of pool-breeding vertebrate and invertebrate species;

- Roles of pool-breeding amphibians in forest ecology;
- Effects of forestry practices (or other landscape-scale disturbances) on migratory and dispersal patterns of adult and juvenile pool-breeding amphibians;
- Identification of specific forest microsite conditions necessary for supporting pool-breeding amphibians and their relationship with forest management.

Vernal Pool Indicator Species

In-depth natural history accounts of vernal pool amphibian indicator species are presented in *Maine amphibians and reptiles* (Hunter et al. 1999), *Salamanders of the United States and Canada* (Petranka 1998), or *The ecology of vernal pools in the glaciated northeastern United States: a community profile* (Colburn, in prep.). Following is a brief summary of the natural history of each of the four vernal pool indicator species. Egg mass and larval descriptions are presented in Tables 3 and 4.

Fairy shrimp (Eubranchipus spp.)

Fairy shrimp, or anostracan crustaceans, currently are the only documented obligate invertebrate indicator for vernal pools in Maine. There are seven families of anostracans in North America; species common in the glaciated northeastern United States belong to the family Chirocephalidae, genus *Eubranchipus*. Species of fairy shrimp found in the northern region are most commonly *Eubranchipus bundyi; Eubranchipus vernalis* replaces *E. bundyi* in dominance in southern New England. Fairy shrimp from the family Branchinectidae occur in eastern Atlantic Canada (*Branchinecta paludosa)* and may occur in northern Maine.

Description

Fairy shrimp vary in size, color, and shape among species. They range in length from 0.5-1.0 inches (1.25-2.5 cm). Morphologically, young and adults are similar in appearance. Young individuals are usually orange or salmon-colored, with mature males taking on a greenish cast and females a bluish cast. Most fairy shrimp have a long tail, sometimes with neon spots near the tip. All fairy shrimp have stalked eyes and swim upside down while waving with up to 10 pairs of leaf-shaped limbs with which they feed. Fairy shrimp are related to brine shrimp, most commonly known as "sea monkeys."

Distribution and status

Fairy shrimp are found throughout North America. Fairy shrimp may disperse from pool to pool as eggs adhered to the fur, feather, or feet of animals. In Maine, they have been documented in vernal pools throughout the state. However, work remains to be done to document species presence, abundance, and distribution in pools statewide.

Breeding habitat and reproduction

Fairy shrimp occur only in waters free of fish populations---primarily seasonal and semi-permanent vernal pools. Habitat requirements for fairy shrimp are not well-documented. Studies in Maine have not explained why fairy shrimp commonly occur in some pools and are absent from others (Calhoun, unpub. data). Potential factors affecting their distribution include water chemistry, hydrology, depth of unfrozen water in the winter, and presence of algae in the spring. Certain environmental conditions required by eggs for maturation and hatching, including soil moisture conditions, precipitation patterns, and freezing, may be primary factors dictating habitat suitability (Colburn, in prep.). Dexter and Kuehnle (1951) studied vernal pools over a 10-year period and concluded that flooding history of a pool during the previous season, and precipitation during the winter and spring, affected hatching of *Eubranchus* spp. *Eubranchus* spp. are known to be intolerant of pollution, siltation, salinity, high alkalinities, and temperatures in excess of 20 degrees C. Both *E. intricatus* and *E. bundyi* appear to be restricted to clear waters (Pennak 1978).

Fairy shrimp hatch from eggs that lie on the bottom of dry vernal pool basins, where hatching is stimulated by flooding. In Maine, they often hatch soon after pools flood or ice melts from semi-permanent pools. Juveniles and adults pass through several molts, breed, and die in as few as three weeks. Fertilized eggs are released into the water and fall to the pool bottom. Females may produce several clutches. Egg maturation may require freezing and/or drying depending on the species.

Spotted salamanders (Ambystoma maculatum)

Description

Adult spotted salamanders are robust salamanders with relatively broad bodies and wide faces. They generally sport two irregular rows of bright yellow to orange spots (20-50) on their backs to either side of the mid-dorsal line. Otherwise, spotted salamanders are greyish brown to bluish black on the dorsal side with a light greyish-blue venter. Spotted salamanders have four toes on the front feet and five toes on the hind feet. They range in length from 5.9-7.7" (15 to 19.6 cm).

Distribution and status

Spotted salamanders occur throughout New England, the Great Lake States, the southeastern United States (excluding Florida), and Atlantic Canada (Figure 1).

Breeding habitat and reproduction

Spotted salamanders preferentially breed in seasonal to semi-permanent vernal pools. Although they may breed in beaver flowages, lakeshores, and anthropogenic pools (i.e., roadside ditches, borrow pits, skidder ruts), reproductive success (recruitment) may be limited and variable in these environments. The presence of fish or short hydroperiods may render these sites biological sinks. Research on the success of vernal pool amphibians in beaver flowages and other wetlands supporting fish populations is ongoing (K. Babbitt, University of New Hampshire pers. comm.; M. Kolozsvary, Jesse Cunningham, University of Maine).

Spotted salamanders typically emerge from hibernation on the first warm, rainy nights of spring. In southern Maine, this may occur as early as mid-March while in northern Maine, breeding activity may begin as late as mid-May. Generally, males migrate en masse to breeding pools (often the same pool from which they hatched) before females. They engage in elaborate group courtship behaviors (known as congressing) in which males deposit spermatophores (sperm packets) to be picked up and stored in the cloaca by females. Females deposit, on average, two to four egg masses typically attached to vegetation or sticks (Table 5). Adults do not necessarily breed every year. Eggs hatch in roughly four to eight weeks, depending on hydrology and water temperature. Larvae take an additional 10-14 weeks until metamorphosis. Metamorphs may emerge from pools in July in southern Maine and as late as September in central and northern Maine.

Terrestrial habitat and hibernation

Spotted salamanders are found in deciduous, mixed, and softwood forests and on some occasions, in open fields near forest edges. The majority of time is spent below ground (hence the name “mole salamanders”), commonly in shrew or other small mammal burrows (Kleeberger and Werner 1983; Madison 1997). They also seek refuge under leaf-litter and coarse woody debris. Adults feed on forest-floor invertebrates including earthworms, snails, spiders, and insects. Home ranges vary from 1 m^2 (11 ft^2)to 40 m^2 (430 ft^2)(Douglas and Monroe 1981; Kleeberger and Werner 1983.). Windmiller (1996) estimated adult densities within 200 m of a Massachusetts seasonal pool to be 1-4 per 100 m^2 (1076 ft^2); juvenile densities within 55 m (592 ft^2)of the pool were 3-20 per 100 m^2.

Spotted salamanders hibernate in upland forests, most commonly below ground (up to three feet) in small mammal burrows or channels created by tree roots.

Blue- spotted salamander (Ambystoma laterale)

Blue-spotted and Jefferson (*Ambystoma jeffersonianum*) salamanders interbreed producing polyploid hybrids formerly known as Tremblay’s or silvery salamanders (depending on the number of chromosomes from the blue-spotted and Jefferson's respectively). It is believed that the great majority of Maine's blue-spotted salamanders are hybrids (Knox unpub. data). For a complete discussion of the genetic complexities associated with these hybrids, refer to Petranka (1998) or Hunter et al. (1999). For the purposes of this account, realize that variability in physical characteristics, egg mass morphology, and habitat preferences may stem from our inability to easily identify hybrids versus pure populations.

Description

Blue-spotted salamanders have a dark blue or black body liberally sprinkled with bluish-white flecks. The speckling may be distributed over the entire body or confined to limbs, lower sides, throat, and belly. The pattern and color of these salamanders is often compared to old blue enamel cookware. Hybrids tend to be more brownish. Breeding adults range from 3.9-5 inches (9.8 to 12.7 cm). Hybrids may grow to 6.7" (17 cm). The head is narrow and tapers to a rounded snout.

Distribution and status

Blue-spotted or "Tremblay's" salamander (the most likely hybrid in Maine) probably occur throughout Maine, however they are less commonly reported than the spotted salamander (Figure 2). To date, no genetically pure populations of blue-spotted salamanders have been reported in Maine. Blue-spotted salamanders are found throughout New England (with the exception of Rhode Island), the Great Lake States, and Atlantic Canada. This salamander is listed as a Species of Special Concern in

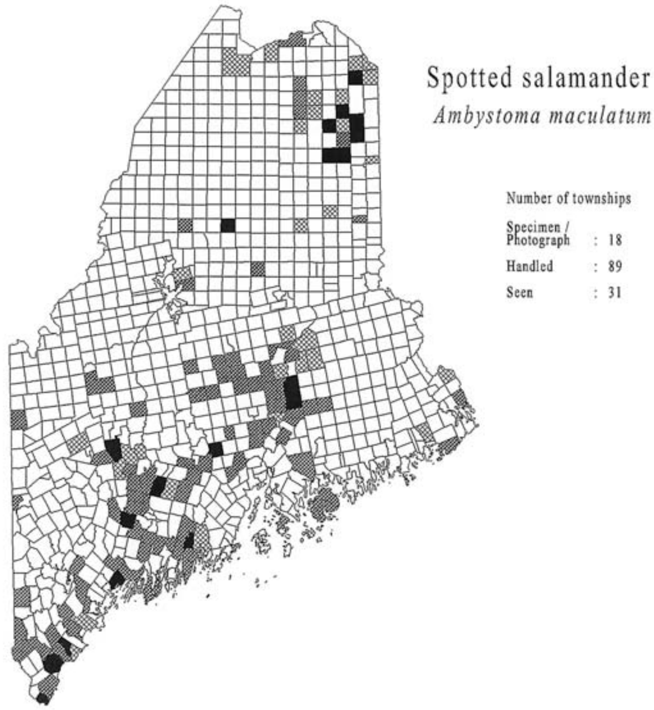

Figure 1. Documented distribution of the spotted salamander (*Ambystoma maculatum*) in Maine (from Hunter et al. 1999)

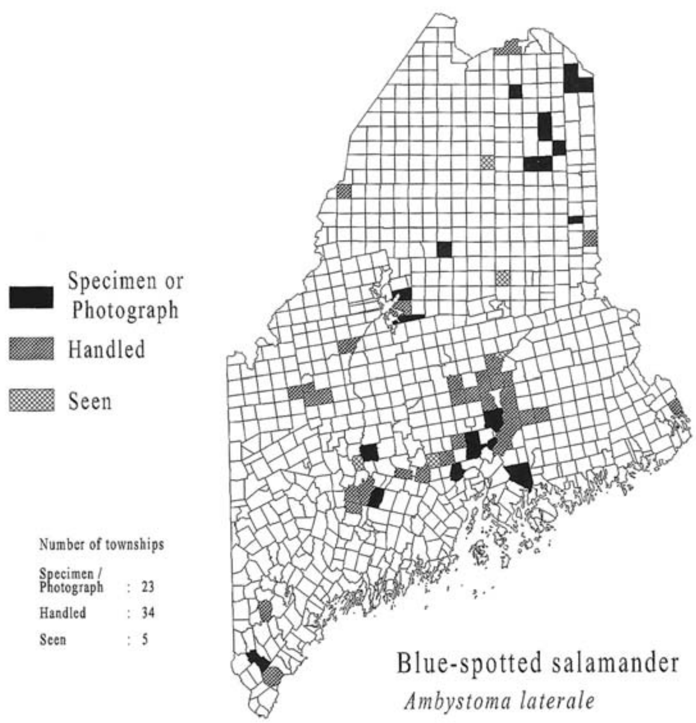

Figure 2. Documented distribution of the blue-spotted salamander (*Ambystoma laterale*) in Maine (from Hunter et al. 1999)

Vermont and Massachusetts and is listed as Threatened in Connecticut (Hunter et al. 1999).

Breeding habitat and reproduction

Blue-spotted salamander breeding habitat is reportedly more variable than that of spotted salamanders. Researchers in New Hampshire and Vermont most commonly associate breeding blue-spotted salamanders with streamside pools and red maple forested wetlands. In Maine, blue-spotted salamander breeding habitat is similar to that described for spotted salamanders: seasonal pools and a variety of anthropogenic pools and beaver flowages. Preliminary surveys of pool-breeding amphibians throughout the state show that pools are either dominated by spotted or blue-spotted egg masses: rarely are pools equally shared by the two species. Reasons for this division are being investigated (Calhoun, unpub. data). Possible reasons may be differences in upland habitat requirements or differences in tolerances to within-pool variables including temperature, depth, hydrologic regime, and oxygen concentrations. There is evidence that blue-spotted salamanders are more sensitive than spotted salamanders to low pH and cannot reproduce successfully in highly acidic waters (Karns 1992; Sadinski and Dunson 1992). High sulfate, zinc, and aluminum concentrations also have been documented to exclude breeding populations (Freda and Dunson 1985; Horne and Dunson 1994).

Blue-spotted salamanders tend to breed slightly earlier than spotted salamanders in Maine. Otherwise, the breeding cycle is equally brief, and the migration and congressing patterns are similar to those observed in spotted salamanders. Depending on purity of the population being observed, eggs range from single eggs deposited on the pool bottom to groups of 5-20 eggs loosely adhering to vegetation (more common in the hybrids). For more detailed egg mass descriptions, see Table 5. For description of larvae, see Table 6.

Terrestrial habitat and hibernation

Because of the difficulty in tracking juvenile and adult salamanders, little is known about the upland distribution of blue-spotted salamander populations and their specific habitat requirements. However, the terrestrial habitat of the blue-spotted salamander is probably similar to that described for the spotted salamander. Upland forests with ample canopy cover, deep, uncompacted leaf litter, and coarse woody debris to provide shading, cool refugia, and a moist environment may be requisite. Similarly, these mole salamanders also seek winter refuge in mammal burrows and root channels. Blue-spotted salamanders may be more tolerant of open habitats than spotted salamanders (Downs 1989; Klemens 1993).

TABLE 5. CHARACTERISTICS OF EGGS OF AMPHIBIANS USING VERNAL POOLS

	Indicator Species			**Other Amphibians Using Vernal Pools**				
	Wood Frog	**Spotted Salamander**	**Blue-spotted Salamander**	**Eastern Newt**	**Spring Peeper**	**Grey Treefrog**	**American Toad**	**Green Frog**
Size of Mass	2.5" - 4" (6 - 10 cm) Often deposited communally.	variable size. 1" to over 4" (6 – 10 cm)	variable size. generally smaller than spotted salamander egg masses.	single eggs deposited	single eggs deposited	up to 4" x 5" flattish mass	up to 3 feet long	6" - 12" (15 - 30 cm)
# Of Eggs Per Mass	~ 1,000 eggs per mass	50-250, avg. 125	highly variable, 1 -30	80-450 per ╓	900 per ╓	10 - 40	thousands	1500 - 5000
Shape of Mass	individual mass, ball-shaped; communal deposits like a lumpy sheet.	globular to oval	small, loose scattered groups that may be cylindrical or sausage-shaped attached to vegetation, or single eggs deposited on leaf litter.	—	—	flattish mass or surface film	long, parallel spiraling strings	floating masses of jelly; no shape
Color of Mass	clear, becoming green	clear, milky or green	clear or clouded with sediment film.	—	—		transparent, later cloudy as silt & algae adhere	—
Attachment	twigs and stems	usually sticks and stems, also sedges	submerged branches, stems & leaves	aquatic vegetation	submerged vegetation	loosely attached to vegetation at surface	sometimes threaded through vegetation	emergent floating vegetation
Depth	just below surface	8" - 10" or more below surface	from 8" - 10" below surface to on or near bottom.			at or near surface	on open bottom	shallow water
Incubation Period	~ 3 weeks	4 - 8 weeks	3 - 5 weeks	~ 4 weeks	~ 6 days	3 - 5 days	3 - 12 days	3 - 5 days

TABLE 6. CHARACTERISTICS OF LARVAL AMPHIBIANS USING VERNAL POOLS

	Indicator Species			**Other Amphibians Using Vernal Pools**				
	Wood Frog	**Spotted Salamander**	**Blue-spotted Salamander**	**Eastern Newt**	**Spring Peeper**	**Grey Treefrog**	**American Toad**	**Green Frog**
Bushy Gills	No	Yes (3 per side) Prominent ruff of gills	Yes (3 per side) Prominent ruff of gills	Yes (4 per side)	No	No	No	No
Size	Hatch 7-9 mm (2.8 – 5.5"); metamorphosis 10-12 mm (4.5 ")	Hatch 12-13 mm (0.5"); metamorphosis 40-75 mm (2-3.5")	Hatch 8-10 mm; metamorphosis ~ 50 mm (2")		Metamorphosis 15-16 mm (0.5-0.6")	Metamorphosis 45-50 mm (1.7"-1.9")	Tiny new toads, 8-10 mm (0.3"-0.4")	6.4 cm (2.6")
Color Pattern	At hatch, velvety black, then lightening to mottled olive-brown, sometimes appearing gold-flecked. Venter with pinkish bronze iridescence.	Dull greenish-yellow; sides of head & upper jaw same color as top of head; head broad and blunt, wider than body; chin & throat without markings	Dark brown with yellow blotches dorsally; indistinct light lateral band; underside unpigmented; noticeable paired black spots on dorsum, on either side of tail fin.	Light yellow to green-yellow with grey or brown flecks or bands above; belly pale yellow without bands or spots; Distinct dark stripe on sides of head from nostrils to gills, head narrow. Lower jaw somewhat pointed; upper jaw lighter than top of head.	Beige, tan or orangish dorsum, with dark spots and greenish tone. Iridescent creamy or bronze venter.	Light brown to dark green to black; venter white; intestinal coil visible.	Very dark, almost black, even on venter. Body somewhat flattened; eyes small and dorsal.	Olive green with numerous dark spots on back and cream color underside.
Tail	Tail fin rounded dorsally, tapering to a fine point. Faint, small markings on tail fin.	Tail fin extends forward onto back; fin heavily mottled with black, often giving hind area a dark appearance; gills reddish.	Tail fin extends well forward on body, nearly to head. Fins broad, clouded with black.		Tan to brown to orange tinge with black spots on outer edge. Fin extends along back.	Orangish to wine to scarlet tailfins, extends along back & heavily mottled with black. Tail fins end in well-developed flagellum.	Relatively short tail with rounded end. Tail fin low, without pigment.	Tail fin with dark mottling. Tail musculature usually more or less uniformly mottled or marbled, often about as dark as the body.
Larval Period	60 - 70 days	Variable; 70 -100 days	Variable; 60 - 80 days	80 - 112 days	60 -90 days	Around 60 days	50 - 60 days	A little over one year
Other	Transform late May-mid-August. Eyes are just above sides, not bulging out on sides like spring peepers or grey treefrogs. Intestinal coil partly visible.	More slender appearance than blue spotted salamander. Transform Aug.-Sept., rarely Oct.; may overwinter.	Big-headed appearance.	Unusual life history with 3 distinct stages. Larvae & adults are aquatic; juveniles are terrestrial red efts.	When viewed from above, pop-eyed appearance; eyes bulge to side.	When viewed from above, pop-eyed appearance; eyes bulge to side.	Congregate in schools. Anus median; all other tadpoles in vernal pool will have anus on right side.	Intestinal coil not visible. A few dark markings present on body.

Wood frog (Rana sylvatica)

Description

Wood frogs vary in color from light tan to dark brown; females may be pinkish-tan. A brown band or "robber's mask" extends back from each eye. A dark line of the same color runs from the front of the eye to the snout. Two pronounced dorso-lateral ridges are present. Wood frogs range in size from 1.5 to 2.75 inches (3.75 to 7 cm). Females are larger than males.

Distribution and status

Wood frogs are found throughout New England, the Great Lakes States, and Atlantic Canada (Figure 3). They are not currently a state-listed species in New England, although major population declines have been noted in Rhode Island (C. Raithel, Rhode Island Department of Environmental Management, pers. comm.), and they have disappeared from some areas in the Midwest (Minton 1972; Lannoo 1998).

Breeding habitat and reproduction

Wood frogs breed in early spring in seasonal to semi-permanent woodland pools, beaver flowages, and artificial pools (ditches, gravel pits, skidder ruts). Males may move closer to breeding pools in the fall to hibernate. Wood frogs move en masse to breeding pools, generally on warm, rainy nights. However, in Maine and Massachusetts, wood frogs have been observed moving to pools during periods of drought and cold temperatures, and seem to be much less dependent on weather

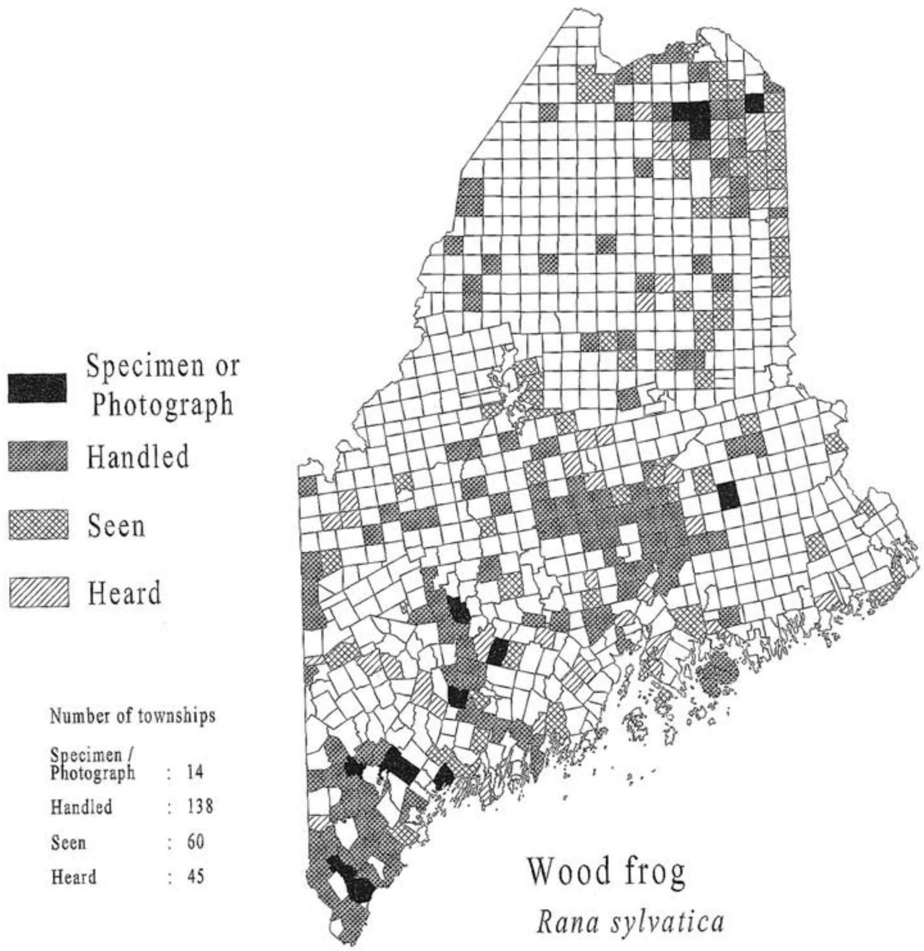

Figure 3. Documented distribution of the wood frog (*Rana sylvatica*) in Maine (from Hunter et al. 1999)

conditions than mole salamanders. Perhaps the most conspicuous vernal pool species, wood frogs announce their breeding sites in the spring with a chorus reminiscent of quacking ducks. Known as explosive breeders, wood frogs may complete mating and egg-laying in less than a week. Females lay one to two egg masses, often communally, each containing up to over 1,000 eggs. Egg masses are attached to woody or herbaceous vegetation or to woody debris in pools. Larvae hatch in approximately three weeks with metamorphs emerging in seven to eight weeks.

Terrestrial habitat and hibernation

During the non-breeding season, wood frogs live in deciduous or softwood forests, wooded wetlands, bogs, and along vegetated pond and lake shores. The terrestrial habitat of wood frogs may be a considerable distance from breeding pools (more than half a mile). Reported home ranges average 45 (Windmiller 1996) to 64 m^2 (Bellis 1965). Little is known about the ecological role of wood frogs in upland forests where they are often present in large numbers in the Northeast. Windmiller (1996) estimated the biomass of wood frogs in 53 acres of forest adjacent to a breeding pool in Massachusetts to be in excess of 150 lbs. Given their abundance and intermediate trophic position, it is likely that wood frogs play an important role in many forest ecosystems.

Wood frogs overwinter under leaf litter or in shallow burrows near the surface of the ground. They are able to hibernate at much shallower depths than mole salamanders because of their adaptations for freeze tolerance. Within five minutes of experiencing temperatures of freezing or below,, wood frogs accumulate high levels of glucose in the liver and leg muscles. Glucose is subsequently released into the bloodstream and tissues preventing freezing (Storey and Storey 1986). Because of this unique adaptation, wood frogs have the most northerly distribution of any North American frog and are the only frog found in Alaska.

MANAGEMENT

Regulatory Authority

Federal

The Army Corps of Engineers regulates all “navigable waters of the United States,” including isolated wetlands, through a 1972 amendment to Section 404 of the Clean Water Act. However, the Supreme Court decision in Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers (January 9,2001) rescinded the 1972 Amendment’s expansion of the term “navigable waters” to include isolated wetlands. Therefore isolated wetlands, including vernal pools, no longer fall under federal jurisdiction. This ruling puts even more pressure on individual states to take the lead in protection of these resources.

State

In Maine, regulation of jurisdictional wetlands in organized towns is overseen by the Maine Department of Environmental Protection (DEP) through the Maine Natural Resources Protection Act (NRPA 1988, 1995). In the unorganized towns and plantations, wetlands are regulated by the Land Use Regulation Commission (LURC).

Vernal pools generally (no longer federal regulation) state wetland definitions and are subject to regulation. However, the degree of environmental review in DEP jurisdiction depends upon the size of the *impact* to the wetland. Impacts to wetlands that are less than 4,300 sq. ft. (approximately 0.1 acres) require no reporting. Impacts between 4,300 sq ft and 15,000 sq ft (approximately 0.1 to 0.3 acres) require the lowest level of review, Tier 1, and have an expedited 30-day review process with no requirement of compensation for wetland loss. Many vernal pools slip through the cracks in this system because they fall below the size threshold of wetland impact that is regulated. For example, a vernal pool survey in southern Maine demonstrated that 58% and 80% of the vernal pools identified were less than 4,300 and 15,000 sq ft respectively. In central Maine, 93% of the pools were less than 4,300 sq ft (Calhoun et al., unpub data). In summary, most vernal pools surveyed in Maine are smaller than 1 acre, with more than half less than 4,300 sq ft. Thus, current federal and state wetland regulations do not seem to adequately protect small, isolated wetlands, including vernal pools.

Land Use Regulation Commission (LURC)

LURC's language on vernal pools is consistent with the statutory provisions in NRPA. However, LURC's regulatory authority over vernal pools is tied to MDIFW's ability to define and identify vernal pools. In unorganized towns, MDIFW is relying on a voluntary, cooperative strategy for protecting vernal pools. LURC wetland protection rules regulate any wetlands shown on their zoning maps (essentially, wetlands identified on National Wetland Inventory maps). The rules provide for an additional route to identify, and subsequently protect, Significant Wildlife Habitat when assessing development activities. Specifically, any applicant whose project will disturb 15,000 square feet of a mapped wetland or an acre or more of land (either upland or wetland) is required to provide a delineation of all wetlands in the project area. Therefore, if LURC learns of the existence of vernal pools through a wetland delineation associated with an application, LURC may consider impacts to the vernal pool in its evaluation of the application.

The identification of “Significant Vernal Pools” as “Significant Wildlife Habitat” in the 1995 amendments to NRPA (see *Current Management* section) has focused both state (DEP and LURC) and federal resource agency attention on this habitat. As outlined in the section on *Current habitat*, pilot projects to study biological and physical characteristics of vernal pools in Maine have been conducted by MDIFW, Maine Audubon Society (MAS), and University of Maine (UME). A recent memo from the EPA Region I coordinator (S. Silva, EPA memo, April 20, 1999) urges the State to resolve the issue of defining and identifying “Significant Vernal Pools” before the state’s Programmatic General Permit (PGP) expires in 2000. A key issue in the reauthorization of Maine’s PGP is how well the protection of small wetlands, particularly vernal pools, is being addressed. If these concerns are not met, the state may be faced with drafting new wetland regulations. Conservation of vernal pools was highlighted as a key goal in the Maine Wetland Conservation Plan (WCP). A Vernal Pool Working Group was formed in 1999 to provide guidance on both regulatory, voluntary, and educational strategies for realizing this goal. Current national attention, coupled with MDIFW’s mandate to define and identify vernal pools, continues to hold this resource in the limelight, making it one of many current conservation priorities.

Current Management

MDIFW has been fostering voluntary protection of vernal pools through its ongoing involvement in the development of Best Management Practices (BMPs) for both timber harvesting and residential development around vernal pools. Outreach efforts include public workshops and slide presentations on vernal pool ecology, dissemination of the *Maine Citizen's Guide for Locating and Documenting Vernal Pools*, and support of vernal pool inventory projects.

To date, MDIFW has not actively pursued regulatory protection for vernal pools under provisions of the NRPA (or any other Significant Wildlife Habitat with the exception of seabird nesting islands). Yet, the designation of vernal pools as Significant Wildlife Habitat puts in place a potential tool for regulating vernal pools if the conservation status of these breeding habitats is significantly compromised.

Although "Significant Vernal Pools" were listed as "Significant Wildlife Habitat" in Maine's 1995 revisions of the Natural Resources Protection Act (NRPA), such status for pools is pending a definition of "Significant Vernal Pools" and development of a system to preidentify vernal pools. A definition is pending and MDIFW continues to support voluntary efforts to identify and protect vernal pools as well as efforts to continue collecting biological and physical data on pools (*see Current Use and Demand*).

HABITAT ASSESSMENT

Past Habitat

Because of their small size and assumed limited economic value, seasonal pools have received far less scientific and regulatory attention than is merited by their ecological significance (Folkerts 1997, Kaiser 1998, Semlitsch 1998; Semlitsch and Brodie 1998). Until recently, most studies on wetlands have focused on estuarine systems (because of their role in marine fisheries), riverine wetlands (because of their role in flood abatement and timber production), and extensive marshes (because they support fishing, hunting, and other recreational activities). As a result, research on seasonal wetlands in the glaciated northeastern United States is in its infancy (Windmiller 1996; Brooks et al. 1998; Dimauro 1998; Burne 1999; Perillo in prep). In Maine, wetlands under 10 acres were not regulated until 1996. Thus, no baseline inventory of seasonal pools in Maine exists. Estimates of wetland area for the state range from 25-30%. Because of their small size, vernal pools most likely make up a small percentage of the total wetland area, but likely represent a larger percentage of the total number of wetlands in Maine. Overall, estimated anthropogenic wetland losses for the State are substantial (approximately 20%), albeit lower than those for the nation overall (> 50%; Whitney 1994). Historically, wetland loss in Maine has been largely attributable to commercial and residential development (Widoff 1988). Losses of vernal pools are most likely greatest in southern Maine and will continue to occur in rapidly developing parts of the state (see “Habitat Projection). It is suspected that there continues to be frequent and incremental loss of vernal pools in Maine. Because of the permit process, this loss has not been tracked or quantified by the Department of Environmental Protection. Also, new vernal pools have been created incidentally (e.g., skidder ruts and borrow pits) and purposefully (as a result of wetland mitigation), but the ability of these artificial pools to replace the number or function of naturally-occurring pools remains unknown.

Current Habitat

Recent vernal pool studies in Maine

Three Master's theses and one Ph.D. thesis related to vernal pool ecology have been completed at the University of Maine within the last five years. Joyal (1996) looked at the population ecology of spotted and Blanding's turtles in southern Maine; Perillo (in prep.) studied the physical and biological characteristics of over 20 vernal pools in three York county study areas; Dimauro (1998) compared the reproductive success of wood frogs and spotted salamanders in artificial and natural vernal pools on industrial forest land in central Maine; and deMaynadier (1996) studied the effects of common forest management practices (forest roads, clearcuts and associated edges) on patterns of movement and habitat use by Maine's amphibians. A cooperative project (MAS, MDIFW, and UME) to characterize physical and biological features of vernal pools in southern, central, and northern Maine was completed in 1998 (Calhoun et al. in prep). Currently, three UME projects related to vernal pools are ongoing in Maine: a Master's project evaluating the ecology of created vernal pools on Sear's Island and two Ph.D projects assessing wetland habitat use of amphibians in Acadia National Park.

These projects will shed more light on factors affecting amphibian breeding patterns and reproductive success.

Summary of results

Joyal (1996) found that vernal pools were used extensively for foraging and resting by both spotted and Blanding's turtles in her southern Maine study sites. Furthermore, turtles made use of different pools at different times of the year suggesting a network of adjacent pools may be an important habitat requirement.

The results of Perillo's work on vernal pools in southern Maine are still being compiled. Preliminary analysis of the relationship between physical and biological variables and reproductive effort of vernal pool amphibians suggest that there is no one clear predictor, or suite of predictors, for reproductive effort.

The majority of Maine is wooded (roughly 89%) with over 40% of that land in industrial forest ownership. As a result of normal silvicultural activities, anthropogenic pools are created from skidder ruts, borrow pits, blocked road drainages, and road ditches. DiMauro (1998) worked in central Maine on industrial forest lands to evaluate the relative quality of anthropogenic versus natural pools as breeding habitat for the vernal pool indicator species. She found that anthropogenic pools may contribute significantly to the total number of seasonal pools available to breeding wood frogs and spotted salamanders with artificial pools outnumbering natural pools by almost fourfold. Because forest harvests around human-made pools are often clearcuts, areas surrounding natural pools may have greater coverage by closed-canopy forest. Forest coverage and canopy closure can significantly influence wood frog and spotted salamander reproductive effort, probably because these factors are related to the suitability of terrestrial habitats outside of the breeding season (Windmiller 1996) and to the length of time a pool holds water. The results of this study suggest that many artificial pools may not successfully replace natural pools (DiMauro 1998).

deMaynadier (1996) studied the effects of common, upland forest management practices on amphibians in central Maine. In quantifying the response of individual species to clearcuts and their associated edges, he found that three of the four amphibians most sensitive to forest canopy removal during upland life history movements comprised Maine's suite of vernal pool indicator species. Furthermore, juvenile pool-breeding species (wood frogs and spotted salamanders) appeared to be even more discriminating than adults in their choice of closed overstory forested habitat for dispersal movements following metamorphosis. Results from this study highlight the importance of maintaining forest habitat integrity in the upland landscape immediately surrounding seasonal forested pools.

In 1998, MDIFW, MAS, and UME collaborated in a one-year pilot project characterizing 286 vernal pools in southern, central, and northern Maine (Calhoun et al. in prep.). The southern study area (SSA) in York County encompassed approximately 3,642 hectares in the towns of York and South Berwick on lands owned by the York and Kittery water districts, the town of York, the Maine Department of Inland Fisheries and Wildlife, and some private lands. The central Maine study area (CSA) in Penobscot County included the Edinburg Wildlife Management Area (EWMA) (1,881 ha) owned by the James River Timber Corporation and 170 ha along route 116 in Edinburg. The northern survey was conducted in Ashland and Masardis on lands managed by Seven Islands and Great Northern Paper/Bowater. The goals of this project were to test the efficacy of two scales of black and white aerial photography (1:400 and 1:1000) and National Wetland Inventory maps in pre-identifying seasonal pools, and to explore geographic variability in physical and biological pool characteristics. All potential pools for a given area were selected using aerial photography. Pools that supported one of the four breeding indicator species were included in the study. For each pool field-checked, data were collected on biological parameters including presence of indicator species, amphibian breeding effort (measured by numbers of egg masses per pool), vegetation composition and structure, and physical attributes including size, landscape setting of each pool, percent canopy cover, and maximum depth at time of amphibian breeding. Results showed that vernal pools in Maine vary geographically with respect to physical setting, wetland vegetation class, size, spatial distribution patterns, hydroperiod, and mean intensity of reproductive effort per pool by each of the primary pool-breeding amphibian species. A summary of preliminary results include:

- Pools in northern Maine tended to be larger; pools in central Maine tended to be less deep (Table 7).
- The majority of pools in southern Maine were upland-isolated (situated in upland settings with no surficial hydrologic connections to other wetlands); in central Maine, pools in upland-isolated and wetland complexes were equally common, and in northern Maine the majority of pools were wetland complexes (Table 8).
- The density of pools in southern Maine was ten times that for central Maine (13.5 and 1.4 pools per km^2 respectively, including artificial pools). Two studies in Massachusetts report densities of 1.9 (Stone 1992) and 1.1 (Brooks et al. 1998) pools per km^2.
- In southern Maine, the majority of the pools were natural and temporary; in the central sites, most pools were artificial and temporary; in northern Maine, the majority of pools were natural pools with roughly half temporary and half permanent (Table 9).

Table 7. Mean size and depth of *natural* pools in northern, central, and southern study sites.

	Pool size (m^2)	Pool depth (cm)
North	392	46
Central	36	21.2
South	176	76

North (N=26); Central (N=7), South (N=189)
(Differences were not significant; size p=0.7, depth p =0.32)

Table 8. Distribution (percent) of pools in three landscape settings.

	Wetland complex	Upland Isolated	Bottomland Isolated
North	78.6	17.9	3.6
Central	53.8	42.3	0
South	11.8	88.2	0

North (N=28); Central (N=55), South (N=195)

Table 9. Percent natural and artificial seasonal pools in northern, central, and southern study areas.

	Permanent natural	Temporary natural	Permanent artificial	Temporary artificial
North	50	42.9	3.6	3.6
Central	7.7	19.2	3.8	69.2
South	10.3	88.2	0	1.5

North (N=28); Central (N=55), South (N=195)

Results from these studies provide guidance for further research. In particular, amphibian reproductive effort (measured in terms of egg mass numbers was not clearly correlated with any of the physical and biological parameters measured. The lack of a clear parameter for predicting amphibian reproductive effort in individual wetlands suggests that the relationship between reproductive effort (and potentially success) and physical or biological predictors is more complex than originally assumed. What is clear is that in evaluating and conserving seasonal pool habitat, the surrounding land-use practices, and quality of terrestrial habitat for pool-breeding amphibians are as critical to assess as specific pool characteristics.

Habitat Projection

Data on site location permits and demographic patterns in permit applications for wetland alterations from the Department of Environmental Protection are not yet available. Recent development trends suggest that loss of vernal pools and other small wetlands has been, and will continue to be, acute in York and Cumberland Counties and near population centers along the I-95 corridor to Bangor (Widoff 1988; Maine State Planning Office 1997). Losses of additional wetlands and associated upland habitat are especially critical in southern Maine where exceptional vernal pool complexes with high ecological value have been documented. Furthermore, several state Endangered and Threatened species are closely associated with these habitats. It is clear that the future for habitat for pool-breeding amphibians in a developing Maine landscape will depend on successful strategies to reduce habitat loss, degradation, and fragmentation, especially in resource-rich areas. Artificial pool creation, either as mitigation for wetland loss or incidentally (e.g., road ditches, borrow pits, skidder ruts) may represent a significant increase in potential breeding habitat as was seen on forest lands in Edinburg. However, the function of created pools as compared to natural pools is still unclear. DiMauro (1999), in a comparison of amphibian breeding success of natural and artificial pools, concluded that artificial pools may function as biological sinks in dry years. For this reason, our current projection assumes a goal of conserving natural pools.

Given the life-history of pool-breeding amphibians, the quality of the surrounding upland habitat is as critical to the maintenance of their populations as is the protection of individual breeding pools. A combination of habitat protection strategies including regulation, acquisition, easements, and voluntary agreements may be required to successfully conserve vernal pools, or complexes of pools, and associated upland on large tracts of land (>100 acres).

A recent report published by the State Planning Office (1997), *The Cost of Sprawl*, addresses the phenomenon of unplanned development or "sprawl." Current patterns of development and ongoing sprawl pose the greatest immediate threat to vernal pool wildlife in Maine. The report states that an increasing desire by the state's population for a low-density, suburban life style has resulted in a 30-year trend of populace moving 10 to 25 miles away from population centers to "new suburbs" (Figure 4; Maine State Planning Office 1997). As the population expands, so does the infrastructure necessary to support it. Development of roads, schools, services (power lines, buildings), and associated residential structures increases habitat fragmentation

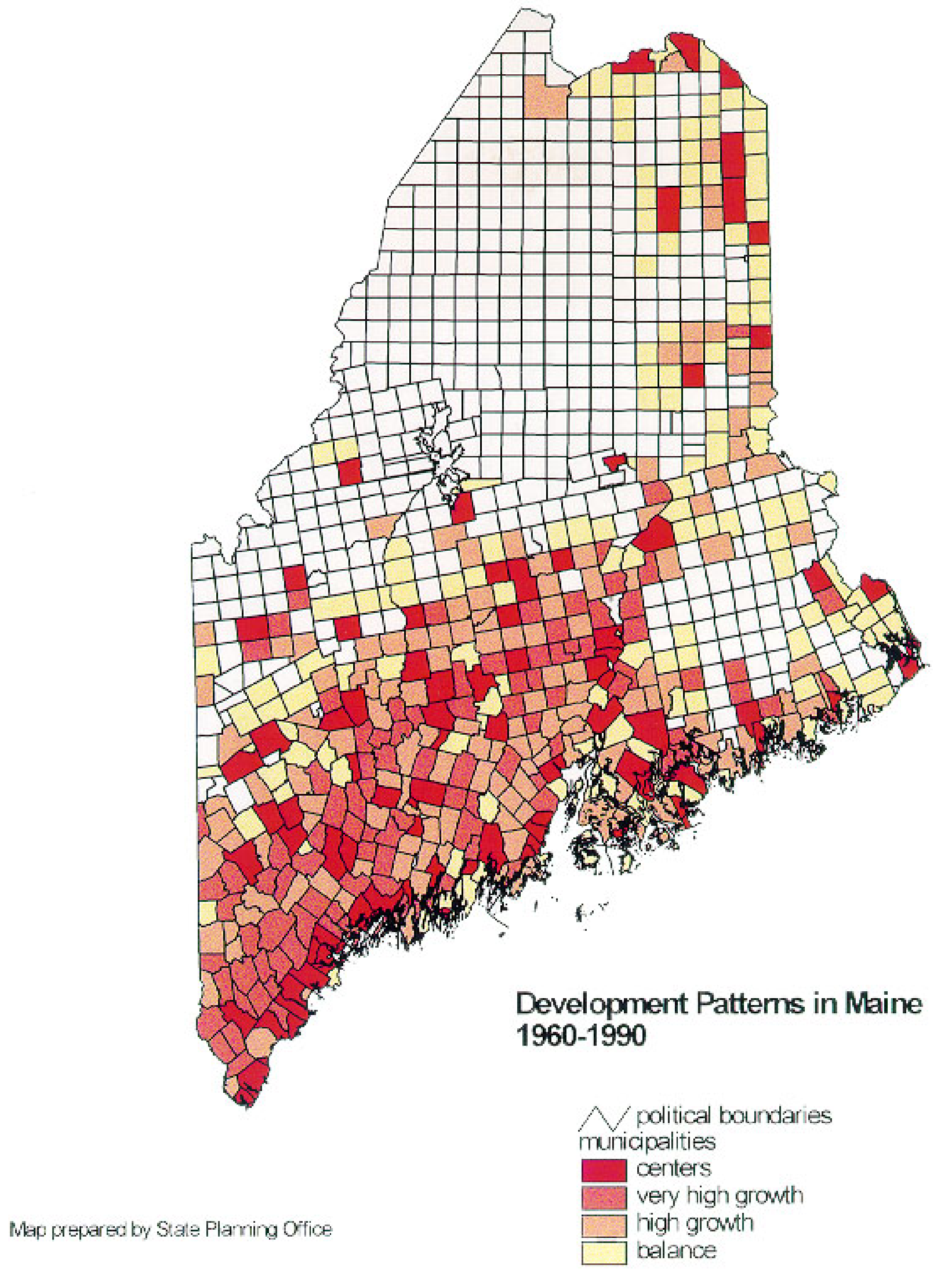

Figure 4. The fastest growing towns in Maine (Maine State Planning Office 1997)

and loss. The following environmental ramifications of sprawl threaten future habitat availability:

- Direct loss of seasonal pools is inevitable. Current regulations do not adequately protect seasonal wetlands. Pools often occur in isolated, forested wetlands, a wetland class that receives less regulatory scrutiny and relatively low wetland functional assessment ratings in site evaluations for permits to alter wetlands. Some wetland assessment procedures now include a vernal pool check-off, but vernal pools likely are accounted for only in the largest projects. Many pools are likely overlooked in single-family developments or when they are dry or under snow. Few members of the public are knowledgeable of what vernal pools are or their value to wildlife.
- Habitat fragmentation results from the scattered development patterns typifying sprawl. In Massachusetts, Windmiller (1996) documented the loss of 75% of vernal pool amphibians from a pool following residential development of 25% of the area immediately surrounding the pool. deMaynadier and Hunter (1999) discuss the adverse implications of emigration barriers such as roads, clearcuts, and powerlines on dispersal of juvenile, pond-breeding amphibians; they suggest that habitat suitability for pool-breeding amphibians is defined by characteristics of the surrounding upland landscape. Juvenile dispersal is a key mechanism for maintaining the integrity of metapopulations of pool-breeding amphibians. Amphibian census data from Rhode Island suggest that habitat fragmentation surrounding large tracts of reserve lands (>1000 acres) may be adversely affecting pool-breeding amphibians. Wood frogs and red-spotted newts are either absent or

declining in protected lands in the highly developed matrices of coastal and southern regions of the state (C. Raithel, Rhode Island Department of Environmental Management, pers. comm.). Gibbs (1993) simulated the loss of small wetlands (less than 10 acres) in 600 km^2 in Maine. He found that removal of small wetlands resulted in a 62% decrease (from 354 to 136) in the number of wetlands in the landscape, and a 67% increase (from 0.6 to 1.0 km) in the mean distance from one wetland to the next. The implications for habitat accessibility for pool-breeding amphibians are significant.

- Increases in non-point and point sources of pollution to open waters may increase with expanding population. Source and non-point sources of pollution may significantly degrade pool water quality in these small, isolated depressions having no permanent inflow or outflow. Some water-borne toxins are implicated in recent amphibian malformations (Morell 1999).

Proactive conservation efforts need to be focused, at the very least, in the southern part of the state. It is in this region that vernal pools host several species of rare and vulnerable wildlife species in a rapidly developing landscape with very limited public land reserves.

POPULATION ASSESSMENT

Past and Current Populations

Systematic, baseline data for the status and distribution of vernal pool fauna does not exist. However, interest in documenting the herpetofauna of Maine was initiated when the MDIFW was charged with promulgating a list of Threatened and Endangered species. This exercise led to the realization that Maine had very little information on the distribution and status of its amphibians and reptiles. In 1984, the Maine Amphibian and Reptile Atlasing Project (MARAP) was initiated. This citizen-based effort to document the distribution of Maine's amphibians and reptiles resulted in the publication *The Amphibians and Reptiles of Maine* (Hunter et al. 1992). The recently updated version, *Maine Amphibians and Reptiles* (Hunter et al. 1999), includes over 1,200 new entries and provides the latest information on the distribution and relative abundance of Maine's herps, including the pool-breeding amphibians.

Interest in continuing to monitor amphibian populations has been fueled by recent worldwide declines in amphibian populations (Baringa 1990, Wyman 1990, Wake 1991, Griffiths and Beebee 1992). Suggested causes of declines include various human-induced processes, including habitat loss (Griffiths and Beebee 1992, Blaustein et al.1994), acid deposition (Freda 1986, Horne and Dunson 1994), climate warming, increases in UV-radiation (Blaustein et al. 1994), spread of toxic substances, introduction of predators, and disease (Jancovich et al. 1997, Morell 1999).

Reports of declining amphibians and malformations may seem irrelevant to rural states such as Maine, yet incidences of amphibian malformations and localized mortality events are increasing. In a recent study of seasonal wetlands, both salamander and wood frog mortality events were documented from breeding pools in Aroostook County in 1998 (Guerry 2000; Calhoun unpub. data). Salamander larvae were infected with an iridovirus (National Wildlife Health Center). The cause of mass larval mortality in wood frogs remains unknown. The chytrid fungus (phylum Chytridiomycota) has been isolated from 3 frog species in Maine, including the wood frog. This fungus was responsible for massive die-offs in Australian frog populations and has recently been isolated in North American frog populations (Longcore et al. 1999, Daszak et al. 1999). Whether the chytrid fungus is endemic or introduced to North America has yet to be determined, but patterns of infection associated with the fungus in Australia and Central America are characteristic of an introduced virulent pathogen dispersing through native populations having no natural defenses (Daszak et al. 1999). Juvenile frogs are particularly susceptible to the pathogen. Leopard frog malformations in Sunkhaze National Wildlife Refuge (Old Town, ME) are currently being monitored by UME and National Wildlife Health Center. Monitoring programs spawned by concerns for status and trends in amphibian populations in Maine include:

1. **The North American Amphibian Monitoring Program (NAAMP)**. In 1996, MAS, MDIFW, and the UME collaborated to participate in NAAMP, an international effort organized by the U.S. Geological Survey's Biological Resource Division to monitor the status and trends of amphibians. The Maine Amphibian Monitoring Program (MAMP) is in its third year. Currently, 62 amphibian chorus monitoring routes have been established statewide. Each route has 12 listening stations. Volunteers monitor these routes three times per year recording species heard and an

abundance code based on number of individuals chorusing. A minimum of 10 years of data will be needed to initially assess population trends. In the short-term, these data are valuable in adding to our knowledge of the phenology, distribution, and yearly variability of chorusing amphibians, including the pool-breeding wood frog.

2. The **Very Important Pool (VIP)** monitoring program. In spring, 1999, a vernal pool volunteer monitoring program was initiated by MAS and the UME. The goal of this project is to collect long-term data (a minimum of three years) on pools, to make this data accessible to the public through development of a web page database, and to map vernal pools on a GIS database. Currently, 120 pools are being monitored. The Sweetwater Trust awarded a grant to the project to purchase water quality monitoring equipment, host training workshops, and support the web page while funding from the Environmental Protection Agency and the Outdoor Heritage Fund has supported a vernal pool volunteer coordinator for the 2nd and 3rd years of the project

3. **Wetland Connections: A K-16 initiative**. Three high schools are involved in collecting long-term data on vernal pools and other wetland habitats as part of a UME/MAS initiative to engage volunteers and educators in long-term monitoring programs. Data will be archived on a website.

4. Incidences of malformed amphibians are being monitored in four National Wildlife Refuges in Maine by the USFWS. This program, initiated in 1997, is ongoing. To

date, malformations in three species (green, pickerel, and leopard frogs) have been noted in two of the four Refuges (L. Eaton-Poole, USFWS, pers. comm.).

Population Projections

No specific trend analysis of the population dynamics of vernal pool-breeding amphibians has been conducted in Maine; however, findings reported by Windmiller (1996) for spotted salamanders in Massachusetts are relevant to conservation issues throughout New England. Windmiller identified the greatest threat to spotted salamander populations as destruction and fragmentation of upland forests upon which pool-breeding species depend. He found spotted salamander population sizes were correlated with the area of accessible upland forest (which is primarily a function of land-use patterns). Empirical evidence for population trends is lacking for pool-breeding amphibians; however, anecdotal evidence from southern New England points to sharp declines. If the pattern of urban sprawl continues, Maine will undoubtedly face similar declines. Similarly, ecologically based forestry practices will be essential for maintaining healthy populations of pool-breeding amphibians in lands dedicated to fiber and timber production.

Limiting Factors

Limiting factors for populations of vernal pool breeding amphibians have been outlined throughout this assessment. To summarize, key threats to Maine's seasonal wetlands and the species that breed in them are:

- direct loss of pools and increasing isolation of remaining pools.

- habitat fragmentation of the surrounding upland matrix, thereby:
    1. creating barriers to juvenile emigration from breeding pools and adult migrations to and from breeding pools;
    2. reducing the carrying capacity of the forest to support surrounding upland populations of vernal pool amphibians; and
    3. disrupting connectivity between pools, potentially threatening population dispersal movements critical for maintaining genetic integrity and for allowing extinction/recolonization processes to operate.
- degradation of environmental quality. Increases in disease and malformities in Maine's amphibians may signal changes in habitat quality. Amphibians, with their moist, permeable skin, are highly sensitive to chemical contamination of their breeding habitats by atmospheric and land-based introductions.

USE AND DEMAND ASSESSMENT

Past Use and Demand

Public interest in vernal pools in the past was largely limited to the enjoyment people derive from listening to frogs sing in the spring. Children, and most people who enjoy the outdoors, can tell you about at least one favorite frog pond that dries up by the end of the summer. However, because of their small size and ephemeral nature, vernal pools are easily overlooked and rarely thought of as critical landscape features and wildlife habitat. The lack of appreciation for the large role these very small wetlands play in ecosystem dynamics is slowly being replaced by concern for conserving these areas. Recent alarm over potential declines in amphibian populations, and increases in incidences of malformations (see Introduction), have increased public interest in amphibian habitat in general. Further, the appearance of popular publications on vernal pools (DesMeules and Nothnagle 1997; Stoltzenburg 1997; Kenney and Burne 2000) has helped to heighten public awareness and sustain public interest in the fate of vernal pools.

Current Use and Demand

Vernal pools, and amphibian conservation in general, have captured the interest of Maine citizenry as well. Over 250 volunteers assisted with the MARAP effort. Currently over 250 volunteers participate in programs for monitoring singing amphibians and vernal pools. Numbers of volunteers are expected to increase as the programs mature. Many examples, beyond active participation in monitoring programs, point to increasing public concern about, and interest in, Maine's herpetofauna and vernal pools in particular.

- *The Maine Citizen's Guide for Locating and Documenting Vernal Pools*, developed in 1997 and presented in a series of workshops, was extremely popular, soon exhausting the supply of 500 printed copies. A revised edition of this manual, complete with color photographs, will be available by spring 2000 (1,000 copies). This updated document will be presented at a series of workshops targeting town resource managers and planners, educators, land trusts, and interested citizens.

- To date, three high schools are actively involved in monitoring vernal pools. As part of that project, funded by the Maine Math and Science Alliance, a web page archiving all the vernal pool data is available and will serve as repository for data collected by vernal pool monitors statewide (www.wetlandconnections.org). Data will be available for analysis from any interested parties. So many schools expressed interest in this program that a waiting list was developed, pending publication of the updated manual and availability of personnel to provide training.

- Demand from municipalities on vernal pool conservation strategies has prompted MAS and UME to launch a project to develop model local ordinances for protection of small wetlands. This work is funded by an EPA block grant awarded to the Maine State Planning Office.

- The popularity of the March 1999 publication of *Maine's Amphibians and Reptiles* (Hunter et al. 1999) reflects the public's growing interest in herpetofauna. During the first 3 months after publication, approximately 1,500 copies have sold with requests from as far afield as Minnesota.

- Interest in vernal pool conservation efforts is growing at the regional level. A workshop on vernal pools was held in Connecticut in 1998. An entire session of the

1999 Northeast Fish and Wildlife conference was dedicated to reptiles and amphibians. It was the most popular session of the conference, reflecting the increased concern and interest in non-game conservation issues. A two-day workshop bringing together approximately 500 scientists, educators, policy makers, and land managers to assess the status of vernal pool science and conservation was held at the University of Rhode Island in March 2000. The conference helped foster a regional approach to conserving and studying the resource. Other regional efforts include publication of Best Management Practices (BMPs) for vernal pools in a developing landscape. This cooperative effort among MAS, UME, and other northeastern states is being launched this summer. Draft BMPs for timber harvesting around vernal pools are currently under review by MDIFW. Already, other New England states and New York have expressed interest in using this Maine-specific document as a template for conservation efforts in their states. *The ecology of vernal pools in the northeastern United States: a community profile* (Colburn, in prep.), will synthesize current knowledge and highlight the importance of these habitats to both scientific and lay communities.

SUMMARY AND CONCLUSIONS

Vernal pools are naturally-occurring, seasonal to permanent bodies of water. They occur in shallow depressions that fill during the spring and fall and may dry during the summer. These seasonal wetlands are free of predatory fish. Vernal pools provide the primary breeding habitat for one or more of Maine's four vernal pool indicator species—spotted and blue-spotted salamanders, wood frogs, and fairy shrimp. They also provide habitat for other wildlife including several Endangered and Threatened species. The blue-spotted salamander is listed as a Species of Special Concern in Vermont and Massachusetts and is listed as Threatened in Connecticut (Hunter et al. 1999). Four-toed salamanders, strongly associated with sphagnum-dominated vernal pools, are listed as a Species of Special Concern in Maine. Three state- listed turtles are associated with vernal pools during significant portions of their life history including Blanding's (Endangered), spotted (Threatened), and wood turtles (Species of Special Concern).

Research projects on various aspects of vernal pools have been conducted in Maine (Joyal 1996; Dimauro 1998; deMaynadier and Hunter 1999; Calhoun et al. [in prep]; Perillo [in prep]). It is clear from recent studies that the ecological integrity of upland areas associated with breeding pools is as integral to the success of these species as the quality of the breeding pool. It is known that some pool-breeding species travel over a kilometer from their natal pools. What remains to be quantified is the amount of suitable terrestrial habitat associated with a pool that is necessary to support viable amphibian populations. Similarly, more research needs to be done to identify critical habitat elements (e.g., coarse woody debris, canopy cover, ground condition, and litter cover) and the limits around them.

Vernal pools receive federal and state regulatory protection to the degree that any wetland does. However, because of their small size (often under the 4,300 ft^2 state exemption for wetland impacts), many pools slip through the regulatory cracks. "Significant Vernal Pools" are currently listed in the Natural Resources Protection Act (NRPA 1996) as Significant Wildlife Habitat. However, protection afforded by this status is not available until MDIFW develops a regulation defining "Significant Vernal Pools" and a method is developed for pre-identifying pools eligible for protection. A Vernal Pool Working Group was formed in 1999 to provide guidance on both regulatory, voluntary, and educational strategies for realizing this goal, one of many current state wetland conservation priorities.

Major threats to Maine's vernal pools and the species that breed in them are:

- Direct loss of pools and increasing isolation of remaining pools.
- Habitat fragmentation and loss of the surrounding upland matrix.
- Degradation of water quality.

Current patterns of development and ongoing sprawl pose the greatest immediate threat to amphibian populations in Maine. It is clear that the future for habitat for pool-breeding amphibians in a developing Maine landscape will depend on successful strategies to reduce habitat loss, fragmentation, and degradation, especially in resource-rich areas. Habitat protection strategies including regulation, acquisition, easements, or voluntary agreements that can succeed in protecting vernal pools, or complexes of pools, and associated upland in large tracts of land (>100 acres) are desirable. Conservation efforts need to be focused, at the very least, in the southern part of the state. Vernal pools in this region host several species of rare and vulnerable wildlife species in a rapidly developing landscape with very limited public land reserves.

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