Appendix A: Amphibians

Blue-spotted/Jefferson Salamander complex

Ambystoma laterale & jeffersonianum

Federal Listing	N/A
State Listing	SGCN
Global Rank	G4/G5
State Rank	S2
Regional Status	Very High

Photo by Eric Aldrich

Justification (Reason for Concern in NH)

Blue-spotted salamanders and Jefferson salamanders are known to form hybrids. Populations of pure blue-spotted or Jefferson salamander populations are probably very rare; however, a pure male of either species (blue-spotted or Jefferson) is required for the production of viable offspring. Only a handful of individuals have actually been genotyped as pure blue-spotted in New Hampshire, and only one pure Jefferson salamander has ever been identified in New Hampshire. These species and their hybrids may be sensitive to habitat disturbance. Data on this species in New Hampshire is limited. In Massachusetts, a study documented drastic declines in blue-spotted salamander complex breeding populations, having sex ratios consistently skewed towards females (Homan et al. 2007). Often the location of a salamander observation in New Hampshire will indicate the likelihood of either a Jefferson (near the Connecticut River) or blue-spotted salamander (distant from the Connecticut River). However, genetic tests would be required to confirm whether a specimen was truly a blue-spotted or Jefferson salamander versus a blue-spotted/Jefferson hybrid (also referred to as a 'complex'). Reports of a Jefferson or blue-spotted salamander are often documented as 'blue-spotted salamander/Jefferson complex.'

Distribution

Jefferson Salamander
This "species" is limited to the eastern United States and Canada. It ranges from western New England to eastern Illinois, north to Ontario, and south to central Kentucky to Virginia to Maryland (Klemens 1993, DeGraaf and Yamasaki 2001). In New England, it occurs west of the Connecticut River in Vermont, Massachusetts, and Connecticut; and east of the Connecticut River in southwestern New Hampshire and Massachusetts (Klemens 1993, French and Master 1986). Despite the New England range, populations consisting only of pure Jefferson salamanders are known from Pennsylvania southward to Kentucky and West Virginia (NatureServe 2004, Conant and Collins 1998). The Jefferson genotype was found in hybrid individuals (carrying more blue-spotted than Jefferson chromosome sets) in central Maine (Knox 1999).

In New Hampshire, only one pure Jefferson salamander has ever been identified (using DNA analysis). This was a pure male from Winchester in Cheshire County identified in 1984 (French and Master 1986, Bogart and Klemens 1997). It is unknown whether this male represented a pure or mixed pure-hybrid population (Bogart and Klemens 1997). Jefferson salamanders have been reported to the RAARP program for other towns in New Hampshire but it is not known whether these individuals represent pure Jefferson salamanders or hybrids dominated by either Jefferson or blue-spotted

salamander genomes. Recent undocumented reports have come from Merrimack, Cheshire, and Hillsborough counties.

Blue-spotted salamander
This "species" ranges from the maritime provinces of Canada to southeastern Manitoba, southward to northern Illinois, east to New York, then north along the Atlantic coast through New England (Klemens 1993, DeGraaf and Yamasaki 2001). Disjunct populations are located in New Jersey, Long Island (NY), Iowa, and Labrador (Klemens 1993, DeGraaf and Yamasaki 2001). In New England, it occurs widely throughout eastern and central Massachusetts, southeastern New Hampshire, Maine, and the Lake Champlain lowlands in Vermont (Klemens 1993). Scattered populations occur in southwestern New England, but the species does not occur on Cape Cod (Klemens 1993). Only 2 populations of pure (non-hybrid) blue-spotted salamanders are known (one on Prince Edward Island, Canada; the other on Long Island, New York; Knox 1999), though 5 others are suspected in Massachusetts and Connecticut (Bogart and Klemens 1997).

In New Hampshire, pure blue-spotted salamanders have been documented in Hollis (1 female), Rockingham County (2 females and a male), and Strafford County (1 female) (Bogart and Klemens 1997). Additionally, hybrid blue-spotted salamanders (blue-spotted genotype dominant or equal to the Jefferson genotype) were reported in Hollis (4 females), Rockingham County (six females and an unsexed individual), and Strafford County (2 females) (Bogart and Klemens 1997). Taylor (1993) also reported several blue-spotted salamanders (pure or hybrid) observations from Strafford County, Rockingham County, and Hillsborough County, and 1 observation from Coos County. However, Taylor (1993) and Bogart and Klemens (1997) may have been reporting some of the same individuals. Some of these individuals were museum specimens and may actually be historic records. Finally, RAARP has received several reports of blue-spotted salamander observations, but these reports do not distinguish between pure and hybrid salamanders. These reports are primarily from Rockingham and Strafford counties, but some reports have come from Hillsboro, Cheshire, Coos, Grafton, and Merrimack counties.

Hybrids
Most of the individuals across the range of both species are likely hybrids (Klemens 1993). To produce viable offspring, hybrids must mate with a pure male of either parent species. Thus, pure diploid Jefferson salamander and blue-spotted salamander males are likely present throughout parts of New England, but the exact distribution of the pure genotype is unknown (Bogart and Klemens 1997). A recent study documented blue-spotted complex populations in southeast New Hampshire, and Jefferson complexes were documented in southwest New Hampshire (Bogard and Klemens 2008). Local populations of blue-spotted salamanders, Jefferson salamanders, and their associated hybrids, where they exist in New Hampshire, will be clustered in relatively undisturbed forest uplands around temporary and semi-permanent pools and other palustrine wetlands. Such a habitat mosaic, of palustrine wetlands embedded in forested upland, is common throughout New Hampshire but is increasingly fragmented by human development, especially in the southern portion of the state.

Habitat

Jefferson Salamander
Jefferson salamanders breed in palustrine wetlands, but spend most of their lives in nearby forested uplands (Klemens 1993, Faccio 2003). Jefferson salamanders can breed in several types of palustrine

wetlands (i.e. grassy pasture ponds, small impoundments filled by seasonal stream, and vernal shrub swamps), but favor vernal pools (Klemens 1993). High breeding success in vernal pools is attributed to the absence of fish predators. To sustain a viable Jefferson salamander population, these pools must hold standing water until late summer in most years, so that the salamander larvae have sufficient time to develop and metamorphose (Harding 1997). This species attaches its egg masses to vegetation and dead branches within the water column of the vernal pool.

Jefferson salamanders prefer deciduous forest, but also occur in mixed deciduous-hemlock forest (Klemens 1993). This species also seems to prefer steep rocky areas with rotten logs and heavy duff layers (Klemens 1993). It seeks cover and hibernates in small mammal burrows, coarse woody debris, leaf litter, and stones (Faccio 2003, Klemens 1993). Jefferson salamanders have been observed at elevations ranging up to 1,700 feet (Klemens 1993, USFS 2002).

Blue-Spotted Salamander
Blue-spotted salamanders breed in fresh-water wetlands but spend most of their lives in nearby forested uplands (Downs 1989, Klemens 1993, Knox 1999). Blue-spotted salamanders use many wetlands types for breeding, including ephemeral and semi-permanent pools, swamps, ponds, marshes, ditches, and flooded sections of logging roads (Downs 1989, Klemens 1993, Knox 1999). In Connecticut, this species breeds frequently in acidic red maple/sphagnum moss swamps but also occurs in calcareous wetlands (Klemens 1993). Where the ranges of the closely related Jefferson salamanders (*Ambystoma jeffersonianum*) and blue-spotted salamanders overlap, Jefferson salamanders prefer ridge-top vernal pools, whereas blue-spotted salamanders seem to prefer lowland swamps (Klemens 1993). To sustain a viable blue-spotted salamander population, a wetland must hold standing water until late summer in most years so that the salamander larvae have time to develop and metamorphose (Harding 1997). Water depth in breeding wetlands is usually less than 40 cm (Knox 1999). This species sometimes attaches its eggs (singly or in small clusters) to grass and other wetland vegetation (Klemens 1993).

For upland habitat, blue-spotted salamanders prefer damp, deciduous, or mixed woodlands with moderate shade (Downs 1989, Knox 1999). Blue-spotted salamanders are commonly found in water-saturated loamy soil and damp crumbly sand (Downs 1989, Klemens 1993). They seek cover under rocks, rotting stumps and logs, moss, vegetative debris, small mammal burrows, woodpiles, and human debris (Klemens 1993, Knox 1999).

General
The size and configuration of upland habitat needed to sustain Jefferson, blue-spotted, or hybrid populations are unknown. They may require large areas of undisturbed upland forest connected by suitable dispersal corridors to maintain metapopulations (Semlitsch 1998, USFS 2002). Salamanders may migrate several hundred meters from their breeding pools into the adjacent uplands (Williams 1973, Faccio 2003, Carr Research Laboratory and Hyla Ecological Services 2003).
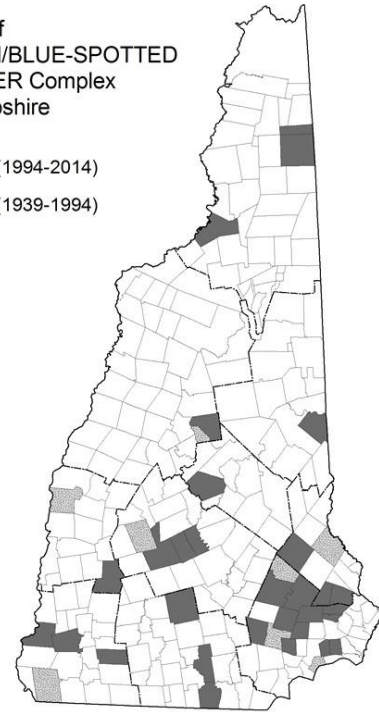
NH Wildlife Action Plan Habitats

- Vernal Pools
- Hemlock Hardwood Pine Forest
- Appalachian Oak Pine Forest
- Floodplain Habitats
- Marsh and Shrub Wetlands
- Northern Hardwood-Conifer Forest
- Northern Swamps
- Peatlands
- Temperate Swamps

Distribution of JEFFERSON/BLUE-SPOTTED SALAMANDER Complex in New Hampshire

Current (1994-2014)
Historic (1939-1994)

Distribution Map

Current Species and Habitat Condition in New Hampshire

There are insufficient data from which to determine the relative health of populations.

Population Management Status

Jefferson salamanders, blue-spotted salamanders, and their hybrids are not specifically protected or managed. No management plan exists for the population from which the only pure Jefferson salamander was collected.

Regulatory Protection (for explanations, see Appendix I)

- NHFG Rule FIS 803.02. tiImportation.
- NHFG Rule FIS 804.02. Possession.
- NHFG Rule FIS 811.01 Sale of tiReptiles.
- NHFG FIS 1400 Nongame special rules
- Fill and Dredge in Wetlands - NHDES
- Clean Water Act-tiSection 404

Quality of Habitat

There are insufficient data from which to determine the relative quality of habitat patches.

Habitat Protection Status

There are insufficient data from which to determine the habitat patch protection status.

Habitat Management Status

Salamander habitat is indirectly managed through wetland and water resource protection, forestry management regulations (i.e., New Hampshire RSA 482-A; New Hampshire Rule Chapters Wt 100-800; Best Management Practices for Erosion Control on Timber Harvesting Operations in New Hampshire), and through land preservation (e.g., conservation restrictions and land acquisitions). These efforts are not specifically designed to manage for salamanders. Population growth and associated development will likely destroy or degrade potential habitat, despite measures aimed at slowing and redirecting development. Additionally, some forest management techniques (e.g., clear cutting) could also contribute to the fragmentation and degradation of potential habitat (deMaynadier and Hunter 1999, Pough and Wilson 1976 cited in DeGraaf and Yamasaki 2001, Faccio 2003).
Basic distribution and habitat use data for the species is needed to develop effective habitat management plans. In the absence of this basic data, habitat management efforts might focus on limiting disturbance in and around vernal pools that are embedded within a relatively large matrix of minimally disturbed forest. The goal of habitat management efforts should be to maintain habitat patches that allow for metapopulation dynamics (i.e., multiple pool/upland patches connected by dispersal habitat). Thus, the usefulness (to salamanders) of pool buffer zones and dispersal corridors between habitat patches needs to be evaluated.

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat conversion due to development of surrounding uplands and associated edge effects (Threat Rank: Medium)

Residential or commercial development may affect breeding habitat (loss and degradation of vernal pools), upland habitat (loss and degradation of forests), and dispersal corridors (by fragmenting landscapes), and may even directly kill amphibians such as salamanders. Opportunistic predators (e.g., raccoons) and invasive plant and animal species are more common near human development. Myriad stressors associated with development collectively reduce local population sizes of amphibians, reduce gene flow between populations, and may ultimately extirpate local populations.

The long-term persistence of salamander populations depends on the exchange of individuals through dispersal and the colonization probability of vernal pools or other wetlands from terrestrial adult populations (Dodd 1997, Semlitsch and Bodie 1998, Skelly et al. 1999). Most amphibians use terrestrial habitat to obtain food and shelter from predation, desiccation, or freezing (Madison 1997, Lamoureaux and Madison 1999, Knutson et al. 1999). Therefore, the suitability of terrestrial habitat surrounding a wetland is likely to have a significant influence on the composition and abundance of amphibians that breed in or otherwise utilize nearby wetlands.
In recent decades, commercial and residential development in New Hampshire have increased

dramatically, in conjunction with accelerated human population growth and immigration (Sundquist and Stevens 1999). Windmiller (1996) noted that increasing urbanization likely reduces mole salamander abundance and excludes salamanders from otherwise suitable habitat. Gibbs (1998a) suggested that ambystomatids are predisposed to local extinction caused by habitat fragmentation.

Habitat conversion from the direct filling of wetlands for development (Threat Rank: Medium)

The direct filling of wetlands for development reduces the availability of breeding habitat for Jefferson and blue-spotted salamanders, through the direct loss and degradation of vernal pools, swamps, ponds, and marshes.

Amphibians, particularly ambystomatid salamanders including marbled salamanders, generally breed in the same wetland every year (Semlitsch et al. 1993, Semlitsch 1998). It is not well known how these species respond when a breeding wetland is no longer available (i.e., filled). Some ambystomatid salamanders will return to breeding wetlands even after those wetlands have been filled, whereas others have been able to disperse to nearby created wetlands (Pechmann et al. 2001). Created mitigation wetlands usually are unsuccessful at replicating the wildlife habitat of the wetlands they are intended to replace (Brown 1999).

Wetland loss in the United States from historic draining and filling is well documented (e.g., Dahl 1990, 2000). Lack of reliable data for vernal pools creates difficulty in accurately determining historic losses. An important aspect of wetland loss is not simply the continued loss of habitat, but the continued under-valuing of vernal pool habitat as well. Size has traditionally been used an important criterion for assessing wetland value. Without increased protection priority for vernal pools, it is certain that vernal pool habitat will decrease in the future.

Mortality of individuals from vehicles on roadways (Threat Rank: Medium)

Vehicle traffic can kill salamander species by hitting and crushing them as they cross roads. This can have a significant impact on some species, and in severe cases could result in local extirpation. Roads may act as partial barriers to overland dispersal or migration, perhaps resulting in decreased gene flow between populations and decreased colonization of unpopulated wetlands or vernal pools. This could disrupt metapopulation dynamics and long-term viability of some species.

Roads also create edge habitat. Along these edges, soil and air moisture may be reduced, leading to increased salamander desiccation. Roads may act as conduits for predators that prey on amphibians (e.g., skunks and raccoons), and dispersal avenues for invasive plants and animals. Runoff from roads can also reduce habitat quality of vernal pools via pollution, increased salt levels, sedimentation, and erosion in pools and adjacent habitats.

Roads are a significant source of direct mortality for migrating amphibians (Fahrig et al. 1995, Ashley and Robinson 1996, Mazerolle 2004, Forman 2003), and salamander abundance in roadside habitats may be reduced (deMaynadier and Hunter 2000). Gibbs (1998) found that forest-road edges are less permeable to ambystomatid salamanders than are forest interior and forest-open land edges. Research conducted in southern New Hampshire suggests that roads have a negative impact on wood frogs (*Lithobates sylvatica*) and spotted salamanders (*Ambystoma maculatum*), a similar salamander that also breeds in vernal pools (Mattfeldt 2004). Amphibians can experience delayed development or mortality from runoff contamination from roads, including road salt (Trombulak and Frissell 2000, Turtle 2000).

Species impacts from hybridization (reduced fitness) (Threat Rank: Medium)

Jefferson-blue-spotted salamander hybrids may come to dominate salamander populations where pure Jefferson salamanders are also present (see Distribution). Through competition with hybrids or with pure blue-spotted salamanders, or through local extinction events, pure Jefferson salamanders may be eliminated, and thus, the species as a pure lineage may go extinct.

Jefferson and blue-spotted salamanders hybridize throughout much of their range (Conant and Collins 1998), and other hybrid combinations occur at the western extent of the Jefferson range (Bogart and Klemens 1997). Changes in regional climate, caused by global warming, may facilitate future range overlap. Hybrid populations seem unsustainable without sexual stimulation from pure males, but the pure genome is either not, or only temporarily, incorporated into the lineage (Bogart and Klemens 1997). Hybrids are usually dominant where they are present (Bogart and Klemens 1997). Hybrids may be better adapted to a wider range of habitats and environmental conditions than either parent species.
Hybridization is viewed as a very serious threat by the research and conservation communities (see Wright and Marchand 2002). However, hybridization seems a natural evolutionary step for two species that recently diverged due to temporary geographic isolation (for evolutionary history, see Bogart and Klemens 1997). Were this evolution untouched by human influence, both or either species might still go extinct. Alternatively, they might re-merge into a single species, or survive as two species. The threat is more the potential for human influence to impact this process (i.e., through habitat destruction and fragmentation), than the hybridization itself.

Mortality and species impacts (reduced fitness) from acid deposition (Threat Rank: Medium)

Acid rain and contaminated runoff and discharge may increase soil and water acidity within salamander habitat.

Mole salamanders exhibited a decreased hatching success, larval survival, embryonic developmental rates, and abundance of egg masses at low water pH levels (Pough 1976, Rowe et al. 1992, Rowe and Dunson 1993, Horne and Dunson 1994a, 1994b). Negative effects of low water pH have been observed in amybstomatids (as summarized in Kiesecker 1996). Additionally, metal mobility, and hence toxicity of metals to salamanders, changes with pH (Rowe et al. 1992, Rowe and Dunson 1993, Horne and Dunson 1994b, Horne and Dunson 1995a, 1995b). Research with other amphibians has demonstrated a negative synergistic interaction between low pH and other threats (e.g., UV-B radiation; Long et al. 1995, Hatch and Blaustein 2000). Low soil pH may lead to increased desiccation among terrestrial salamanders, and terrestrial salamanders may avoid habitat that has acidic soil.

List of Lower Ranking Threats:

Mortality and habitat degradation from fertilizer use near wetlands

Mortality and species impacts (reduced fitness) from toxins and contaminants

Mortality and species impacts (decreased fitness) from various diseases (ranavirus, chytrid)

Habitat degradation from introduced or invasive plants

Mortality and degradation from legal and illegal OHRV activity

Mortality and habitat conversion from forestry practices

Mortality and degradation from increased droughts

Actions to benefit this Species or Habitat in NH

Protect habitat

Primary Threat Addressed: Habitat conversion from the direct filling of wetlands for development

Specific Threat (IUCN Threat Levels): Residential & commercial development

Objective:
Maintain and protect habitat for salamanders statewide.

General Strategy:
Maintaining vernal pool habitat, upland habitat, and dispersal corridors will be the most effective way to protect this species. To assist in understanding habitat use and population health, surveys should consider the following: the size and configuration of upland habitat needed to sustain Jefferson, blue-spotted, or hybrid populations; proximity of occupied habitat to roads, development, and other disturbances, the exact distribution of the pure Jefferson genotype; density of species at various sites and the potential for genetic exchange between local populations; habitat use; the degree of isolation and regional persistence mechanism of local populations in New Hamp-shire and neighboring states and the usefulness to salamanders of pool buffer zones and dispersal corridors between habitat patches.

Political Location:
Statewide

Watershed Location:
Statewide

Conduct a survey for the presence of blue-spotted salamanders and Jefferson salamanders and complete a threat assessment for the species and its hybrids

Objective:
To better understand the distribution, status, and habitat use of Jefferson and blue-spotted salamanders. If pure populations are discovered, habitat, life history, and dispersal data should be collected.

General Strategy:
New Hampshire needs a statewide systematic survey to determine the distribution of blue-spotted and Jefferson salamanders and their hybrids. Much of the existing distributional data for New Hampshire is unreliable because it does not distinguish between pure Jefferson salamanders, blue spotted salamanders, and their hybrids. This survey should distinguish (genetically) between pure and hybrid blue-spotted salamanders so that distribution maps can be drawn for pure populations, populations where pure forms and hybrids coexist, and hybrid populations that lack pure genotypes.
It may help to first delineate its potential habitat. A GIS habitat layer could be produced using remote sensing (e.g., aerial photography) and ground truthing. Potential habitat should be determined by comparing a vernal pool data layer to a forest cover data layer. Additional research is needed to establish and thoroughly detail the specific effects of various threats to Jefferson and blue-spotted salamanders. Data for the species is needed to develop effective habitat management plans. In the

absence of this basic data, habitat management efforts might focus on limiting disturbance in and around vernal pools that are embedded within a relatively large matrix of minimally disturbed forest. The goal of habitat management efforts should be to maintain habitat patches that allow for metapopulation dynamics (i.e., multiple pool/upland patches connected by dispersal habitat). Thus, needs to be evaluated.

Political Location:	**Watershed Location:**
Statewide	Statewide

Location Description:
Surveys should start with known occupied sites, and historic occurrences.

Education and outreach to facilitate amphibian migration across roads

Primary Threat Addressed: Mortality of individuals from vehicles on roadways

Specific Threat (IUCN Threat Levels): Transportation & service corridors

Objective:
Reduce the impacts of roads on amphibian population and metapopulation dynamics, and thus maintain viable populations of breeding amphibians.

General Strategy:
Facilitation activities could be coordinated at the state level by a government, non-profit, or consulting group. Facilitation could alternatively be implemented and monitored at the municipal level. Volunteers should be trained and utilized to perform much of this conservation action. Installing tunnels beneath roads that intersect amphibian migration routes will facilitate dispersal. Community education may further decrease the threat of road traffic to migrating amphibians. Community members can help salamanders cross roads and witness the migrations at these locations (see Jackson 1996, 2003, Jackson and Tyning 1989).

Political Location:	**Watershed Location:**
Statewide	Statewide

References, Data Sources and Authors

Data Sources
Information relating to the distribution of this species was gathered during a literature review. Two primary sources of information and references were DeGraaf and Yamasaki (2001) and the "Species Data Collection Form" completed by the USFS (Wright and Marchand 2002); the latter included information from state databases, meetings, and expert reviews.
Threat assessments were conducted by a group of NHFG biologists (Michael Marchand, Brendan Clifford, Loren Valliere, Josh Megysey).

Data Quality
No comprehensive survey has been conducted for these species in New Hampshire. Much of the

existing distributional data for New Hampshire is unreliable to the species level because it does not distinguish between pure Jefferson salamanders, blue spotted salamanders, and their hybrids. The work of Bogart and Klemens (1997), which genetically identified 18 pure/hybrid blue-spotted salamanders from New Hampshire, is highly accurate, but of limited quantity. Regional distribution maps suggest that the species may be present throughout the state.

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Literature

Ash, A.N., and K.H. Pollock. 1999. Clearcuts, salamanders, and field studies. Conservation Biology. 13: 206-208.

Ashley, E.P., and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field-Naturalist. 110: 403-412.

Barbour, R.W. 1971. Amphibians and reptiles of Kentucky. University Press of Kentucky, Lexington.

Blaustein, A.R., and J.M. Kiesecker. 2002. Complexity in conservation: lessons from the global decline of amphibian populations. Ecology Letters. 5: 597-608. in New York and New England. American Museum Novitates 3218. New York: American Museum of Natural History.

Blaustein, A.R., L.K. Belden, A.C. Hatch, L.B. Kats, P.D. Hoffman, J.B. Hays, A. Marco, D.P. Chivers, and J.M. Kiesecker. 2001. Ultraviolet radiation and amphibians. Pages 63-79 in C.S. Cockell and amphibians. Pages 63-79 in C.S. Cockell and A.R. Blaustein, editors. Ecosystems, Evolution, and Ultraviolet Radiation. Springer, New York.

Bogart, J.P., and M.W. Klemens. 1997. Hybrids and genetic interactions of mole salamanders (*Ambystoma jeffersonianum* and *A. laterale*) (Amphibia: Caudata)

Bogart, J.P., and M.W. Klemens. 2008. Additional records of *Ambystoma laterale, A. jeffersonianum* (Amphibia: Caudata) and their unisexual kleptogens in Northeastern North America. American Museum Novitates: No. 3627.

Boone, M.D., and R.D. Semlitsch. 2001. Interactions of an insecticide with larval density and predation in amphibian experimental communities. Conservation Biology. 15: 228-238.

Bridges, C.M. 1997. Tadpole swimming performance and activity affected by acute exposure to sublethal levels of carbaryl. Environmental Toxicology and Chemistry. 16: 1935-1939.

Brown, S. 1999. Effectiveness of compensatory wetland mitigation in Massachusetts. Assoc. Mass. Wetland Sci. Newsletter. 20: 5.

Chazal, A.C., and P.H. Niewiarowski. 1998. Responses of mole salamanders to clearcutting: using field experiments in forest management. Ecological Applications. 8: 1133-1143.

Conant, R., and J.T. Collins. 1998. A field guide to reptiles and amphibians of eastern and central North America. Third edition, expanded. Houghton Mifflin Company, Boston, Massachusetts, USA.

Dahl, T.E. 1990. Wetlands losses in the United States 1780s to 1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Appendix A: Amphibians

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997 U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

DeGraaf, R.M., and M. Yamasaki. 2001. New England wildlife: habitat, natural history, and distribution. University Press of New England, Hanover, New Hampshire.

deMaynadier, P.G., and M.L. Hunter. 1999. Forest canopy closure and juvenile emigration by pool-breeding amphibians in Maine. Journal of Wildlife Management. 63: 441-450.

deMaynadier, P.G., and M.L. Hunter. 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal. 20: 56-65.

Dodd, C.K., Jr. 1997. Imperiled amphibians: a historical perspective. Pages 165 – 200 in G. W. Benz and D. E. Collins, editors. Aquatic Fauna in peril: the southeastern perspective.

Faccio, S.D. 2003. Postbreeding emigration and habitat use by Jefferson and spotted salamanders in Vermont. Journal of Herpetology. 37: 479-489.

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor, and J.F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation. 73: 177-182.

Forman, R.T.T., and R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. Conservation Biology. 14: 36-46.

Freda, J. and W.A. Dunson. 1986. Effects of low pH and other chemical variables on the local distribution of amphibians. Copeia. 1986: 454-466.

French, T.W., and L.L. Master. 1986. Geographic distribution: *Ambystoma jeffersonianum* (Jefferson salamander). Herpetological Review. 17: 26.

Gibbs, J.P. 1998a. Distribution of woodland amphibians along a forest fragmentation gradient. Landscape Ecology. 13: 263-268

Gibbs, J.P. 1998b. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management. 62: 584-589.

Harding, J.H. 1997. Amphibians and reptiles of the Great Lakes region. The University of Michigan Press, Ann Arbor.

Harper, C.A., and D.C. Guynn, Jr. 1999. Factors affecting salamander density and distribution within four forest types in the Southern Appalachian Mountains. Forest Ecology and Management. 114: 245-252.

Hatch, A.C. and G.A. Burton, Jr. 1998. Effects of photoinduced toxicity of fluoranthene on amphibian embryos and larvae. Environmental Toxicology and Chemistry. 17: 1777-1785.

Hatch, A.C., and A.R. Blaustein. 2000. Combined effects of UV-B, nitrate, and low pH reduce the survival and acticity level of larval Cadcades frogs (*Rana cascadae*). Archives of Environmental Contamination and Toxicology. 39: 494-499.

Hatch, A.C., L.K. Belden, E. Scheessele, and A.R. Blaustein. 2001. Juvenile amphibians do not avoid potentially lethal levels of urea on soil substrate. Environmental Toxicology and Chemistry. 20: 2328-2335.

Horne, M.T., and W.A. Dunson. 1994a. Behavioral and physiological responses of the terrestrial life stages of the Jefferson salamander, *Ambystoma jeffersonianum*, to low soil pH. Archives of Environmental Contamination and Toxicology. 27: 232-238.

Horne, M.T., and W.A. Dunson. 1994b. Exclusion of the Jefferson salamander, *Ambystoma jeffersonianum*, from some potential breeding ponds in Pennsylvania: effects of pH, temperature, and metals on embryonic development. Archives of Environmental Contamination and Toxicology. 27: 323-300.

Appendix A: Amphibians

Horne, M.T., and W.A. Dunson. 1995a. Toxicity of metals and low pH to embryos and larvae of the Jefferson salamander, *Ambystoma jeffersonianum*. Archives of Environmental Contamination and Toxicology. 29: 110-114.

Horne, M.T., and W.A. Dunson. 1995b. Effects of low pH, metals, and water hardness on larval amphibians. Archives of Environmental Contamination and Toxicology. 29: 500-505.

Jackson, S.D. 1996. Underpass systems for amphibians. In G.L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Trends in Addressing Transportation Related Wildlife Mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar; FL-ER-58-96. State of Florida Department of Transportation, Tallahassee.

Jackson, S.D. 2003. Proposed design and considerations for use of amphibian and reptile tunnels in New England. Department of Natural Resources Conservation, University of Massachusetts at Amherst, Amherst.

Jackson, S.D., and T.F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders (*Ambystoma maculatum*) under roads. Pages 93-99 in T.E.S. Langton, editor. Amphibians and Roads: Proceedings of the Toad Tunnel Conference. ACO Polymer Products, Shefford, England.

Joly, O., C. Miaud, A. Lehmann, and O. Grolet. 2001. Habitat matrix effects on pond occupancy in newts. Conservation Biology. 15: 239-248.

Kagan, J., P.A. Kagan, and H.E. Buhse, Jr. 1984. Light-dependent toxicity of alpha-terthienyl and anthracene toward late embryonic stages of *Rana pipiens*. Journal of Chemical Ecology. 10: 1115-1122.

Kiesecker, J.M. 1996. pH induced growth reduction and its effects on predator-prey interactions between *Ambystoma tigrinum* and *Pseudacris triseriata*. Ecological Applications. 6: 1325-1331.

Klemens, M.W. 1993. Amphibians and reptiles of Connecticut and adjacent regions. Bull. 112. Hartford: Connecticut State Geological and Natural History Survey.

Knapp, S.M., C.A. Haas, and D.N. Harpole. 2003. Initial effects of clearcutting and alternative silvicultural practices on terrestrial salamander abundance. Conservation Biology. 17: 752-762.

Knox, C.B. 1999. Blue-spotted salamander. In M.L. Hunter, A.J.K. Calhoun, and M. McCollough, editors. Maine Amphibians and Reptiles. The University of Maine Press, Orono.

Knutson, M.G., J.R. Sauer, D.A. Olsen, M.J. Mossman, L.M. Hemesath, and M.J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on Frog and Toad abundance and species richness in Iowa and Wisconsin, USA. Conservation Biology 13: 1437-1446.

Kutka, F.J. 1994. Low pH effects on swimming activity of *Ambystoma* salamander larvae. Environmental Toxicology and Chemistry. 13: 1821-1824. survival of mole salamanders (Genus *Ambystoma*). Environmental Contamination and Toxicology. 32: 383-388.

Lefcort, H., K.A. Hancock, K.M. Maur, D.C. Rostal. 1997. The effects of used motor oil, silt, and the water mold *Saprolegnia parasitica* on the growth and survival of mole salamanders (Genus *Ambystoma*). Environmental Contamination and Toxicology. 32: 383-388.

Long, L.E., L.S. Saylor, M.E. Soule. 1995. A pH/UV-B synergism in amphibians. Conservation Biology. 9: 1301-1303.

Madison, D.M. 1997. The emigration of radioimplanted spotted salamanders, *Ambystoma maculatum*. Journal of Herpetology 31:542–551.

Marco, A., C. Quilchano, and A.R. Blaustein. 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific Northwest. Environmental Toxicology and Chemistry. 18: 2836-2839.

Mattfeldt, S. 2004. Effects of wetland isolation and surrounding landscape characteristics on vernal pool-dependent amphibians. M.S. Thesis. University of New Hampshire, Durham, New Hampshire.

Mazerolle, M.J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica. 60: 45-53.

McLeod, R.F., and J.E. Gates. 1998. Response of herpetofaunal communities to forest cutting and burning at Chesapeake Farms, Maryland. American Midland Naturalist. 139: 164-177.

Monson, P.D., D.J. Call, D.A. Cox, K. Liber, and G.T. Ankley. 1999. Photoinduced toxicity of fluoranthene to northern leopard frogs (*Rana pipiens*). Environmental Toxicology and Chemistry. 18: 308-312.

Naughton, G.P., C.B. Henderson, K.R. Foresman, and R.L. McGraw. 2000. Long-toed salamanders in harvested and intact Douglas-fir forests of western Montana. Ecological Applications. 10: 1681-1689.

Oliver, J.A., and J.R. Bailey. 1939. Amphibians and reptiles of New Hampshire exclusive of marine forms: Pages 195-217 in Biological Survey of the Connecticut Watershed. New Hampshire Fish and Game Department Survey Rep. 4.

Pechmann, J.H.K., R.A. Estes, D.E. Scott, and J.W. Gibbons. 2001. Amphibian colonization and use of ponds created for trial mitigation of wetland loss. Wetlands. 21: 93-111.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington D.C.

Petranka, J.W. 1999. Recovery of salamanders after clearcutting in the southern Appalachians: a critique of Ash's estimates. Conservation Biology. 13: 203-205.

Petranka, J.W., M.E. Eldridge, K.E. Haley. 1993. Effects of timber harvesting on Southern Appalachian salamanders. Conservation Biology. 7: 363-370.

Petranka, J.W., M.P. Brannon, M.E. Hopey, and C.K. Smith. 1994. Effects of timber harvesting on low elevation populations of southern Appalachian salamanders. Forest Ecology and Management. 67: 135-147.

Pough, F.H. 1976. Acid precipitation and embryonic mortality of spotted salamanders, *Ambystoma maculatum*. Science. 192: 68-70.

Raymond, L.R., and L.M. Hardy. 1990. Demography of a population of *Ambystoma talpoideum* (Caudata: *Ambystomatidae*) in north-western Louisiana. Herpetologica. 46: 371-382.

Rothermel, B.B. and R.D. Semlitsch. 2002. An experimental investigation of landscape resistance of forest versus old-field habitats to emigrating juvenile amphibians. The Journal of the Society for Conservation Biology. 16: 1324.

Rowe, C.L., and W.A. Dunson. 1993. Relationships among abiotic parameters and breeding effort by three amphibians in temporary wetlands of central Pennsylvania. Wetlands. 13: 237-246.

Rowe, C.L., W.J. Sadinski, and W.A. Dunson. 1992. Effects of acute and chronic acidification on three larval amphibians that breed in temporary ponds. Archives of Environmental Contamination and Toxicology. 23: 339-350.

Semlistch, R.D., D.E. Scott, J.H.K. Pechmann, and J.W. Gibbons. 1993. Phenotypic variation in the arrival time of breeding salamanders: individual repeatability and environmental influences. Journal of Animal Ecology. 62: 334-340.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology. 12: 1113-1119.

Semlitsch, R.D., and J.R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Skelly, D.K., E.E. Werner, and S. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. Ecology 80:2326-2337.

Appendix A: Amphibians

Sparling, D.W., G.M. Fellers, and L.L. McConnell. 2001. Pesticides and amphibian population declines in California, USA. Environmental Toxicology and Chemistry. 20: 1591-1595.

Sundquist, D., and M. Stevens. 1999. New Hampshire's changing landscape: population growth, land use conversion, and resource fragmentation in the Granite State. New Hamphire, Concord, Society for the Protection of New Hampshire Forests and The Nature Conservancy, 159 pp.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14: 18-30.

Turtle, S.L. 2000. Embryonic survival of the spotted salamander (*Ambystoma maculatum*) in roadside and woodland vernal pools in southeastern New Hampshire. Journal of Herpetology. 34:60-67.

Marbled Salamander
Ambystoma opacum

Federal Listing	N/A
State Listing	E
Global Rank	G5
State Rank	S1
Regional Status	High

Photo by Lloyd Gamble

Justification (Reason for Concern in NH)

The marbled salamander is a Regional Species of Greatest Conservation Need, and is of high regional concern. The marbled salamander is at the northern periphery of its range in New Hampshire and appears to be extremely rare in the state. Few documented occurrences of the species exist for New Hampshire; however, a systematic survey to determine the location of all potential populations has not been conducted. The southern distribution of this species in the state, together with intensive developmental pressure in the same area, places this species at significant risk of extirpation.

Distribution

The marbled salamander is endemic to the eastern half of the United States. It ranges from southern New Hampshire, west through southeastern New England and Pennsylvania to the Lake Michigan region, and south to eastern Texas and northern Florida (Klemens 1993, DeGraaf and Yamasaki 2001, NatureServe 2004). In New England, this species occurs throughout Connecticut, Rhode Island, Massachusetts east of the Connecticut River, and in the Berkshire Hills of western Massachusetts (Klemens 1993, DeGraaf and Yamasaki 2001). One specimen was collected from western Vermont (DeGraaf and Yamasaki 2001).

Historically, marbled salamanders were reported from Milford (Hoopes 1938) and Hollis (NHNHB 1965), both in Hillsborough County south-central New Hampshire. Records from RAARP (2005) indicated that a marbled salamander was observed in Hinsdale, Cheshire County in 2000 (photo verified), and another was possibly observed in Hollis in 1997 (no photo or specimen but near location of historic report). Beginning in 2006, visual surveys were conducted in the spring for the presence of marbled salamanders in pools in Hollis, Brookline, Mason, Hinsdale, and Milford. In 2006-2008, surveys documented two sites occupied by marbled salamander; one of the sites was occupied for three consecutive years.

Habitat

Marbled salamanders breed in seasonally flooded, palustrine wetlands, but spend most of their lives in the forested uplands surrounding these wetlands (Noble and Brady 1933, Bishop 1941, Petranka 1989, Klemens 1993). Marbled salamanders use several types of palustrine wetlands (e.g., ephemeral pools and streams, fishless swamps, ponds with low water levels) for breeding and nesting (Noble and Brady 1933, Bishop 1941, Petranka 1989). Eggs are laid along the exposed edges of the wetlands, and wetlands must flood in the late fall or early winter in order for eggs to hatch (Bishop 1941, Petranka 1989). Salamanders hide nests, usually in bare mineral soil, beneath leaf litter, grass clumps, or logs, or within root complexes (Jackson et al. 1989, Petranka 1990, Figiel and Semlitsch 1995). To sustain a viable marbled salamander population, a wetland must hold standing water for about 10 months in

most years (approximately September to June), so that the salamander larvae have sufficient time to develop and metamorphose (Noble and Brady 1933, Bishop 1941).

For upland habitat, marbled salamanders seem to prefer deciduous or mixed-deciduous woodlands (Klemens 1993), especially oak-maple and oak-hickory woods (Minton 1972) and floodplain forests (Petranka 1998). Marbled salamanders also seem to favor dry, friable soils, including sand and gravel deposits and rocky slopes (Bishop 1941, Klemens 1993). Marbled salamanders can inhabit somewhat drier areas than other Ambystoma species (Bishop 1941). Marbled salamanders use deeply imbedded rocks or logs (Klemens 1993) as cover objects, and probably use small mammal burrows as shelter throughout most of the year and as hibernacula in the winter (DeGraaf and Yamasaki 2001). In Connecticut, this species was observed at elevations ranging from 30 to 335 m (Klemens 1993). The area and configuration of upland habitat needed to sustain a marbled salamander population is unknown, but probably varies according to local site conditions. This species likely operates as metapopulations, which require a multitude of habitat patches (i.e., breeding wetland and adjacent upland forest) connected by habitat that is hospitable to dispersing salamanders, in order to persist (Semlitsch 1998). At the local population level, salamanders in Indiana migrated an average distance of 194 m (range 0- 450 m) from breeding wetlands into the surrounding uplands (Williams 1973 as cited in Semlitsch 1998).

NH Wildlife Action Plan Habitats

- Vernal Pools
- Appalachian Oak Pine Forest

Distribution of MARBLED SALAMANDER in New Hampshire

■ Current (1994-2014)
▒ Historic (1939-1994)
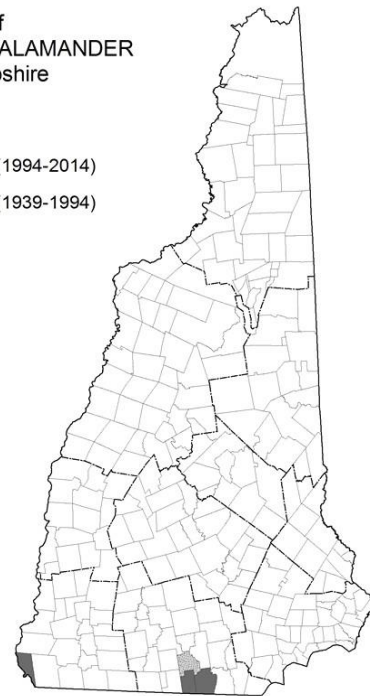
Distribution Map

Current Species and Habitat Condition in New Hampshire

There are no data on population number or population sizes from which to determine relative health of populations. However, as it is likely that the species occurs in low numbers, it may be in danger of extirpation.

Population Management Status

No specific management plans exist for populations at these observation locations. Confirmation of the existence of these populations is necessary. Additionally, a systematic survey, focused on southern New Hampshire, is needed to locate other potential marbled salamander populations. Population management plans can be created after populations have been identified.

Regulatory Protection (for explanations, see Appendix I)

- NHFG Rule FIS 803.02. Importation.
- NHFG Rule FIS 804.02. Possession.
- NHFG Rule FIS 811.01 Sale of Reptiles.
- Endangered Species Conservation Act (RSA 212-A)
- NHFG FIS 1400 Nongame special rules
- Fill and Dredge in Wetlands - NHDES
- Alteration of Terrain Permitting - NHDES

Quality of Habitat

Two known occupied pools (documented in 2006) are on conservation land. Populations of marbled salamanders, where they exist in New Hampshire, will likely be clustered in relatively undisturbed forest uplands around temporary and seasonally flooded wetlands. Such a habitat mosaic, of seasonally-flooded wetlands embedded in forested upland, is common throughout much of New Hampshire, but is increasingly fragmented by human development, especially in the southern portions of the state, which is where this species is most likely to occur.

Habitat Protection Status

There are insufficient data with which to assess protection status because very few breeding pools have been identified. The two pools documented during 2006 are on conservation lands.

Habitat Management Status

Marbled salamander habitat is indirectly managed through wetland and water resource protection, forestry management regulations (i.e., New Hampshire RSA 482-A; New Hampshire Rule Chapters Wt 100-800; Best Management Practices for Erosion Control on Timber Harvesting Operations in New Hampshire), and through land preservation (e.g., conservation restrictions and land acquisitions). These efforts are not specifically designed to manage for marbled salamanders. Population growth and associated development will likely destroy or degrade potential marbled salamander habitat, despite measures aimed at slowing and redirecting development. Additionally, some forest management techniques (e.g., clear cutting) could also contribute to the fragmentation and degradation of potential marbled salamander habitat (deMaynadier and Hunter 1999, Pough and Wilson 1976 cited in DeGraaf and Yamasaki 2001, Faccio 2003).

Basic distribution and habitat use data for the species are needed to develop effective habitat management plans. In the absence of these basic data, habitat management efforts might focus on limiting disturbance in and around vernal pools that are embedded within a relatively large matrix of minimally disturbed forest. The goal of habitat management efforts should be to maintain habitat patches that allow for metapopulation dynamics (i.e., multiple pool/upland patches connected by dispersal habitat). Thus, the usefulness (to salamanders) of pool buffer zones and dispersal corridors between habitat patches needs to be evaluated. Findings from a study in Massachusetts found that

existing regulations for buffer widths (typically 30m) were not sufficient to protect upland habitat use by mole salamanders and highlighted the need to approach conservation of these animals at a broader scale (Gamble et al 2006).

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat conversion due to development of surrounding uplands and associated edge effects (Threat Rank: High)

Development may affect breeding habitat (loss and degradation of vernal pools), upland habitat (loss and degradation of forests), and dispersal corridors (by fragmenting landscapes), and may even directly kill vernal pool wildlife such as marbled salamanders. Opportunistic predators (e.g., raccoons) and invasive plant and animal species are more common near human development. Myriad stressors associated with development collectively reduce local population sizes of amphibians, reduce gene flow between populations, and may ultimately extirpate local populations.

Vernal pools, an essential habitat feature for marbled salamanders, often occur in discrete patches within a matrix of terrestrial habitat. Amphibians that breed in these habitats may exist as metapopulations (e.g., Gill 1978, Sjögren 1991, Sinsch 1992, Marsh and Trenham 2001). The long-term persistence of populations depends on the exchange of individuals through dispersal and the colonization probability of vernal pools from terrestrial adult populations (Hanski and Gilpin 1991, Sjögren, 1991, Dodd 1997, Semlitsch and Bodie 1998, Skelly et al. 1999). Most amphibians use terrestrial habitat to obtain food and shelter from predation, desiccation, or freezing (Madison 1997, Lamoureaux and Madison 1999, Knutson et al. 1999). Therefore, the suitability of terrestrial habitat surrounding a vernal pool is likely to have a significant influence the composition and abundance of amphibians that breed in or otherwise utilize a vernal pool.

In the last few decades, commercial and residential development in New Hampshire have increased dramatically, in conjunction with accelerated human population growth and immigration (Sundquist and Stevens 1999). Similar urbanization has eliminated the marbled salamander from large portions of its former range on Long Island and mainland New York (Klemens 1993). Petranka (1998) noted that thousands of local populations of marbled salamanders have already been eliminated due to habitat loss. Windmiller (1996) noted that increasing urbanization likely reduces mole salamander abundance and excludes salamanders from otherwise suitable habitat. Gibbs (1998a) suggested that ambystomatids are predisposed to local extinction caused by habitat fragmentation.

Habitat conversion and impacts of the loss of breeding pools from the direct filling of wetlands for development (Threat Rank: Medium)

Vernal pools are filled for residential and commercial development, recreation, agriculture, and road development. Vernal pool filling results in immediate loss of habitat and, for some species, population extirpation. Wetland filling also increases the distance that dispersing amphibians must travel to reach suitable breeding habitat, resulting in decreased gene flow between local populations and decreased colonization of unpopulated breeding pools. This could disrupt metapopulation dynamics and long-term viability of the species.

Amphibians, particularly ambystomatid salamanders including marbled salamanders, generally breed

in the same wetland every year (Semlitsch et al. 1993, Semlitsch 1998). It is not well known how these species respond when a breeding wetland is no longer available (i.e., filled). Some ambystomatid salamanders will return to breeding wetlands even after those wetlands have been filled, whereas others have been able to disperse to nearby created wetlands (Pechmann et al. 2001). Created mitigation wetlands usually are unsuccessful at replicating the functions or wildlife habitat of the wetlands they are intended to replace (Brown 1999).

Wetland loss in the United States from historic draining and filling is well documented (e.g., Dahl 1990, 2000). Lack of reliable data for vernal pools creates difficulty in accurately determining historic losses. An important aspect of wetland loss is not simply the continued loss of habitat, but the historic undervaluing of vernal pool habitat as well. Size has traditionally been used an important criterion for assessing wetland value. Without increased protection priority for vernal pools, it is certain that vernal pool habitat will decrease in the future.

Mortality of individuals from vehicles on roadways (Threat Rank: Medium)

Vehicle traffic can kill vernal pool-dependent species by hitting and crushing them as they cross roads. This can have a significant impact on some species and in severe cases could result in local extirpation. Roads may act as partial barriers to overland dispersal or migration, perhaps resulting in decreased gene flow between populations and decreased colonization of unpopulated vernal pools. This could disrupt metapopulation dynamics and long-term viability of some species.

Roads also create edge habitat. Along these edges, soil and air moisture may be reduced, leading to increased salamander desiccation. Roads may act as conduits for predators that prey on amphibians or turtle eggs (e.g., skunks and raccoons), and dispersal avenues for invasive plants and animals. Runoff from roads can also reduce habitat quality of vernal pools via pollution, increased salt levels, sedimentation, and erosion in pools and adjacent habitats.

Roads are a significant source of direct mortality for migrating amphibians (Fahrig et al. 1995, Ashley and Robinson 1996, Mazerolle 2004, Forman 2003), and salamander abundance in roadside habitats may be reduced (deMaynadier and Hunter 2000). Gibbs (1998) found that forest-road edges are less permeable to ambystomatid salamanders than are forest interior and forest-open land edges. Recent research conducted in southern New Hampshire suggests that roads have a negative impact on wood frogs (*Lithobates sylvatica*) and spotted salamanders (*Ambystoma maculatum*), a similar salamander that also breeds in vernal pools (Mattfeldt 2004). Amphibians can experience delayed development or mortality from runoff contamination from roads, including road salt (Trombulak and Frissell 2000, Turtle 2000).

List of Lower Ranking Threats:

Mortality and habitat degradation from toxins and contaminants

Mortality and habitat degradation from acid deposition

Mortality and species impacts (decreased fitness) from various diseases (ranavirus, chytrid)

Mortality and habitat degradation from heavy recreational and education near pools

Mortality and habitat loss from forestry practices

Mortality and degradation from increased droughts

Actions to benefit this Species or Habitat in NH

Determine habitat use and dispersal patterns of marbled salamanders

Objective:
Determine habitat use and dispersal patterns of marbled salamanders in New Hampshire occupied sites.

General Strategy:
Collect existing information on salamander dispersal and use of vegetated corridors, and conduct New Hampshire-specific research on salamander species and their use of buffer zones and dispersal corridors. Thus, the usefulness to salamanders of pool buffer zones and dispersal corridors between habitat patches needs to be evaluated.

Political Location:
Cheshire County, Hillsborough County

Watershed Location:
Lower CT Watershed, Merrimack Watershed

Develop conservation plan for marbled salamanders in NH.

Primary Threat Addressed: Habitat conversion due to development of surrounding uplands and associated edge effects

Specific Threat (IUCN Threat Levels): Residential & commercial development

Objective:
Develop a statewide and site-specific conservation plans for marbled salamanders in New Hampshire.

General Strategy:
Use survey data to inform conservation planning process. Develop overall conservation plan for species as well as site-specific plans for any documented sites. Evaluate other potential conservation actions such as species augmentation or translocation.

Political Location:
Cheshire County, Hillsborough County

Watershed Location:
Lower CT Watershed, Merrimack Watershed

Evaluate adverse impacts and develop guidance for minimizing threats.

Primary Threat Addressed: Habitat conversion due to development of surrounding uplands and associated edge effects

Specific Threat (IUCN Threat Levels): Residential & commercial development

Objective:
Evaluate all projects that have potential to cause harm to marbled salamander populations and provide guidance to minimize impacts to those populations.

General Strategy:
Marbled salamanders are listed as endangered in New Hampshire. As such, NHFG will review any proposed activities (residential and commercial development, recreation, habitat management, etc.) that has the potential to harm marbled salamanders. NHFG will work with applicants and permitting

staff from other state and federal agencies, primarily Department of Environmental Services (Wetlands Bureau) and U.S. Army Corps of Engineers, to identify avoidance and minimization conditions for permit applicants. NHFG will develop guidelines for consistent and effective review of projects potentially impacting marbled salamanders. Guidelines will consider scenarios where impacts should be avoided and scenarios where impact minimization of mitigation may be appropriate. Pre- and post- construction monitoring of marbled salamander and associated habitat (e.g., vernal pools) should be considered as a component of project review.

Political Location:	Watershed Location:
Cheshire County, Hillsborough County	Lower CT Watershed, Merrimack Watershed

Monitor for the presence of marbled salamanders

Objective:
Conduct a systematic survey and mapping of the distribution of this species in New Hampshire (and adjacent areas of Massachusetts).

General Strategy:
Monitor populations for habitat patch occupancy and determine stability and growth rates of local populations. Determine potential for regional dynamics at metapopulation level (i.e., determine interaction of spatial arrangement of viable habitat, local threats, and dispersal capacity of the species).

Political Location:	Watershed Location:
Cheshire County, Hillsborough County	Lower CT Watershed, Merrimack Watershed

Location Description:
Start with known occupied sites, and historic sites, then move into adjacent suitable habitat.

References, Data Sources and Authors

Data Sources
Information relating to the distribution of this species was gathered through an extensive literature review, and from surveys conducted from 2006-2009. During this period, 128 pools were surveyed for the presence of marbled salamander.
Threat assessments were conducted by a group of NHFG biologists (Michael Marchand, Brendan Clifford, Loren Valliere, Josh Megysey).

Data Quality
Before 2006, there had been no comprehensive survey conducted for this species in New Hampshire. The species was known to occur in southern New Hampshire historically (Hoopes 1938, Taylor 1993). Out of 128 sites surveyed in 2006-2009, only two sites had marbled salamander present. The New Hampshire Natural Heritage Bureau Rare Species Database has 5 current records (after 1995) of marbled salamander in the state, and one historic record (before 1995).
Information relating to the condition of this species and its habitat was gathered during an extensive literature review, a review of New Hampshire laws and administrative codes, and a review New Hampshire's Reptile and Amphibian Reporting Program.

2015 Authors:

Appendix A: Amphibians

Loren Valliere, NHFG; Michael Marchand, NHFG

2005 Authors:

Jessica Veysey, UNH; Kimberly Babbitt, UNH

Literature

Ashley, E.P., and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field-Naturalist. 110: 403-412.

Bishop, S.C. 1941. The salamanders of New York. N.Y. State Museum Bulletin 324:1-365.

Blaustein, A.R., L.K. Belden, A.C. Hatch, L.B. Kats, P.D. Hoffman, J.B. Hays, A. Marco, D.P. Chivers, and J.M. Kiesecker. 2001. Ultraviolet radiation and amphibians. Pages 63-79 in C.S. Cockell and A.R. Blaustein, editors. Ecosystems, Evolution, and Ultraviolet Radiation. Springer, New York.

Boone, M.D., and R.D. Semlitsch. 2001. Interactions of an insecticide with larval density and predation in amphibian experimental communities. Conservation Biology. 15: 228-238.

Brenes, R., M. J. Gray, T. B. Waltsek, R. P. Wilkes, D. L. Miller. 2014. Transmission of ranavirus between ectothermic vertebrate hosts. PLoS ONE. 9(3):1-6.

Bridges, C.M. 1997. Tadpole swimming performance and activity affected by acute exposure to sublethal levels of carbaryl. Environmental Toxicology and Chemistry. 16: 1935-1939.

Brown, S. 1999. Effectiveness of compensatory wetland mitigation in Massachusetts. Assoc. Mass. Wetland Sci. Newsletter. 20: 5.

Dahl, T.E. 1990. Wetlands losses in the United States 1780s to 1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997 U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

DeGraaf, R.M., and M. Yamasaki. 2001. New England wildlife: habitat, natural history, and distribution. University of New England Press, Hanover, New Hampshire, USA.

deMaynadier, P.G., and M.L. Hunter. 1999. Forest canopy closure and juvenile emigration by pool-breeding amphibians in Maine. Journal of Wildlife Management 63:441-450.

deMaynadier, P.G., and M.L. Hunter. 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal. 20: 56-65.

Dodd, C.K., Jr. 1997. Imperiled amphibians: a historical perspective. Pages 165 – 200 in G. W. Benz and D. E. Collins, editors. Aquatic Fauna in peril: the southeastern perspective. Special Publication I Southeast Aquatic Research Institute. Lenz Design and Communications, Decatur, Georgia, USA.

Faccio, S.D. 2003. Postbreeding emigration and habitat use by Jefferson and spotted salamanders in Vermont. Journal of Herpetology 37:479-489.

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor, and J.F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation. 73: 177-182.

Figiel, C.R., Jr., and R.D. Semlitsch. 1995. Experimental determination of oviposition site selection in the marbled salamander, *Ambystoma opacum*. Journal of Herpetology 29:452-454.

Gamble, L.R., K. McGarigal, C. L. Jenkins, B. C. Timm. 2006. Limitations of Regulated "Buffer Zones" for the conservation of marbled salamanders. Wetlands, The Society of Wetland Scientists, 26:298-306.

Gibbs, J.P. 1998a. Distribution of woodland amphibians along a forest fragmentation gradient. Landscape Ecology. 13: 263-268.

Appendix A: Amphibians

Gill, D.E. 1978. The metapopulation ecology of the red-spotted newt, *Notopthalmus viridescens* (Rafinesque). Ecological Monographs 48:145-166.

Green, D. E., K. A. Converse, A. K. Schrader. 2002. Epizootiology of sixty-four amphibian morbidity and mortality events in the USA, 1996-2001. Annals New York Academy of Sciences 969:323-339.

Hanski, I., and M.E. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnean Society 42:3-16.

Hatch, A.C. and G.A. Burton, Jr. 1998. Effects of photoinduced toxicity of fluoranthene on amphibian embryos and larvae. Environmental Toxicology and Chemistry. 17: 1777-1785.

Hatch, A.C., and A.R. Blaustein. 2000. Combined effects of UV-B, nitrate, and low pH reduce the survival and acticity level of larval Cadcades frogs (*Rana cascadae*). Archives of Environmental Contamination and Toxicology. 39: 494-499.

Hoopes, I. 1938. Marbled salamander from New Hampshire. Bulletin of New England Museum of Natural History 87:16-17.

Horne, M.T., and W.A. Dunson. 1994a. Behavioral and physiological responses of the terrestrial life stages of the Jefferson salamander, *Ambystoma jeffersonianum*, to low soil pH. Archives of Environmental Contamination and Toxicology. 27: 232-238.

Horne, M.T., and W.A. Dunson. 1994b. Exclusion of the Jefferson salamander, *Ambystoma jeffersonianum*, from some potential breeding ponds in Pennsylvania: effects of pH, temperature, and metals on embryonic development. Archives of Environmental Contamination and Toxicology. 27: 323-300.

Horne, M.T., and W.A. Dunson. 1995a. Toxicity of metals and low pH to embryos and larvae of the Jefferson salamander, *Ambystoma jeffersonianum*. Archives of Environmental Contamination and Toxicology. 29: 110-114.

Horne, M.T., and W.A. Dunson. 1995b. Effects of low pH, metals, and water hardness on larval amphibians. Archives of Environmental Contamination and Toxicology. 29: 500-505.

Jackson, S.D., and T.F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders (*Ambystoma maculatum*) under roads. Pages 93-99 in T.E.S. Langton, editor. Amphibians and Roads: Proceedings of the Toad Tunnel Conference. ACO Polymer Products, Shefford, England.

Kagan, J., P.A. Kagan, and H.E. Buhse, Jr. 1984. Light-dependent toxicity of alpha-terthienyl and anthracene toward late embryonic stages of *Rana pipiens*. Journal of Chemical Ecology. 10: 1115-1122.

Kiesecker, J.M. 1996. pH induced growth reduction and its effects on predator-prey interactions between *Ambystoma tigrinum* and *Pseudacris triseriata*. Ecological Applications. 6: 1325-1331.

Klemens, M.W. 1993. Amphibians and reptiles of Connecticut and adjacent regions. Bull. 112. Hartford: Connecticut State Geological and Natural History Survey.

Knutson, M.G., J.R. Sauer, D.A. Olsen, M.J. Mossman, L.M. Hemesath, and M.J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on Frog and Toad abundance and species richness in Iowa and Wisconsin, USA. Conservation Biology 13: 1437-1446.

Kutka, F.J. 1994. Low pH effects on swimming activity of *Ambystoma* salamander larvae. Environmental Toxicology and Chemistry. 13: 1821-1824.

Lamoureux, V.S., and D.M. Madison. 1999. Overwintering habitats of radio-implanted green frogs, *Rana clamitans*. Journal of Herpetology 33:430-435.

Long, L.E., L.S. Saylor, M.E. Soule. 1995. A pH/UV-B synergism in amphibians. Conservation Biology. 9: 1301-1303.

Madison, D.M. 1997. The emigration of radioimplanted spotted salamanders, *Ambystoma*

maculatum. Journal of Herpetology 31:542–551.

Marco, A., C. Quilchano, and A.R. Blaustein. 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific Northwest. Environmental Toxicology and Chemistry. 18: 2836-2839.

Marsh, D.M., and P.C. Trenham. 2001. Metapopulation dynamics and amphibian conservation. Conservation Biology 15:40-49.

Mattfeldt, S. 2004. Effects of wetland isolation and surrounding landscape characteristics on vernal pool-dependent amphibians. M.S. Thesis. University of New Hampshire, Durham, New Hampshire.

Minton, S.A., Jr. 1972. Amphibians and reptiles of Indiana. Indianapolis: Indiana Academy of Science.

Monson, P.D., D.J. Call, D.A. Cox, K. Liber, and G.T. Ankley. 1999. Photoinduced toxicity of fluoranthene to northern leopard frogs (*Rana pipiens*). Environmental   Toxicology and Chemistry. 18: 308-312.

NatureServe. 2004. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.1. NatureServe, Arlington, Virginia. Available at http://www.natureserve.org/explorer. (Accessed: 17 December 2004).

New Hampshire Reptile and Amphibian Reporting Program (RAARP). Coordinated by New Hampshire Fish and Game's Nongame and Endangered Species Program.

NH Natural Heritage Bureau. 2005. Database of Rare Species and Exemplary Natural Community Occurrences in New Hampshire. Department of Resources and Economic Development, Division of Forests and Lands. Concord, New Hampshire, USA.

Noble, G.K., and M.K. Brady. 1933. Observation on the life history of the marbled salamander, *Ambystoma opacum* (*Amphibia, Urodela, Ambystomatidae*). Journal of Herpetology 11: 169-176.

Pask, J. D., D. C. Woodhams, L. A. Rollins-Smith. 1012. The ebb and flow of antimichrobial skin peptides defends northern leopard frogs (*Rana pipiens*) against chytridiomycosis. Global Change Biology. 18:1231-1238.

Pechmann, J.H.K., R.A. Estes, D.E. Scott, and J.W. Gibbons. 2001. Amphibian colonization and use of ponds created for trial mitigation of wetland loss. Wetlands. 21: 93-111.

Petranka, J.W. 1989. Density-dependent growth and survival of larval *Ambystoma*: evidence from whole-pond manipulations. Ecology 70:1752-1767.

Petranka, J.W. 1990. Observations on nest site selection, nest desertion, and embryonic survival in marbled salamanders. Journal of Herpetology 24:229-234.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington D.C.

Pough, F.H. 1976. Acid precipitation and embryonic mortality of spotted salamanders, *Ambystoma maculatum*. Science. 192: 68-70.

Rowe, C.L., and W.A. Dunson. 1993. Relationships among abiotic parameters and breeding effort by three amphibians in temporary wetlands of central Pennsylvania. Wetlands. 13: 237-246.

Rowe, C.L., W.J. Sadinski, and W.A. Dunson. 1992. Effects of acute and chronic acidification on three larval amphibians that breed in temporary ponds. Archives of Environmental Contamination and Toxicology. 23: 339-350.

Semlistch, R.D., D.E. Scott, J.H.K. Pechmann, and J.W. Gibbons. 1993. Phenotypic variation in the arrival time of breeding salamanders: individual repeatability and environmental influences. Journal of Animal Ecology. 62: 334-340.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology. 12: 1113-1119.

Semlitsch, R.D., and J.R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Sinsch, U. 1992. Structure and dynamic of a natterjack toad metapopulation (*Bufo calamita*). Oecologia 90:489–499.

Sjögren, P. 1991. Extinction and isolation gradients in metapopulations: the case of the pool frog (*Rana lessonae*). Biological Journal of the Linnean Society 42:135-147.

Skelly, D.K., E.E. Werner, and S. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. Ecology 80:2326-2337.

Smyers, S.D., M.J. Rubbo, V.R. Townsend, Jr., and C.C. Swart. 2002. Intra- and interspecific characterizations of burrow use and defense by juvenile ambystomatid salamanders. Herpetologica 58: 422-429.

Sparling, D.W., G.M. Fellers, and L.L. McConnell. 2001. Pesticides and amphibian population declines in California, USA. Environmental Toxicology and Chemistry. 20: 1591-1595.

Sundquist, D., and M. Stevens. 1999. New Hampshire's changing landscape: population growth, land use conversion, and resource fragmentation in the Granite State. New Hamphire, Concord, Society for the Protection of New Hampshire Forests and The Nature Conservancy, 159 pp.

Taylor, J. 1993. The amphibians and reptiles of New Hampshire. New Hampshire Fish and Game Department, Concord New Hampshire, USA.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Turtle, S.L. 2000. Embryonic survival of the spotted salamander (*Ambystoma maculatum*) in roadside and woodland vernal pools in southeastern New Hampshire. Journal of Herpetology. 34:60-67.

Williams, P.K. 1973. Seasonal movements and population dynamics of four sympatric mole salamanders, genus *Ambystoma*. Ph.D. dissertation. Indiana University.

Windmiller, B.S. 1996. The pond, the forest, and the city: spotted salamander ecology. Dissertation, Tufts University, Medford, Massachusetts, USA.

Fowler's Toad
Anaxyrus fowleri

Federal Listing	N/A
State Listing	SC
Global Rank	G5
State Rank	S3
Regional Status	High

Photo by Michael Marchand

Justification (Reason for Concern in NH)

Fowler's toads have apparently declined throughout much of the northeast and are listed as a species of high regional concern (NEPARC 2010, Weir et al. 2014). New Hampshire constitutes the northeastern limit of the range of the Fowler's toad. Little information on the Fowler's toad exists in New Hampshire and it is possible that the species occurs in low numbers. The lack of confirming evidence of a robust population in southern New Hampshire is cause for concern. The lack of information on this species in the state is the most serious threat, as it is currently unknown whether the species is locally abundant, but not widespread, or rare. This information is crucial for informing habitat protection and species management guidelines.

Distribution

The Fowler's toad range is southern New England westward through southeast New York, New Jersey and northern parts of Pennsylvania, the Midwest (parts of Michigan, Illinois and Ohio), and southern Ontario, Canada. Throughout its range in New England and New York, the species has an irregular or spotty distribution, although it is often described as being "widespread". The species occurs throughout the south, with the exception of coastal plain areas of Georgia and South Carolina and peninsular Florida. Fowler's toads are limited to the southern portion of the states of Vermont and New Hampshire and are described as reaching the Atlantic Coast almost into Maine (Stewart and Rossi 1981, Krauss and Schuett 1982, Shaffer 1991, Harding 1997, Klemens 1993). Limited records exist for the species in New Hampshire.

The distribution pattern of this species in the state is poorly documented. However, it is likely that the species occurred irregularly or patchily in areas with appropriate upland and breeding habitat. There are a limited number of Fowler's toad records in the state, but it is likely that they are associated with the Merrimack and Connecticut rivers. The documented historic sightings (more than 20 years old) are from the towns of Canterbury, Amherst, and Milford. Observations considered verified within the last 20 years are from the towns of Boscawen and Hinsdale. Overall, available data suggest that either the species suffers from poor monitoring and documentation or that it is rare and therefore constitutes a very small proportion of the regional Fowler's toad population.

Habitat

Throughout most of its range the Fowler's toad occurs mainly in habitats with loose, well-drained sandy or gravelly soils including river banks, lake margins, beach and coastal dune systems, and sandy or scrubby woodlands (Wright and Wright 1949, Smith 1961, Minton 1972, Green 1989, Breden 1987, Klemens 1993). Fowler's toads can be found along roadsides, near homes and gardens, and in fields and pastures (Wright and Wright 1949). Breeding habitat is generally the shallow margins of

permanent water bodies, including lakes, farm ponds, rivers, and slow-moving streams (Wright and Wright 1949, Smith 1961, Breden 1988, Kemens 1993). Vernal pools may also be used for breeding (Wright and Wright 1949, Green 1989). In areas in which the species co-occurs with the American toad (Anaxyrus americanus), the Fowler's toad is often found in dryer areas whereas the American toad is found in more mesic habitats (Klemens 1993).

NH Wildlife Action Plan Habitats

- Large Warmwater Rivers
- Appalachian Oak Pine Forest
- Dunes
- Marsh and Shrub Wetlands
- Pine Barrens
- Shrublands
- Vernal Pools
- Warmwater Lakes and Ponds
- Warmwater Rivers and Streams

Distribution of
FOWLER'S TOAD
in New Hampshire

Current (1994-2014)
Historic (1939-1994)
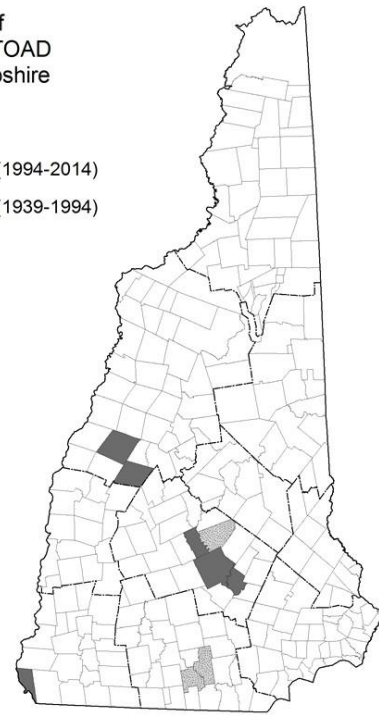
Distribution Map

Current Species and Habitat Condition in New Hampshire

There are not sufficient data available from which to make conclusions about population health or trends for this species.

Population Management Status

There is no population monitoring efforts currently occurring for this species.

Regulatory Protection (for explanations, see Appendix I)

- NHFG Rule FIS 803.02. Importation.
- NHFG Rule FIS 804.02. Possession.
- NHFG Rule FIS 811.01 Sale of Reptiles.
- NHFG FIS 1400 Nongame special rules
- Fill and Dredge in Wetlands - NHDES
- Rivers Management and Protection Program - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

There are not sufficient data available to assess the quality of habitat patches for the Fowler's toads.

Habitat Protection Status

As the distribution of this species is not known, there is insufficient data to assess protection status.

Habitat Management Status

There are no habitat management efforts being made for Fowler's toads. Because the distribution and abundance of the species is unknown, management efforts that might indirectly benefit this species cannot be assessed at this time.

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat conversion due to development (Threat Rank: Medium)

Fowler's toads require sandy upland habitat near appropriate breeding sites. As many of these sites are likely to be along large river systems and lakes, and these areas are places where humans often build houses, Fowler's toads may suffer loss of habitat and fragmentation. As habitat suitable for Fowler's toads likely has a patchy distribution since not all shorelines are sandy, development on parcels used by Fowler's toad could result in local extirpation if adjacent areas are mesic (and therefore unsuitable habitat) and interpatch distances are beyond dispersal capabilities of Fowler's toads.

There is no direct information regarding this threat because Fowler's toad population information is generally lacking. However, the most likely areas in which Fowler's toads may occur are in the southern part of the state and along riverine areas such as the Connecticut and Merrimack Rivers. Given current population growth and development trends (Sundquist and Stevens 1999), and the expansion of I-93, it is likely that there will be increasing developmental pressures in areas where Fowler's toads may occur.

Habitat conversion and mortality from mining (sand & gravel) (Threat Rank: Medium)

Fowler's toad's preference for loose sand and gravel substrate elevates the risk of mortality and habitat destruction from mining.

One vouchered RAARP Fowler's toad observation was recorded in close proximity to an active sand and gravel pit in Boscawen, but the effect this has on the local population is not known.

Mortality of individuals from vehicles on roadways (Threat Rank: Medium)

Direct mortality of toads caused by vehicle traffic can be a significant mortality agent, and may be particularly problematic for small populations. Roads fragment toad habitat and may act as partial barriers to migration. Thus, roads may decrease toad dispersal, resulting in decreased exchange of individuals among populations and consequently reduce colonization/recolonization and gene flow among local populations. This could disrupt (meta) population dynamics of the species and reduce the ability of the species to remain viable.

There is substantial support in the literature that roads are a significant source of direct mortality for migrating amphibians (e.g., Fahrig et al. 1995, Ashley and Robinson 1996, Mazerolle 2004) and Fowler's toads may use roads at a higher frequency (i.e., non-rainy nights) due to behavioral, structural, and physiological anti-desiccation adaptations. At Cape Cod National Seashore in Massachusetts, Fowler's toads were documented using roads as movement corridors for hydro-thermo regulation, ease of movement, and foraging opportunities (Timm and McGarigal 2014). Given current population growth and development trends (Sundquist and Stevens 1999), and the ongoing widening of I-93, it is likely that there will be increasing developmental pressures in areas where Fowler's toads may occur.

List of Lower Ranking Threats:

Common reed may dominate breeding wetlands, reducing habitat

Mortality and species impacts (reduced fitness) from contaminants

Mortality and species impacts (decreased fitness) from various diseases (ranavirus, chytrid)

Species impacts from hybridization (with American toads)

Mortality from drawdowns of lakes and ponds that results in the desiccation of eggs and tadpoles

Mortality and degradation from increased droughts

Actions to benefit this Species or Habitat in NH

Monitor Fowler's toad populations

Primary Threat Addressed: Habitat conversion and mortality from mining (sand & gravel)

Specific Threat (IUCN Threat Levels): Energy production & mining

Objective:
Monitor the distribution, condition, and risk to Fowler's toad populations.

General Strategy:
The distribution and condition of Fowler's toad populations is not well known. Calling surveys can be effective at identifying breeding populations of Fowler's toads. Targeted distribution surveys should be conducted near potential Fowler's toad habitat. Once populations are confirmed, the condition of populations should be assessed.

Political Location:	**Watershed Location:**
Cheshire County, Hillsborough County, Merrimack County	Lower CT Watershed, Merrimack Watershed

Conserve habitat at known priority Fowler's toad sites.

Primary Threat Addressed: Habitat conversion due to development

Specific Threat (IUCN Threat Levels): Residential & commercial development

Objective:
Identify priority sites and conserve habitat at those sites.

General Strategy:
Population condition is not known for Fowler's toad sites in NH. Once that information is acquired, priority sites can be established and these areas can be included in land conservation priorities.

Political Location:	Watershed Location:
Cheshire County, Hillsborough County, Merrimack County, Rockingham County, Strafford County	Lower CT Watershed, Merrimack Watershed, Coastal Watershed

References, Data Sources and Authors

Data Sources
Information was obtained from an extensive literature search, RAARP (2015), and the New Hampshire Wildlife Sightings database.
Threat assessments were conducted by a group of NHFG biologists (Michael Marchand, Brendan Clifford, Loren Valliere, Josh Megysey).

Data Quality
The collective published works on Fowler's toad provide little insight into the species in New Hampshire. There have been no systematic surveys for Fowler's toads in the state. The quality of the existing data on Fowler's toad distribution in the state is extremely poor.
Although the literature can provide a general description of habitat associations for this species, distribution and population numbers are lacking for this species in New Hampshire. Because American toads are commonly misidentified as Fowler's toads, few records have been confirmed in New Hampshire (M. Marchand, NHFG, personal communication).

2015 Authors:
Joshua Megyesy, NHFG; Michael Marchand, NHFG

2005 Authors:
Kimberly Babbitt, UNH

Literature

Ashley, E.P., and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field-Naturalist. 110: 403-412.

Barrett, K., C. Guyer, D. Watson. 2010. Water from urban streams slows growth and speeds metamorphosis in Fowler's toad (*Bufo fowleri*) larvae. Journal of Herpetology. 44(2):297-300.

Breden, F. 1987. Population structure of Fowler's toad, Bufo woodhousei fowleri. Copeia. 1987:386-395.

Breden, F. 1988. The natural history and ecology of the Fowler's toad, *Bufo woodhousei fowleri*, (Amphibia: *Bufonidae*) in the Indiana Dunes National Lakeshore. Fieldiana Zoology. 49:1-16.

Bunnell, J. F., J. L. Ciraolo. 2010. The potential impact of simulated ground-water withdrawals on oviposition, larval development, and metamorphosis of pond-breeding frogs. Wetlands Ecology and Management. 18:495-509.

Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian declines. Emerging Infectious Diseases 5:735-748.

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor, and J.F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation. 73: 177-182.

Green, D. 1989. Fowler's toad, *Bufo woodhousii fowleri*, in Canada: Biology and population status. Canadian Field-Naturalist. 103:486-496.

Green, D. M. 1984. Sympatric hybridization and allozyme variation in the toads *Bufo americanus* and B. fowleri in southern Ontario. Copeia. 1:18-26.

Green, D. M., C. Parent. 2003. Variable and asymmetric introgression in a hybrid zone in the toads, *Bufo americanus* and *Bufo fowleri*. Copeia. 1:34-43.

Greenberg, D. A., D. M. Green. 2013. Effects of an invasive plant on population dynamics in toads. Conservation Biology. 27(5):1049-1057.

Harding, J.H. 1997. Amphibians and reptiles of the Great Lakes region. University of Michigan Press. Ann Arbor, Michigan.

Jones, J. M. 1973. Effects of thirty years hybridization on the toads *Bufo americanus* and *Bufo woodhousii fowleri* at Bloomington, Indiana. Evolution. 27:435-448.

Klemens, M.W. 1993. Amphibians and reptiles of Connecticut and adjacent regions. State Geological and Natural History survey of Connecticut, Bulletin Number 112. Hartford, Connecticut.

Krauss, F. and G.W. Schuett. 1982. A herpetofaunal survey of the coastal zone of northwest Ohio. Kirtlandia 35-38:21-54.

Mazerolle, M.J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica. 60: 45-53.

Minton, S.A., Jr. 1972. Amphibians and reptiles of Indiana. Monograph Number 3. Indiana Academy of Science. Indianapolis, Indiana.

Parris, M. J., T. O. Cornelius. 2004. Fungal pathogen causes competitive and developmental stress in parval amphibian communities. Ecology. 85(12):3385-3395.

Shaffer, L.L. 1991. Pennsylvania amphibians and reptiles. Pennsylvania Fish Commission. Harrisburg, Pennsylvania.

Smith, P.W. 1961. The amphibians and reptiles of Illinois. Bulletin of the Illinois Natural History Survey, Number 28. Urbana, Illinois.

Appendix A: Amphibians

Stewart, M.M. and J. Rossi. 1981. The Albany Pine Bush: a northern outpost for southern species of amphibians and reptiles in New York. American Midland Naturalist. 106:282-292.

Sundquist, D., and M. Stevens. 1999. New Hampshire's changing landscape: population growth, land use conversion, and resource fragmentation in the Granite State. New Hamphire, Concord, Society for the Protection of New Hampshire Forests and The Nature Conservancy, 159 pp.

Timm, B. C., K. McGarigal. 2014. Fowler's toad (*Anaxyrus fowleri*) activity patterns on a roadway at Cape Cod National Seashore. Journal of Herpetology. 48(1):111-116.

Venesky, M. D., M. J. Parris, A. Storfer. 2009. Impacts of *Batrachochytrium dendrobatitis* infection on tadpole foraging performance. EcoHealth. 6:565-575.

Venesky, M. D., R. J. Wassersug, M. J. Parris. 2010. Fungal pathogen changes the feeding kinematics of larval anurans. The Journal of Parasitology. 96(3):552-557.

Volpe, E. P. 1959. Experimental and natural hybridization between *Bufo terrestris* and *Bufo fowleri*. The American Midland Naturalist. 61(2):295-312.

Weir, L. A., J. A. Royle, K. D. Gazenski, and O. Villena. 2014. Northeast regional and state trends in anuran occupancy from calling surveys data (2001-2011) from the North American amphibian monitoring program. Herpetological Conservation and Biology 9:223-245.

Wright, A.H. and A.A. Wright. 1949. Handbook of frogs and toads. Third edition. Comstock Publishing Associates. Ithaca, New York.

Northern Leopard Frog

Lithobates pipiens

Federal Listing	N/A
State Listing	SC
Global Rank	G5
State Rank	S3
Regional Status	High

Photo by Michael Marchand

Justification (Reason for Concern in NH)

Northern leopard frogs have apparently declined throughout much of New England and are listed as a species of high regional concern in the northeast (NEPARC 2010, Weir et al. 2014). The decline is likely related to development of floodplains, conversion of grassland habitat and farm abandonment and forest regeneration. The current distribution and abundance of northern leopard frogs and the status of remaining populations in New Hampshire is poorly known.

Distribution

The northern leopard frog has a broad distribution in the United States and Canada. Northern leopard frogs range from New England to the mid-Atlantic to west of the Rockies, and in Canada, populations exist from southeastern British Columbia east to the Maritimes. The northern leopard frog is absent from most of the southeast. The recent description of a new leopard frog species, the Atlantic coast leopard frog (*Lithobates kauffeldi*), likely reduces the previously proposed range and distribution of the northern leopard frog. Feinberg et al. (2014) documented this new species centered in New York City as well as throughout Long Island, eastern Pennsylvania, southern Connecticut, and New Jersey. More research will likely improve the resolution of distribution maps and where overlap exists between the northern, Atlantic coast, and southern leopard frogs (*Lithobates sphenocephalus*). Throughout its range, the northern leopard frog often has a spotty distribution, and is considered critically imperiled (S1) or imperiled (S2) in several states in the west and south and in British Columbia. In New England, the species is considered imperiled (S2) in Connecticut and Rhodes Island, Vulnerable (S3) in New Hampshire and Maine, and apparently secure (S4) in Vermont and (S3S4) in Massachusetts (Nature Serve 2015). Throughout New England, the species has a very spotty distribution, and is strongly associated with grassy riparian floodplains. For example, in Connecticut, Klemens (1993) found that the species is restricted mainly to the Housatonic and Connecticut drainage basins and their tributaries.

In New Hampshire, records from the RAARP database indicate that northern leopard frogs were observed in the following counties and towns between 1992 and 2015: Coos (Errol, Pittsburg), Grafton (Lyme), Carroll (Chatham), Belknap (Gilford), Sullivan (Charlestown), Merrimack (Canterbury, Concord, Hopkinton), Hillsborough (Deering, Litchfield), and Rockingham (Newbury, Nottingham, Portsmouth, Stratham, Portsmouth, Windham). Most observations were from the Merrimack River, Connecticut River, Androscoggin River and associated floodplains.

Habitat

Northern leopard frogs require three distinct habitat types during their life cycle for breeding, foraging, and overwintering. Breeding (May to late June), egg deposition, and tadpole development

occur in areas of shallow standing water and emergent vegetation, such as lake inlets, slow streams, ponds, temporary wetlands holding water until at least July or August (i.e., long-hydroperiod vernal pools), overflows, or the backwater of rivers (Merrell 1977, Hine et al. 1981, Hunter et al. 1999, Kendell 2002, Alberta Sustainable Resource Development 2003). Vegetation and sites without fish predators provide the most suitable habitat for egg laying (Merrill 1977). During the summer adult (post-breeding), juvenile (non-breeding), and young-of-the-year (post-metamorphosis) frogs are typically found close to water (Kendell 2002, Alberta Sustainable Resource Development 2003). However, leopard frogs will travel a considerable distance away (1-2 km) from major waterbodies to areas that have some moisture, such as wet meadows, pastures, hay fields, scrub vegetation, sedge meadows, drainage/irrigation ditches, or damp wooded areas (Hunter et al. 1999, Kendell 2002). Leopard frogs must overwinter in permanent bodies of water or streams that do not freeze to the bottom because they cannot withstand prolonged freezing (Schmid 1982, Costanzo et al. 1992, Layne 1992, 1993, Hunter et al. 1999, Russell and Bauer 2000, Alberta Sustainable Resource Development 2003). Hibernacula are most often located in springs, streams, spillways below dams, or in deeper lakes and ponds (Emery et al. 1972, Merrell 1977, Cunjak 1986). Within waterbodies, leopard frogs have been found hibernating under rocks, logs, leaf litter or vegetation, or in depressions in sand or mud (Emery et al. 1972).

NH Wildlife Action Plan Habitats

- Floodplain Habitats
- Grasslands
- Coldwater Rivers and Streams
- Lakes and Ponds with Coldwater Habitat
- Large Warmwater Rivers
- Marsh and Shrub Wetlands
- Shrublands
- Warmwater Rivers and Streams
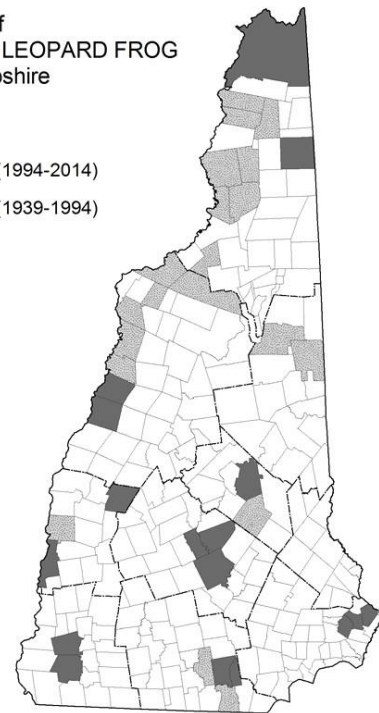
Distribution Map

Current Species and Habitat Condition in New Hampshire

There are not sufficient data available from which to make assessments about population health or trends for this species.

Population Management Status

There are no ongoing management efforts for any particular northern leopard frog population in New Hampshire at this time.

Regulatory Protection (for explanations, see Appendix I)

● NHFG Rule FIS 803.02. Importation.
● NHFG Rule FIS 804.02. Possession.
● NHFG Rule FIS 811.01 Sale of Reptiles.
● NHFG FIS 1400 Nongame special rules
● Fill and Dredge in Wetlands - NHDES
● Rivers Management and Protection Program - NHDES
● Comprehensive Shoreland Protection Act - NHDES
● Clean Water Act-Section 404
● Alteration of Terrain Permitting - NHDES

Quality of Habitat

Data are insufficient to determine relative quality of habitat patches.

Habitat Protection Status

There are insufficient data to assess protection status for this species.

Habitat Management Status

Northern leopard frog habitat is not specifically managed in New Hampshire.

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

Habitat conversion due to development (Threat Rank: Medium)

The loss of leopard frog habitat (breeding, overwintering, or foraging) to commercial or residential development will result in a population reduction. If habitat loss is extreme enough, extirpation of the local population will occur. Habitat fragmentation isolates (or separates by greater distances) northern leopard frog populations. As habitat is lost and becomes more fragmented, (re)colonization of the remaining habitat patches becomes increasingly difficult. This separation limits immigration from neighboring populations, which leads to reduced gene flow and increases the likelihood that the isolated population will become extirpated from environmental or demographic stochasticity (Alberta Sustainable Resource Development 2003, Blaustein et al. 1994, Corn 1994). In New Hampshire, the most significant habitat loss and fragmentation threat comes from development in riparian floodplain areas and conversion of farmland to suburban or commercial development.

Habitat loss is believed to be one of the causes of northern leopard frog declines in Washington, Oregon, Idaho and Montana (Alberta Sustainable Resource Development 2003). The extent to which wetland loss and alteration have affected northern leopard frog populations in New Hampshire is

unknown; however, significant loss of early successional grassland habitat and farm land has been well documented in the state (see grassland habitat profile for details). The loss of wetlands and grassland communities reduces the amount of available leopard frog habitat. Northern leopard frogs are dependent on specific wetland habitats for breeding and overwintering and grassland habitats for summer foraging. The common requirement among amphibians for more than one habitat (i.e., landscape complementation) makes this group particularly vulnerable to the impacts of habitat loss. Reduction or removal of any one of the required habitats may render the landscape unsupportive of northern leopard frogs (Pope et al. 2000).

Northern leopard frogs require three distinct habitats to complete their life cycle: a breeding site, midsummer foraging habitat, and a stream or other suitable water body for overwintering. The impairment of movement between these habitat types could result in/extirpation of a local population (Alberta Sustainable Resource Development 2003). On a regional basis, many amphibian populations exist as metapopulations, represented by a set of linked but geographically discrete local populations occupying suitable habitats (Alberta Sustainable Resource Development 2003, Blaustein et al. 1994, Marsh and Trenham 2001). The size of local populations will fluctuate because of environmental factors, and natural stochastic mechanisms and local extinction may occur. Regionally, populations will be maintained through dispersal of individuals between populations and recolonization of vacant habitat. When the natural landscape processes are disrupted because of habitat fragmentation, (re)colonization often cannot occur. Thus, a local extirpation event may lead to the regional collapse of a species (Seburn and Seburn 2000).

Mortality from mowing and agricultural machinery & vehicles (Threat Rank: Medium)

Adult leopard frogs spend most of their time in grassy areas near water during the summer months of June to August (Hunter et al. 1999). Direct mortality of adult individuals from mowing and/or agricultural machinery/vehicles where waterbodies are in close proximity to farm fields is likely.

Haying fields may cause mortality, but can also maintain crucial foraging habitat that has been otherwise declining in New Hampshire. Mowing mortalities have not been documented in the state and the impact on leopard frog populations is currently unknown.

Mortality of individuals from vehicles on roadways (Threat Rank: Medium)

Direct mortality of northern leopard frogs caused by vehicle traffic can be a significant mortality agent, and may be particularly problematic for small populations. Roads fragment habitat and may act as partial barriers to migration. Thus, roads may decrease frog dispersal, resulting in decreased exchange of individuals among populations and consequently reduce colonization/recolonization and gene flow among local populations. This could disrupt (meta) population dynamics of the species and reduce the ability of the species to remain viable.

Amphibians are especially vulnerable to traffic mortality because their life histories often involve migration between wetland and upland habitats, and individuals are inconspicuous and sometimes slow-moving (Trombulak and Frissell 2000). Ehmann and Cogger (1985) estimated that more than five million amphibians and reptiles are killed each year on roads in Australia. Research conducted in the Ottawa area indicates that anuran populations decrease in size with increasing traffic volume (Fahrig et al. 1995). Even at high traffic sites Bouchard et al. (2009) found that northern leopard frogs show no behavioral avoidance of roads. Additionally, Carr and Fahrig (2001) found that traffic can influence leopard frog population abundance out to at least 1.5 km from the population and that more vagile species, such as northern leopard frogs, are more strongly affected by road traffic than less vagile species (for example, the green frog). Roads can be demographic barriers that cause habitat and population fragmentation (Trombulak and Frissell 2000). Northern leopard frog roadkill has been

documented in Concord, New Hampshire (M. N. Marchand, personal observation).

Disturbance and mortality from agricultural pesticide use (Threat Rank: Medium)

Pesticide wetting agents can interfere with cutaneous respiration in metamorphosed and adult frogs and gill respiration in tadpoles, leading to indirect or direct mortality. Chemicals can suppress the immune system, cause endocrine disruption, developmental malformations, and alter behavior which may lead to decreased vigor, ability to fight off disease, reproduce, or escape predation, thereby increasing the chance of mortality.

The northern leopard frog is a frequent subject of toxicity experiments (e.g., see Hoffman et al. 2003). The evidence outlined in this section is meant to provide examples, as opposed to being an exhaustive review.

Leopard frogs are commonly found near agricultural areas where they are exposed to pesticides, herbicides, and nitrate and nitrite runoff from the widespread use of fertilizers. Low levels of nitrates can cause reduced activity, feeding, reproductive ability, and increases in deformities in tadpoles (Hecnar 1995). Allran and Karasov (2000) report that nitrate slowed the growth of leopard frog larvae. Such a decrease in growth as a larva can have a significant detrimental impact later in the life of a frog by decreasing survival, size as an adult, rate of sexual maturation, mate selection, and locomotion ability for predator evasion (Allran and Karasov 2000). Ouellet et al. (1997) found higher rates of limb deformities in northern leopard frogs in Ontario, Canada, at sites in agricultural areas compared to non-agricultural areas and suggested that contaminants were the likely causal agent. In addition, *Lithobates pipiens* tadpoles are also sensitive (e.g., have lower survival, experience paralysis, delayed growth, or abnormal behavior) to low concentrations of insecticides and herbicides commonly used in forest management (Berrill et al 1994, Berrill et al 1995).

 It has also been demonstrated that, for leopard frogs, pesticides can act as immunosuppressive agents at sublethal doses that are present in wild frogs. The immunosuppressive effects of pesticides may be contributing to amphibian declines by rendering exposed populations susceptible to common pathogenic organisms (Gilbertson et al. 2003). Hayes et al. (2002) reported that very small doses (0.1 ppb) of the commonly used herbicide Atrazine can cause hermaphrodism in northern leopard frogs. Further research indicates that the immunosuppressant effects of Atrazine in northern leopard frogs may have a synergistic relationship with known amphibian pathogens such as tremetode (*Ribeiroia ondatrae*) and lung worm (*Rhabdias ranae*) (Brodkin et al. 2007). Two other common pesticides, endosulfan and mancozeb, have been shown to be lethal to northern leopard frog tadpoles at environmentally relevant doses and slowed growth rates at sublethal concentrations. Such slower growth rates in amphibians have been associated with increased predation risk and desiccation at ephemeral ponds (Shenoy et al. 2009).

Although fertilizer inputs and excretory products from farm animals (e.g., dairy cows) often increase water pH, because of the low buffering capacity of most water bodies in New Hampshire, northern leopard frogs in New Hampshire may be at risk from decreased environmental pH resulting from emissions of sulphur dioxide and nitrogen oxides through the burning of fossil fuels. Simon et al. (2002) demonstrated that frogs experimentally exposed to pH 5.5 had spleens colonized with both Gram-positive and Gram-negative bacteria whereas spleens of frogs exposed to pH 7.0 either were sterile or exhibited little bacterial colonization. Resulting systemic infections combined with decreased natural defenses may in part cause increased mortality in leopard frogs (Simon et al. 2002). In a laboratory experiment, leopard frogs collected early in the spring, immediately following hibernation, but prior to the breeding season, exhibited 100% mortality within the first four days of exposure to pH 5.5 (Vatnick et al. 1999). At this level of pH, exposed adult frogs suffer a 72% mortality

rate over 10 days (Vatnick et al. 2006). Watkins-Colwell and Watkins-Colwell (1998) found that prolonged exposure to pH less than 4.0 was lethal for leopard frogs, and that bacterial infection, inhibition of yolk plug retraction, thoracic swelling and caudal curling occur at a pH less than 6.3 (Watkins-Colwell and Watkins-Colwell 1998).

In general, amphibians are particularly vulnerable to a variety of contaminants, including insecticides and herbicides (Alberta Sustainable Resource Development 2003, Bishop 1992, Harfenist et al. 1989). The extent of use of these chemicals in New Hampshire and their potential effects on amphibians is unclear and requires greater attention.

List of Lower Ranking Threats:

Mortality and degradation from fertilizers that cause eutrophication

Mortality and species impacts (decreased fitness) from various diseases (ranavirus, chytrid)

Mortality from subsidized or introduced predators

Mortality and habitat conversion from lake and river drawdowns during winter

Mortality and degradation from increased droughts

Actions to benefit this Species or Habitat in NH

Conserve habitat at known priority leopard frog sites.

Primary Threat Addressed: Habitat conversion due to development

Specific Threat (IUCN Threat Levels): Residential & commercial development

Objective:
Identify priority sites and conserve habitat at those sites.

General Strategy:
Population condition is not known for leopard frog sites in NH. Once that information is acquired, priority sites can be established and these areas can be included in land conservation priorities.

Political Location:	**Watershed Location:**
Statewide	Statewide

Location Description:
Populations are localized, usually along major river floodplains.

Monitor the distribution, condition, and risk to leopard frog populations

Objective:
Monitor the distribution, condition, and risk to leopard frog populations.

General Strategy:
Several potential threats have been identified for the species. However, there is minimal information available in NH to assess appropriate actions to implement at this time. NHFG will encourage reports through the reptile and amphibian reporting program to further refine the species distribution in NH. The condition of these sites needs to be determined. Leopard frogs should be considered an indicator for monitoring where appropriate (e.g., response to habitat management, effect of various pesticides,

floodplain restoration projects).

Political Location:	**Watershed Location:**
Statewide	Statewide

Location Description:
Populations are localized, usually along major river floodplains.

References, Data Sources and Authors

Data Sources

Information relating to the distribution and status of this species was gathered through a literature review and from NatureServe, as well as from the RAARP database. Threat assessment conducted by a group of NHFG biologists.
Threat assessments were conducted by a group of NHFG biologists (Michael Marchand, Brendan Clifford, Loren Valliere, Josh Megysey).

Data Quality

No comprehensive survey has been conducted for this species in New Hampshire.

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Literature

Alberta Sustainable Resource Development. 2003. Status of the northern leopard frog (*Rana pipiens*) in Alberta: Update 2003. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 9. Edmonton, AB. 61pp.

Allran, J. W. and W. H. Karasov. 2000. Effects of Atrazine and nitrate on northern leopard frog (*Rana pipiens*) larvae exposed in the laboratory from posthatch through metamorphosis. Environmental Toxicology and Chemistry 19:2850-2855.

Berger, L., R. Speare, P. Daszak, D. E. Green, A. A. Cunningham, C. L. Coggin, R. , M. A. Ragan, A. D. Hyatt, K. R. MacDonald, H. B. Hines, K. R. Lips, G. Marantelli, H. T. Parkes. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rainforests of Australia and Central America. Proceedings of the National Academy of Sciences 95:9031-9036.

Berrill, M., S. Betram, B. Pauli D. Coulson, M. Kolohan, and D. Ostrander. 1995. Comparative sensitivities of amphibians to single and pulsed exposures of the forest-use insecticide fenithrothion. Environmental Toxicology and Chemistry. 14:1011-1018.

Berrill, M., S. Betram, L. McGillivray, M. Kolohan, and B. Pauli. 1994. Effects of low concentrations of forest-use pesticides on frog embryos and tadpoles. Environmental Toxicology and Chemistry. 13:657-664.

Bishop, C. A. 1992. The effects of pesticides on amphibians and the implications for determining causes of declines in amphibian populations. Pp. 67-70 in Declines in Canadian amphibian populations: designing a national monitoring strategy (C. A. Bishop and K. E. Petit, eds.). Canadian Wildlife Service Occasional Paper No. 76, Ottawa, ON.

Appendix A: Amphibians

Blaustein, A. R., D. B. Wake, and W. P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology 8:60-71.

Bouchard, J., A. T. Ford, F. E. Eigenbrod, L. Fahrig. 2009. Behavioral responses of Northern leopard frogs (*Rana pipiens*) to roads and traffic: Implications for population persistence. Ecology and Society. 14(2): 23.

Brodkin, M. A., H. Madhoun, M. Rameswaran, I. Vatnick. 2007. Atrazine is an immune disruptor in adult northern leopard frogs (*Rana pipiens*). Environmental Toxicology and Chemistry 26(1):80-84

Carr, L.W. and L. Fahrig. 2001. Effects of road traffic on two amphibian species of differing vagility. Conservation Biology. 15:1071-1078.

Corn, P. S. 1994. What we know and don't know about amphibian declines in the west. Pp. 59-67 in Sustainable ecological systems: Implementing an ecological approach to land management. U.S.D.A. Forest Service General Technical Report RM-247, Fort Collins, CO. 363pp.

Costanzo, J. P., R. E. Lee Jr., and P. H. Lortz. 1992. Responses of freeze-tolerant and freeze-intolerant frogs to freezing. Cryobiology 29:616-631.

Crawshaw, G. J. 1992. The role of disease in amphibian decline. Pp. 60-62 in Declines in Canadian amphibian populations: designing a national monitoring strategy. (C. A. Bishop and K. E. Petit, eds.). Canadian Wildlife Service Occasional Paper No. 76, Ottawa, ON. 120pp.

Cunjak, R. A. 1986. Winter habitat of northern leopard frogs, *Rana pipiens*, in a southern Ontario stream. Canadian Journal of Zoology 64:255-257.

Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian declines. Emerging Infectious Diseases 5:735-748.

Ehmann, H., and H. Cogger. 1985. Australia's endangered herpetofauna: a review of criteria and policies. Pp. 435-447 in Biology of Australasian frogs and reptiles. (G. Grigg, R. Shine, and H. Ehmann, eds.) Surrey Beatty & Sons, NSW.

Emery, A. R., A. H. Berst, and K. Lodaira. 1972. Under-ice observations of wintering sites of leopard frogs. Copeia 1972:123-126.

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177-182.

Feinberg, J. A., C. E. Newman, G. J. Watkins-Colwell, M. D. Schlesinger, B. Zarate, B. R. Curry, H. B. Shaffer, J. Burger. 2014. Cryptic diversity in metropolis: Confirmation of a new leopard frog species (anura: ranidae) from New York City and surrounding Atlantic coast regions. PLoS ONE 9(10):1-15.

Gibbs, E. L., G. W. Nace, and M. B. Emmons. 1971. The live frog almost dead. BioScience 21:1027-1034.

Gilbertson, M., G. D. Haffner, K. G. Drouillard, A. Albert, and B. Dixon. 2003. Immunosuppression in the northern leopard frog (*Rana pipiens*) induced by pesticide exposure. Environmental Toxicology and Chemistry 22:101-110.

Harfenist, A., T. Power, K. L. Clark, and D. B. Peakall. 1989. A review and evaluation of the amphibian toxicological literature. Canadian Wildlife Service, Environment Canada. 222 pp.

Hayes, T. B., A. Collins, M. Lee, M. Mendoza, N. Noriega, A. A. Stuart, and A. Vonk. 2002. Hermaphroditic, demasculinized frogs after exposure to the herbicide Atrazine at low ecologically relevant doses. Proceedings of the National Academy of Sciences 99:5476-5480.

Hecnar, S.J. 1995. Acute and chronic toxicity of ammonium nitrate fertilizer to amphibians from southern Ontario. Environmental Toxicology and Chemistry 14: 2131-2137

Hine, R. L., B. L. Les, and B. F. Hellmich. 1981. Leopard frog populations and mortality in Wisconsin,

1974-76. Wisconsin Dept. of Natural Resources Technical Bulletin No. 122. Madison, WI. 39 pp.

Hoffmann, D.J., B.A. Rattner, G.A. Burton, Jr., J. Cairns, Jr. eds. 2003. Handbook of Ecotoxicology. Second edition. Lewis Publishers/CRC Press. Boca Raton, Florida.

Hunter, M. L. Jr., A. J. K. Calhoun, and M. McCollough. 1999. Maine amphibians and reptiles. The University of Maine Press, Orono, Maine. 252 pp.

Johnson, P.T. J., K. B. Lunde, E. M. Thurman, E. G. Ritchie, S. N. Wray, D. R. Sutherland, J. M. Kapfer, T. J. Frest, J. Bowerman, and A. R. Blaustein. 2002: Parasite (*Ribeiroia ondatrae*) infection linked to amphibian malformations in the western United States. Ecological Monographs 72:151-168.

Kendell, K. 2002. Survey protocol for the northern leopard frog. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 43, Edmonton, AB. 30pp.

Klemens, M.W. 1993. Amphibians and reptiles of Connecticut and adjacent regions.
Bull. 112. Hartford: Connecticut State Geological and Natural History Survey.

Layne, J. R. Jr. 1992. Postfreeze survival and muscle function in the leopard frog (*Rana pipiens*) and the wood frog (*Rana sylvatica*). Cryobiology 29:759.

Layne, J. R. Jr. 1993. Postfreeze recovery of gastrocnemius muscles of *Rana pipiens* and *R. sylvatica*. Journal of Herpetology 27:478-480.

Marsh, D. M., and P. C. Trenham. 2001. Metapopulation dynamics and amphibian conservation. Conservation Biology 15:40-49.

Merrell, D. J. 1977. Life history of the leopard frog, *Rana pipiens*, in Minnesota. Bell Museum of Natural History, University of Minnesota, Minneapolis, MN.

Meteyer, C. U, I.K. Loeffler, J.F. Fallon, .A. Converse, E.green, J.C. Helgen, S. Kersten, R. Levey, L. Eaton-Poole, and J.G. Burkhart. 2000. Hindlimb malformations in free-living northern leopard frogs (*Rana pipiens)* from Maine, Minnesota, and Vermont suggest multiple etiologies. Teratology. 62:151-171.

NatureServe. 2002. *Rana pipiens*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.1. NatureServe, Arlington, Virginia. Available at http://www.natureserve.org/explorer.

NEPARC. 2010. Northeast Amphibian and Reptile Species of Regional Responsibility and Conservation Concern. Northeast Partners in Amphibian and Reptile Conservation (NEPARC). Publication 2010-1.

Ouellet, M., J Bonin, J Rodrigue, JL DesGranges, and S Laire. 1997. Hindlimb deformities (ectromelia, ectrodactyly) in free-living anurans from agricultural habitats. Journal of Wildlife Diseases. 33:95-104.

Pope S.E., Fahrig L. and Merriam H.G. 2000. Landscape complementation and metapopulation effects on leopard frog populations. Ecology 81:2498-2508.

Russell, A. P., and A. M. Bauer. 2000. The amphibians and reptiles of Alberta. A field guide and primer of boreal herpetology, second edition. University of Calgary Press and University of Alberta Press, Calgary and Edmonton, AB. 279 pp.

Schmid, W. D. 1982. Survival of frogs in low temperature. Science 215:687-698.

Seburn, D.C. and C.N.L. Seburn. 2000. Conservation priorities for the amphibians and reptiles of Canada. Prepared for World Wildlife Fund Canada and the Canadian Amphibian and Reptile Conservation Network. 92 pp.

Shenoy, K., B. T. Cunningham, J. W. Renfroe, P.H. Crowley. 2009. Growth and survival of northern leopard frog (*Rana pipiens*) tadpoles exposed to two common pesticides. Environmental Toxicology and Chemistry. 28(7):1469-1474.

Simon, M.P., I. Vatnick, H.A. Hopey, K. Butler, C. Korver, C. Hilton, R.S. Weimann, and M.A. Brodkin. 2002. Effects of acid exposure on natural resistance and mortality of adult *Rana pipiens*. Journal of Herpetology. 36: 697-699.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14: 18-30.

Vatnick, I., M.A. Brodkin, M.P. Simon, B.W. Grant, C.R. Conte, M. Gleave, R. Myers, and M.M. Sadoff. 1999. The effects of exposure to mild acidic conditions on adult frogs (*Rana pipiens* and *Rana clamitans*): Mortality rates and pH preferences. Journal of Herpetology 33: 370-374.

Vatnick, I., J. Andrews, M. Colombo, H. Madhoun, M. Rameswaren, M. A. Brodkin. 2006. Acid exposure is an immune disruptor in adult *Rana pipiens*. Environmental Toxicology and Chemistry 25(1):199-202.

Watkins-Colwell, K. A. and G. J. Watkins-Colwell. 1998. Differential survivorship of larval leopard frogs (*Rana pipiens*) exposed to temporary and permanent reduced pH conditions. Bulletin of the Maryland Herpetological Society 34:64-75.

Weir, L. A., J. A. Royle, K. D. Gazenski, and O. Villena. 2014. Northeast regional and state trends in anuran occupancy from calling surveys data (2001-2011) from the North American amphibian monitoring program. Herpetological Conservation and Biology 9:223-245.

Mink Frog

Lithobates septentrionalis

Federal Listing	N/A
State Listing	SGCN
Global Rank	G5
State Rank	S3S4
Regional Status	

Photo by Pauline Quesnelle

Justification (Reason for Concern in NH)

Mink frogs are seldom seen or recorded because of their extremely aquatic, shy nature and unique habitat preferences and therefore few data are available for the species in New Hampshire. Its preference for the combination of cold, oxygen rich water and lily pads may restrict mink frogs to a few number of suitable habitats. Lily pads are typically associated with warmer water and are not a common feature of cold, northern water bodies (A. Schafermeyer, New Hampshire Fish and Game, personal communication). Water temperature may restrict mink frogs to northern regions because the higher oxygen level in colder water is required for embryo development (Stockwell 1999). When water is too warm, eggs in the center of an egg mass do not receive sufficient oxygen and the death and decomposition of these eggs can kill surrounding embryos in the egg mass (Stockwell 1999). Because mink frogs are at the southern limit of their geographic range in northern New Hampshire and are dependent on cold waters, there is some concern that the species will be adversely affected by projections of a warming climate (Popescu and Gibbs 2009).

Distribution

Mink frogs are restricted to areas north of 43* latitude North in Maine west to Minnesota and into northern Ontario, Quebec, and Labrador (Stockwell 1999). Historical locations of mink frogs in New Hampshire appear to be clustered in the northern Connecticut River watershed in Coos and Grafton counties. This distribution pattern is an artifact of the biological surveys conducted by Oliver and Bailey in 1938 and 1939 for the NHFG. Reptile and amphibian surveys, incidental to fish distribution surveys, were conducted in the Connecticut River watershed but not in the Androscoggin and Saco watersheds. More recent reports have revealed occurrences of mink frog across Coos County (Berlin, Errol, Pittsburg, Wentworth's Location), and south to Livermore and Thornton in Grafton County. Mink frog can be locally common in New Hampshire North Country water bodies such as along the Magalloway River in Wentworth's Location and marshes at the edge of Lake Umbagog (L.Wunder, Lake Umbagog National Wildlife Refuge, personal communication).

Habitat

The mink frog (*Lithobates septentrionalis*) inhabits the cold water of lakes, ponds, stream edges, springs and occasionally peatlands of northern New Hampshire. Known as "the frog of the north", mink frogs persist at the highest latitude of any North American anuran (Hedeen 1986). They are almost entirely aquatic, preferring shallow, permanent open water with abundant emergent vegetation, especially lily pads (*Nymphaea spp.*) and pickerelweed (*Pontedaria cordata*) for foraging, breeding, and hibernating (DeGraaf and Yamasaki 2001). Adults often feed from lily pads far from shore; adult and larval aquatic invertebrates are common prey (Conant and Collins 1998, Stockwell

Appendix A: Amphibians

1999). Eggs are laid in a globular, jelly mass attached to submerged vegetation, especially the stems of spatterdock (Nuphar spp.) or water lily. Egg masses eventually fall from the stems and drop to the bottom where they develop (Stockwell 1999). Beaver (*Castor canadensis*) activity may a have positive affect on mink frog habitat due to beaver dam conversion of terrestrial to wetland habitat – mitigating drought or temperature extremes. Further, beaver dams are associated with increased landscape heterogeneity that may favor dispersal of a desiccation-prone species such as the mink frog (Popescu and Gibbs 2009).

NH Wildlife Action Plan Habitats

- Lakes and Ponds with Coldwater Habitat
- Northern Swamps
- Marsh and Shrub Wetlands
- Open Water
- Peatlands

Distribution Map
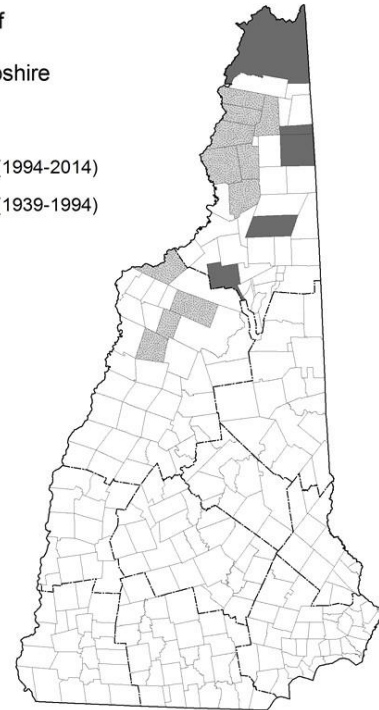
Current Species and Habitat Condition in New Hampshire

No information is available to evaluate the health of mink frog populations.

Population Management Status

Not assessed because of insufficient information.

Regulatory Protection (for explanations, see Appendix I)

- NHFG Rule FIS 803.02. Importation.
- NHFG Rule FIS 804.02. Possession.
- NHFG Rule FIS 811.01 Sale of Reptiles.
- NHFG FIS 1400 Nongame special rules
- Fill and Dredge in Wetlands - NHDES
- Comprehensive Shoreland Protection Act - NHDES
- Clean Water Act-Section 404

Quality of Habitat

Not assessed because of insufficient information.

Habitat Protection Status

Not assessed because of insufficient information.

Habitat Management Status

Not assessed because of insufficient information.

Threats to this Species or Habitat in NH

Threat rankings were calculated by groups of taxonomic or habitat experts using a multistep process (details in Chapter 4). Each threat was ranked for these factors: Spatial Extent, Severity, Immediacy, Certainty, and Reversibility (ability to address the threat). These combined scores produced one overall threat score. Only threats that received a "medium" or "high" score have accompanying text in this profile. Threats that have a low spatial extent, are unlikely to occur in the next ten years, or there is uncertainty in the data will be ranked lower due to these factors.

There are no threats ranked high or moderate for this species.

List of Lower Ranking Threats:

Mortality or species impacts (reduced fitness) from contaminants

Mortality and species impacts (decreased fitness) from various diseases (ranavirus, chytrid)

Disturbance and degradation from increased temperatures that cause droughts and reduce habitat suitability

Actions to benefit this Species or Habitat in NH

Monitor the distribution, condition, and risk to mink frog populations.

Objective:
Monitor the distribution, condition, and risk to mink frog populations.

General Strategy:
Several potential threats have been identified for the species. However, there is minimal information available in NH to assess appropriate actions to implement at this time. NHFG will encourage reports through the reptile and amphibian reporting program to further refine the species distribution in NH. The condition of these sites needs to be determined.

Political Location: **Watershed Location:**

Coos County, Grafton County   Androscoggin-Saco Watershed, Upper CT
                                                            Watershed

References, Data Sources and Authors

Data Sources

Status and ranking information was taken from NatureServe (2014). New Hampshire Reptile and Amphibian Reporting Program (RAARP) records, Taylor (1993), and Oliver and Bailey (1939) were the primary sources of locality records. Habitat and life history information was taken from published literature.

Threat assessments were conducted by a group of NHFG biologists (Michael Marchand, Brendan Clifford, Loren Valliere, Josh Megysey).

Data Quality

The distribution, habitat use, and condition of mink frog populations in New Hampshire are not well understood. This assessment was limited to records in scientific reports, records reported to the New Hampshire RAARP by an expert, and to reports that included a specimen or clear photograph.

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2005 Authors:

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Literature

Berrill, M., S. Betram, B. Pauli D. Coulson, M. Kolohan, and D. Ostrander. 1995. Comparative sensitivities of amphibians to single and pulsed exposures of the forest-use insecticide fenithrothion. Environmental Toxicology and Chemistry. 14:1011-1018.

Berrill, M., S. Betram, L. McGillivray, M. Kolohan, and B. Pauli. 1994. Effects of low concentrations of forest-use pesticides on frog embryos and tadpoles. Environmental Toxicology and Chemistry. 13:657-664.

Brenes, R., M. J. Gray, T. B. Waltsek, R. P. Wilkes, D. L. Miller. 2014. Transmission of ranavirus between ectothermic vertebrate hosts. PLoS ONE. 9(3):1-6.

Conant, R. and J. T. Collins. 1998. Reptiles and amphibians: Eastern and central North America (3rd edition). Houghton Mifflin, Boston, Massachusetts, USA.

DeGraaf, R. M. and M. Yamasaki. 2001. New England wildlife: habitat, natural history, and distribution. University Press of New England, Hanover, New Hampshire, USA.

Green, D. E., K. A. Converse, A. K. Schrader. 2002. Epizootiology of sixty-four amphibian morbidity and mortality events in the USA, 1996-2001. Annals New York Academy of Sciences 969:323-339.

Hayes, T. B., A. Collins, M. Lee, M. Mendoza, N. Noriega, A. A. Stuart, and A. Vonk. 2002. Hermaphroditic, demasculinized frogs after exposure to the herbicide Atrazine at low ecologically relevant doses. Proceedings of the National Academy of Sciences 99:5476-5480.

Hedeen, S. E. 1986. The southern geographic limit of the mink frog, *Rana septentrionalis*. Copeia. 1:239-244.

Hunter, M. L., A.J. K. Calhoun, M. McCollough. 1999. Maine Amphibians and Reptiles. University of Maine Press, Orono, Maine, USA.

NatureServe. 2014. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.2. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: December 22, 2014).

Appendix A: Amphibians

New Hampshire Reptile and Amphibian Reporting Program (RAARP) database. Maintained by the New Hampshire Fish and Game Department, Nongame and Endangered Species Program, Concord New Hampshire (Accessed: February 14, 2005).

Oliver, J. A. and J. R. Bailey. 1939. Amphibians and reptiles of New Hampshire exclusive of marine forms: Pages 195-217 in H.E.Warfel, editor, Biological Survey of the Connecticut watershed. New Hampshire Fish and Game Department Survey Report 4.

Pask, J. D., D. C. Woodhams, L. A. Rollins-Smith. 1012. The ebb and flow of antimichrobial skin peptides defends northern leopard frogs (*Rana pipiens*) against chytridiomycosis. Global Change Biology. 18:1231-1238.

Popescu, V. D. and J. P. Gibbs. 2009. Interactions between climate, beaver activity, and pond occupancy by the cold-adapted mink frog in New York State, USA. Biological Conservation. 142:2059-2068.

Shenoy, K., B. T. Cunningham, J. W. Renfroe, P.H. Crowley. 2009. Growth and survival of northern leopard frog (*Rana pipiens*) tadpoles exposed to two common pesticides. Environmental Toxicology and Chemistry. 28(7):1469-1474.

Stockwell, S. S. 1999. Mink frog. Pages 107-110 in Hunter, M. L. Jr., A. J. Calhoun, and M. McCollough, editors. Maine amphibians and reptiles. The University of Maine Press, Orono, Maine, USA.

Taylor, J. 1993. The Amphibians and Reptiles of New Hampshire. Nongame and Endangered Wildlife Program. New Hampshire Fish and Game Department. Concord, New Hampshire, USA.