# Occurrence of Pond-breeding Amphibians at Alpine Ponds in the White Mountains, New Hampshire

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**Abstract -** Ponds in the White Mountains of Grafton and Coos Counties, NH provide some of the highest elevation breeding habitat for amphibian populations in the northeastern United States. Between 2007 and 2009, we conducted field surveys of alpine ponds above 1100 m on the Presidential Range and Franconia Ridge in the White Mountain National Forest. These ponds include the only currently known amphibian breeding sites in tundra-dominated landscapes reported from the eastern United States. Four species of anuran and one species of salamander were detected at elevations ranging from 1180 to 1546 m, with direct evidence of breeding observed at every pond complex. This preliminary study contributes to available baseline data for amphibian populations in alpine and subalpine environments in the northeastern United States. Amphibian populations may be strong indicators of climate change and environmental stressors in alpine ecosystems; these populations appear to warrant long-term monitoring.

## Introduction

Arctic-alpine habitats are high-elevation communities dominated by a variety of lichens, graminoids, ericaceous species, and stunted conifers, many of which have a generally more northern distribution. Arctic-alpine habitats occur in the eastern United States primarily on the Presidential Range in New Hampshire and Mount Katahdin in Maine (Kimball and Weihrauch 2000). Smaller, more isolated arctic-alpine communities occur on other peaks in Maine, New Hampshire, Vermont, and New York (Harris et al. 1977, Kimball and Weihrauch 2000, Slack and Bell 2006). Because of the overall rarity of arctic-alpine ecosystems in the eastern United States, the alpine ponds in the White Mountain National Forest of New Hampshire appear to comprise a major proportion of potential amphibian breeding sites in tundra-dominated landscapes in the region. While studies of arctic, alpine, and high-elevation amphibians are prevalent in the western United States (Sierra Nevada: Matthews et al. 2001; Denali National Park: Hokit and Brown 2006, Knapp et al. 2007), studies of alpine amphibian communities in New England have been limited. Historical accounts of exploration in New England's mountains appear to be generally devoid of references to amphibians near or above treeline (e.g., Thoreau 1858). Seven species of amphibian were reported from the Lake of the Clouds (1200 m), Mount Mansfield, VT by Trombulak and Andrews (1995), and five species of amphibian were reported from the Lakes of the Clouds (1540 m) on Mount Washington, NH, by Jones (2005), but documented reports of amphibians from alpine wetland complexes appear to remain absent from peer-reviewed scientific literature. Notwithstanding summaries of five species of amphibians in one ecological field guide of the

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New England alpine zone (Slack and Bell, 2006), thorough treatments of amphibian distribution in Maine (Hunter et al. 1999) and New Hampshire (Taylor 1993) do not specifically mention the occurrence, ecology, or status of amphibians in alpine areas at high elevation.

Lakes and ponds at middle-elevations in the Adirondack Mountains of New York have been studied extensively and provide evidence of how environmental contamination and natural geology have combined to impact communities of fish and invertebrates (Jenkins et al. 2007). Although Jenkins et al. (2007) did not study amphibians within small fishless ponds, it is likely that acidic precipitation has impacted amphibians in the Adirondack Mountains and throughout the region. We initiated a long-term study to evaluate the occurrence of pond-breeding amphibians at major alpine pond complexes throughout the White Mountain National Forest.

## Study Sites

Our study sites were four major alpine ponds or "pond complexes" above 1100 m in the White Mountain National Forest. Two of these ponds, Star Lake and Lakes of the Clouds, are located above treeline in ecosystems dominated by alpine tundra, ericaceous shrubs, and the dwarf conifers *Picea mariana* (Mill.) Britton, Sterns & Poggenb. (Black Spruce) and *Abies balsamea* (L.) Mill. (Balsam Fir) (see Harris et al. 1977). The other two pond complexes, Eagle Lake and Hermit Lake, are located at or just below treeline in stunted boreal forest dominated by Balsam Fir.

Eagle Lake is an oval-shaped pond situated at 1278 m, near treeline on the western shoulder of Mount Lafayette, Grafton County, NH (44° 9'38.18"N, 71°39'32.16"W). We surveyed Eagle Lake and a smaller pond to the northwest. The Eagle Lake basin is comprised primarily of large boulders and thick organic sediments and is surrounded by krummholz coniferous and subalpine ericaceous vegetation. The smaller pond has a well-developed *Sphagnum* mat surrounding a deep (>1 m) pool of open water with unconsolidated organic sediment, and is surrounded by krummholz spruce-fir and subalpine ericaceous vegetation, with some mats of graminoids. An outlet flows south from Eagle Lake.

Hermit Lake is an oval-shaped tarn situated at 1180 m on the floor of Tuckerman Ravine, a pronounced glacial cirque on the southeast shoulder of Mount Washington, Carroll County, NH (44°15'38.65"N, 71°17'8.82"W). Cutler Brook Pond is a ponded portion of Cutler Brook where an intermittent stream converges with the main channel 150 m west of Hermit Lake (44°15'35.29"N, 71°17'14.83"W). Hermit Lake has an estimated average depth of between 1 and 2 m, with thick, organic substrate and partially submerged boulders, and is surrounded by balsam fir forest. Cutler Brook Pond is 40–80 cm deep and has a generally gravelly, sandy substrate. Surrounding vegetation is Red Spruce-Balsam Fir forest. We conducted surveys along the perimeter of Hermit Lake, as well as throughout the small ponded portion of Cutler Brook.

The Upper and Lower Lakes of the Clouds comprise two glacial tarns situated at 1546 m and 1528 m, respectively, above the treeline in Ammonoosuc Ravine on the southern shoulder of Mount Washington, Carroll County, NH (44°15'33.53"N, 71°19'0.69"W and 44°15'29.31"N, 71°19'2.70"W, respectively). Upper Lake is an oval-shaped pond with stony substrate, accumulated organic sediments, and partially submerged boulders. Low ericaceous and coniferous growth and exposed bedrock surround the pond. The Lower Lake is an irregularly shaped oval pond with low ericaceous and coniferous growth surrounding the pond. The pond has a rocky substrate with accumulated organic sediments and large, partially submerged boulders. A perennial outlet drains west into the Ammonoosuc River.

Star Lake is a circular alpine pond situated at 1493 m, above treeline in the col between Mounts Madison and Adams at the northern end of the Presidential Range, Carroll County, NH (44°19'30.25"N, 71°17'2.55"W). The basin has narrow fingers of open water extending into the northern shoreline and a perennial, partially subterranean outlet drains west. Most of the basin is comprised of large rocks and boulders, and organic sediments have filled in gaps between large boulders. Vegetation around the pond includes graminoids, ericaceous species, and krummholz. The water depth ranges from 30 cm to more than 1 m.

## Materials and Methods

We visited each site once between 24 May and 17 July 2007, and selected sites on 5–6 June 2008 and 6–7 June 2009, using existing hiking trails in Franconia Notch State Park and the White Mountain National Forest. We used waders and dip nets to search emergent vegetation, pond shores, and shallow water near the pond edges for amphibians. At Hermit Lake, we set collapsible funnel traps (Collapsible Minnow Trap [45.7 x 25.4 cm with 5.1–6.4-cm entrances], Promar, Gardena, CA) overnight with 6 and 4 traps, respectively, in 2008 and 2009. Additionally, logs and stones were overturned, and subsequently carefully replaced, to search for adult amphibians. Sphagnum hummocks overhanging standing water were carefully excavated. We also searched inlets, outlets, and wetlands adjacent to the pond(s). Water temperature was measured using an analog thermometer, and pH was recorded using a waterproof pHTester 2 (Oakton Instruments; Vernon Hills, IL). Taxonomy of amphibians followed Crother (2008), with the exception of historic references to invalid taxa.

## Results

We conducted a total of seven surveys to the four major pond complexes between May 2007 and June 2009, under a variety of environmental conditions (Table 1). We detected five species of amphibians breeding in these alpine pond complexes (Table 2). In every pond complex surveyed, we observed evidence of amphibian breeding.

## Discussion

Our understanding of the influence of elevation on the distribution and ecology of pond-breeding amphibians in northeastern North America is primarily informed by relatively few studies (e.g., Jones 2005, Trombulak and Andrews 1995). We present additional information demonstrating that several species of amphibians, including *Anaxyrus americanus* Holbrook (American Toad), *Lithobates sylvaticus* (LeConte) (Wood Frog) , *Pseudacris crucifer* (Wied-Neuwied) (Spring Peeper), and *Ambystoma maculatum* (Shaw) (Spotted Salamander), are present and, in many cases, breeding at elevations above 1100 m in a diverse array of alpine and subalpine ponds.

Table 1. Environmental conditions at six primary study areas during amphibian surveys in 2007, 2008, and 2009.

| Site Date | Air temp. (˚C) | Water temp. (˚C) | pH |
|---|---|---|---|
| Upper Lake of the Clouds | | | |
| 14 June 2007 | 19 | 19.5 | 5.1 |
| 6–7 June 2009 | 12 | 7.4 | 5.0 |
| Lower Lake of the Clouds | | | |
| 14 June 2007 | 19 | 17 | 5.1 |
| 6–7 June 2009 | 12 | 6.2 | 5.3 |
| Cutler Brook Pond | | | |
| 14 June 2007 | 16 | 10 | 5.4 |
| 5–6 June 2008 | 23 | 5 | 5.9 |
| Hermit Lake | | | |
| 14 June 2007 | 16 | 18 | 4.8 |
| 5–6 June 2008 | 23 | 17 | 5.0 |
| 6–7 June 2009 | 16 | 19 | 4.7 |
| Star Lake | | | |
| 17 July 2007 | 15 | 16 | 4.2 |
| Eagle Lake | | | |
| 24 May 2007 | 22 | 16 | 5.0 |

Table 2. Amphibians detected during surveys of alpine ponds in the White Mountains from 2007 to 2009. Upper = Upper Lakes of the Clouds, Lower = Lower Lakes of the Clouds, Cutler = Cutler Brook Pond, Hermit = Hermit Lake, Star = Star Lake, Eagle = Eagle Lake, and UEL = Upper Eagle Lake. 07 = 2007, 08 = 2008, and 09 = 2009.

| Species | Upper (07/09) | Lower (07/09) | Cutler (07/08) | Hermit (07/08/09) | Star (07) | Eagle (07) | UEL (07) |
|---|---|---|---|---|---|---|---|
| Egg masses | | | | | | | |
| *Ambystoma maculatum* | 0/0 | 0/0 | 0/0 | 6/46/79 | 0 | 1 | 0 |
| *Lithobates sylvaticus* | 0/8 | 0/0 | 0/0 | 0/6/8 | 0 | >281 | >84 |
| *Anaxyrus americanus* | 0/0 | 0/0 | 0/0 | 1/0/0 | 0 | 0 | 0 |
| Larvae and metamorphosed juveniles | | | | | | | |
| *Lithobates sylvaticus* | 0/0* | 0/0 | 1/0 | 0/>100/>100 | >70 | 0 | 0 |
| *Anaxyrus americanus* | 0/0 | 0/0 | 3/0 | 0/0/0 | 0 | 0 | 0 |
| Adults | | | | | | | |
| *Ambystoma maculatum* | 0/0 | 0/0 | 0/0 | 0/5**/0 | 0 | 0 | 0 |
| *Notophthalmus viridescens* (Rafinesque) (Eastern Newt) | 0/0 | 0/0* | 0/0 | 0/0/0 | 0 | 0 | 0 |
| *Anaxyrus americanus* | 1/0* | 1/0* | 0/0 | 0/>24/>21 | 1 | 0 | 0 |
| *Psuedacris crucifer* | 0/1* | 0/0* | 0/0 | 1/>12/>12 | 0 | 0 | 0 |
| *Lithobates clamitans* | 0/0* | 0/0 | 0/0 | 3/1/3 | 0 | 0 | 0 |
| *Lithobates sylvaticus* | 0/1* | 0/0 | 0/0 | 2/1/> 6** | 0 | >20 | 20 |

*Observed between 1999 and 2003 by Jones (2005).
**Males only.

Our results from the White Mountains suggest that pond-breeding amphibian communities in other arctic-alpine regions in northeastern North America, such as Mount Katahdin in Maine; Gaspésie, Monts Groulx, and Monts Otish in Québec; and the Mealy Mountains in Labrador may be more diverse than currently thought. Additionally, exotic amphibians in Newfoundland (where at least three species of anuran have been introduced in the past 150 years [Campbell et al. 2004]) may be capable of colonizing extensive areas of arctic-alpine tundra in the Long Range Mountains. Alpine Wood Frogs and American Toads from our study areas do not exhibit the distinctive coloration exhibited by individuals of both species across portions of subarctic eastern Canada and parts of southern Québec and Maine (formerly described as the northern subspecies *Rana sylvatica cantabrigensis* Baird and *Bufo terrestris copei* Yarrow and Henshaw [see Frost 2004, Hunter et al. 1999]), indicating that amphibian populations in alpine areas of the White Mountains represent recent colonizations from lowland areas, or populations continuous with lowland areas, rather than relictual boreal faunas.

Communities of alpine amphibians may be strong indicators of regional climate change and environmental stressors such as eutrophication, acid precipitation, contamination (e.g., metals), ultra-violet radiation, and their synergistic interactions with pH and disease (Bancroft et al. 2007). Our results provide important baseline data for alpine amphibian communities in the northeast. The species documented herein at each pond are not necessarily surprising and may have been observed by recreational hikers for many years, but not reported. Although our study did not determine the range of these species within the White Mountains in recent history (≈50 yr. B.P.), the documentation of amphibians using ponds with relatively low pH in remote, isolated communities is an important finding. Even slight changes in pH could affect the entire community of amphibians and invertebrates. We hypothesize that if the acidity is decreasing (pH increasing), we could document an increase in amphibian biodiversity in the future. However, if the acidity is increasing, declines in amphibians may occur due to the already low pH levels.

Long-term studies on similar systems have provided valuable data on how environmental changes impact ecosystems over extended periods of time (Jenkins et al. 2007). Amphibians may serve as indicators of numerous environmental trends, including increases or reductions in acid precipitation and other atmospheric contamination. We recommend quantified monitoring of these amphibian communities to determine how they fluctuate in response to short- and long-term environmental trends, as well as to assess population demographics, body-size comparisons to other populations, genetic connectedness, and population viability.

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