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A review of vertebrate community composition in seasonal forest pools of the northeastern United States

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Abstract

Seasonally-flooded wetlands occur throughout the world and provide important foraging, resting, and breeding habitat for a broad array of organisms. This review summarizes our current understanding of vertebrate community composition at seasonal forest pools in the northeastern United States. These wetlands typically have hydroperiods that range from temporarily flooded to intermittently exposed, which reduces densities of many potential predators (e.g., fish). Current research has shown that pool hydroperiod, canopy closure, vegetation structure within pools, presence of potential predators, and landscape structure surrounding pools are the key factors determining vertebrate diversity at seasonal forest pools. Of 25 species of amphibians in the region, frogs (10 of 12 species) are more likely to breed in seasonal forest pools than salamanders (6 of 13 species). Seven of 10 amphibian species that breed in seasonal forest pools are state-listed as threatened or endangered. Among 27 species of reptiles, 3 of 15 species of snakes, and 6 of 12 species of turtles utilize seasonal pools during at least one stage of their annual cycle. Seasonal forest pools are important foraging and basking habitat for three species of turtles listed as threatened or endangered. Compared to other vertebrate taxa, most species of mammals are habitat generalists, with 50 of 63 mammal species potentially foraging at seasonal pools during part of their annual cycle. Chiroptera (bats; all 9 species) are believed to actively forage at seasonal pools and some Insectivora, particularly *Sorex palustris* Richardson and *S. fumeus* (Miller) and *Condylura cristata* (L.), are detected regularly at seasonal pools. Breeding birds are less likely to utilize seasonal pools than other vertebrate taxa, although 92 of 233 species might forage or breed near seasonal pools. Several species of Anatidae, Rallidae, and some Passeriformes use seasonally flooded pools. All vertebrates that use seasonal forest pools use other habitats during some stage in their life cycle; thus gaining a clear understanding of their habitat requirements is critical to their long-term persistence.

Introduction

There is increasing interest among biologists and conservationists in the biodiversity of wetlands that have seasonal hydroperiods (Leibowitz 2003). These wetlands are unique because they are not inundated by surface water throughout the year. Thus, only organisms with life histories adapted to this periodic drying are capable of utilizing seasonal forest pools (Zedler 2003). Throughout the world, endemic flora and fauna are adapted to the physical and chemical environment found in

seasonal wetlands, which are biodiversity hotspots for a broad array of organisms (Schneider and Frost 1996; Gibbs 2000; Preisser et al. 2000; Gibbons 2003).

Much is known about the community composition of selected vertebrate taxa in seasonal wetlands in Australia (Friend and Cellier 1990; Watson et al. 1995), Central America (Lips et al. 2003), and Europe (Salvador and Carrascal 1990; Boix et al. 2001; Jakob et al. 2003). Across North America, considerable research has been conducted on vertebrates associated with isolated wetlands that dry periodically, including the vernal pools of California (King et al. 1996; Riefner and Pryor 1996; Zedler 2003), the Prairie Pothole Region (Austin 2002), the playas of the southern Great Plains (Haukos and Smith 2003), and Carolina bays of the southeastern United States (Pechmann et al. 1989; Snodgrass 2000; Sharitz 2003). Within the past decade, wetland ecologists in the northeastern United States have focused their attention on the wildlife associated with seasonal forest pools (Gibbs 1993; Windmiller 1996; Brooks and Doyle 2001; Milam and Melvin 2001).

Seasonal forest pools [also known as woodland vernal pools (Tiner et al. 2002), vernal pools (Burne 2001), or seasonal ponds (Palik et al. 2001)] are a type of isolated, temporary wetland that occurs throughout the northeastern United States (Tiner et al. 2002; Brooks this issue). Most research conducted in the Northeast on vertebrate community composition in seasonal forest pools has focused on herpetofauna, with the majority of research focusing on amphibians (Gibbs 1993; Crouch and Paton 2002; Calhoun et al. 2003; Egan and Paton 2004). In addition, much is known about habitat associations of turtles that use seasonal forest pools in the region (Graham 1995; Joyal et al. 2001; Milam and Melvin 2001). In contrast, less is known about mammal and bird use of seasonal forest pools, although many species occasionally use these wetlands (Brooks and Doyle 2001; DeGraaf and Yamasaki 2001). The objective of this review is to summarize our current understanding of vertebrate community composition in seasonal forest pools in the northeastern United States, defined as Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine. In addition, I summarize vertebrate use of seasonal forest pools and adjacent terrestrial habitats to stimulate additional research.

Physical characteristics of seasonal forest pools in the northeastern United States

Seasonally flooded isolated wetlands are common in the Northeast, accounting for approximately 57% of the total number of wetlands and 19% of the total wetland acreage in the region (Tiner et al. 2002). Only Massachusetts has attempted to quantify the spatial distribution and abundance of seasonal forest pools across an entire state; Burne (2001) mapped over 29,000 potential seasonal pools (i.e., 1 pool per 44 ha of forest). Other density estimates within the region vary from 1.4 pools per km^2 in central Massachusetts (Brooks et al. 1998), 1 pool per km^2 on loose till to 8 pools per km^2 on alluvium in Rhode Island (Skidds 2003), and 23–50 pools per km^2 in Maine (Calhoun et al. 2003). Thus, although there are many seasonal forest pools in the Northeast and they tend to be widely dispersed across the landscape, pools densities vary considerably across the region.

In the Northeast, seasonal forest pools are usually less than 0.1 ha in maximum surface area (Brooks et al. 1998; Calhoun et al. 2003; Skidds and Golet this issue). In contrast, seasonal wetlands in the southeastern United States can be much larger, ranging from 1 to 15 ha (Snodgrass 2000). In western Massachusetts, 67% of pools were < 0.05 ha (Brooks et al. 1998); in Maine median pool size ranged from 0.0024 to 0.029 ha (Calhoun et al. 2003); and in Rhode Island mean pool size was 0.11 ha (Skidds and Golet this issue). Thus, throughout much of the Northeast, seasonal forest pools account for a small percentage of the landscape and individual seasonal pools account for only part of the annual home range for many species of vertebrates.

Hydroperiod shapes the habitat characteristics and vertebrate community composition of seasonal forest pools (Leibowitz 2003). Skidds and Golet (this issue) found considerable annual variation in pool hydroperiods in Rhode Island; mean hydroperiod for pools that dried ranged from 20 weeks (after 1 March) in a dry year to 28 weeks in a wet year. Thus, many pool basins are often dry by August. Similar hydrological patterns exist in Maine, where most pools (89%) in southern

Maine range from temporarily flooded (i.e., surface water is present for brief periods during the growing season; Cowardin et al. 1979) to semi-permanent (i.e., pools held some water throughout the growing season) in northern Maine (Calhoun et al. 2003), and Brooks (2004) found comparable patterns in Massachusetts. Therefore, the phenology of vertebrate use of seasonal pools is timed to coincide with this cyclical flooding, with adults of many amphibians utilizing seasonal pools for less than one month annually and juveniles emigrating from pools before they dry (Paton and Crouch 2002).

Although most seasonal pools in the Northeast are small and occur in forested landscapes (Brooks this issue; Skidds and Golet this issue), there is considerable variation in habitat characteristics within pools. Using the Cowardin et al. (1979) classification scheme, Calhoun et al. (2003) categorized most seasonal pools in Maine as palustrine forested wetlands, with the remainder classified as palustrine scrub–shrub, palustrine emergent marsh, or palustrine open water. In Rhode Island, most pool basins have extensive tree canopy coverage, extensive persistent emergent plant cover, substantial shrub cover, and some trees within pools basins, although this varies considerably among pools (Skidds and Golet this issue). Therefore, it is difficult to develop a list of vertebrates that utilize seasonal forest pools because this type of wetland encompasses a broad array of habitat conditions.

Vertebrate community composition in seasonal forest pools

To assess vertebrate community composition in seasonal pools in the Northeast, in addition to pertinent journal articles, I relied heavily on recent natural history compilations including those for amphibians (Klemens 1993; Petranka 1998; Hunter et al. 1999), reptiles (Klemens 1993; Hunter et al. 1999), mammals (Whitaker and Hamilton 1998), and birds (Ehrlich et al. 1988). I also used a compilation by DeGraaf and Yamasaki (2001) on wildlife habitat use in New England. I segregated use patterns by vertebrates into three categories: *breeding* – evidence of breeding activity within or immediately adjacent to seasonal forest pools, *foraging* – evidence that the species actively forages in small aquatic habitats, such as seasonal forest pools, or the species may forage in small openings, such as when seasonal forest pools are dry in late summer, and *not associated* – no strong evidence to suggest that the species ever uses seasonal pools during any stage of their annual life cycle.

Class Amphibia, Order Anura

There are 25 species of amphibians in the Northeast including 13 species of caudates (salamanders) and 12 species of anurans (frogs; Table 1, Appendix 1). Anurans are more likely to use seasonal forest pools during one or more stages of their annual cycle than caudates. Although all anurans that occur in the region breed in pools, at least two species typically select wetlands with longer hydroperiods (*Rana catesbeiana* Shaw and *R. clamitans* Latreille) because their larvae take 1–2 years to undergo metamorphosis (Klemens 1993). Most anurans in the Northeast are adapted to pools with seasonal hydroperiods, with juveniles of most species emigrating by the end of August (Paton and Crouch 2002). Three species of anurans are state-listed (Table 2). *Scaphiopus holbrookii* (Harlan) is a species adapted to wetlands with intermittently flooded hydroperiods and is listed in three states, *R. pipiens* Schreber is state-listed in southern New England, and *Pseudacris triseriata* (Wied-Neuwied) is state-listed by Vermont, although it is an abundant species in the Great Plains of North America (Conant and Collins 1991).

Class Amphibia, Order Caudata

Of the 13 species of caudates that occur in the Northeast, 46% use seasonal forest pools as breeding habitat (Table 1). Compared to the southeastern United States, the Northeast has relatively few species of terrestrial salamanders (Petranka 1998). Two species typically reside only in upland habitats (*Plethodon cinereus* [Green] and *P. glutinosus* [Green]), although they may occasionally venture near seasonal forest pools. One species (*Necturus maculosus* [Rafinesque]) inhabits riverine habitats, and four species are generally restricted to streams, springs, and seeps (*Desmognathus fuscus* [Green], *D. ochrophaeus* Cope [only

Table 1. Percent of vertebrate species of the northeastern United States that forage, breed, or are not associated with seasonal forest pools.

Class	Order	% of species			*N*
		Not associated	Forage	Breed	
Amphibia	Anura	0.0	16.7	83.3	
	Caudata	53.8	0.0	46.2	13
Reptilia	Squamata	25.0	75.0	0.0	15
	Testudines	50.0	50.0	0.0	12
Mammalia	Chiroptera	0.0	100.0	0.0	9
	Insectivora	40.9	59.1	0.0	22
	Rodentia, Lagomorpha, Mustelidae	14.2	84.8	0.0	27
	Carnivora, Artiodactyla	0.0	100.0	0.0	5
Aves	Anseriformes	57.7	30.8	11.5	26
	Charadriiformes	69.2	15.2	15.2	13
	Passeriformes	56.1	43.1	0.8	123
	Other waterbirds[a]	78.9	10.5	10.5	19
	Other landbirds[b]	65.4	34.6	0.0	50

[a]waterbirds include: Gaviiformes, Podicipediformes, Pelicaniformes, Ciconiformes, Gruiformes.
[b]landbirds include: Falconiformes, Columbiformes, Cucliformes, Strigiformes, Caprimulgiformes, Coraciiformes, Apodiformes, Piciformes.

found in isolated sites in Vermont], *Eurycea bislineata* [Green], and *Gyrinophilus porphyriticus* [Green]) (Klemens 1993). Six species of caudates are state-listed, with most species considered species of concern (Table 2). *Ambystoma opacum* (Gravenhorst) is state-listed in Massachusetts, New Hampshire, and Vermont, where the species is at the northern limit of their range. *A. opacum* are among the most abundant pond-breeding amphibians in the southeastern United States (Petranka 1998). Two other state-listed ambystomids, *A. jeffersonianum* (Green) and *A. laterale* Hallowell, have complex life histories that readily hybridize to form unisexual species including diploid, triploid, tetraploid, and pentaploid individuals (Klemens 1993). The Northeast is in the center of the range of *A. laterale* and at the eastern edge of the range of *A. jeffersonianum*; available evidence suggests that habitat fragmentation and acid rain are negatively impacting their populations (Klemens 1993; Rowe et al. 1994).

Class Reptilia, Order Squamata

There are 15 species of snakes in the Northeast. Reptiles in the region primarily use seasonal forest pools either for foraging or basking. Approximately 75% of snake species in the Northeast use seasonal forest pools during various stages of their life history (Table 1). Snakes, such as *Thamnophis sauritus* (L.), are often detected foraging near seasonal pools; this species is listed as a species of concern in three states (Table 2). Other state-listed snakes are less likely to occur in seasonal pools. They either specialize in prey from seasonal pools (i.e., *Heterodon platirhinos* Latreille primarily eats *Bufo* toads) or occasionally forage in seasonal pools, but are more likely to be found in semi-permanently or permanently flooded ponds or lakes (e.g., *Nerodia sipedon* [L.]).

Class Reptilia, Order Testudines

There are 12 species of turtles in the Northeast, of which 50% use seasonal forest pools during parts of their annual cycle. Three species of state-listed turtles spend part of their annual cycle in seasonal pools (*Clemmys guttata* Schneider and *Emydoidea blandingii* (Gray); Joyal et al. 2001; and *C. insculpta* (LeConte) Compton et al. 2002), with *C. guttata* using seasonal pools more than any other reptile in the region (Joyal et al. 2001). Wetland alteration and destruction are among the most important factors leading to these species' declines, although collecting individuals for the pet trade and biological supply companies are other serious threats (Klemens 1993). *C. muhlenbergii* Schoepff, one of

Table 2. State- or federally–listed threatened or endangered vertebrates that might utilize seasonal forest pools in the northeastern United States including Connecticut (CT), Massachusetts (MA), Maine (ME), New Hampshire (NH), Rhode Island (RI), and Vermont (VT).

Species	CT	MA	ME	NH	RI	VT	Total number of states
Amphibia:							
Bufo fowleri						SC	1
Hemidactylium scutatum		SC				SC	2
Pseudacris triseriata						SE	1
Rana pipiens	SC				SC		2
Scaphiopus holbrookii	SE	ST			ST		3
Ambystoma jeffersonianum	SC*	SC				SC	3
Ambystoma laterale	SC*	SC				SC	3
Ambystoma opacum		ST		SE		UC	2
Reptilia:							
Nerodia sipedon						UC	3
Pseudemys rebriventris		FE					1
Thamnophis sauritus	SC				SC	SC	3
Clemmys guttata		SC	ST		ST	SE	4
Clemmys insculpta	SC	SC			SC	SC	2
Clemmys muhlenbergii	FT	FT					2
Emydoidea blandingii		ST	SE				4
Mammalia:							
Lasionycteris noctivagans	SC					UC	2
Lasiurus borealis	SC						1
Lasiurus cinereus	SC						1
Myotis leibii	EX	SC		SE		ST	4
Myotis septentrionalis						UC	1
Myotis sodalist	FE	FE				FE	3
Pipistrellus subflavus						UC	1
Sorex fumeus					SC		1
Sorex palustris		SC			SC	UC	3
Synaptomys borealis			SE				1
Synaptomys cooperi	SC	SC			SC	UC	4
Sylvilagus transitionalis					SC	SC	2
Lynx rufus					ST		1
Martes americana				ST		SE	2
Martes pennanti					SC		1
Aves:							
Anas crecca					SC	UC	2
Porzana carolina					SC		1
Rallus longirostris					SC		1
Cistothorus palustris					SC		1
Cistothorus platensis	SE	SE		SE		SE	4
Buteo lineatus	SC						1

FE = Federally endangered, FT = Federally threatened, SE = state endangered, ST = state threatened, SC = State species of concern, UC = uncommon species in VT, EX = extirpated.

two federally listed species of turtles in the Northeast, prefers palustrine wet meadows or open calcareous boggy areas generally dominated by sedges (*Carex* spp.) or sphagnum moss (*Sphagnum* spp. L.) (Morrow et al. 2001). The spread of invasive plants (e.g., *Lythrum salicaria* L. and *Phragmites australis* Cav. Trin. ex. Steud.) is having a negative impact on *C. muhlenbergii* basking and nesting habitat (Morrow et al. 2001).

Class Mammalia

There are 64 species of mammals that occur in the Northeast (Whitaker and Hamilton 1998), including 9 species of bats from the family Vespertilionidae, 22 species of small mammals (i.e., Soricidae, Zapodidae, Muridae), 27 mid-sized mammals (i.e., Sciuridae, Leporidae, Mustelidae, Mephitidae), and 5 species of large mammals (i.e.,

Canidae, Ursidae, Cervidae; Table 1). Bats are apparently more likely than other mammal species to utilize seasonal pools, although much needs to be learned about their foraging ecology. Available evidence suggests that bats often feed over open water (Vaughn et al. 1997) and along habitat edges (Grindal and Brigham 1999), conditions that would include seasonal forest pools. Recent research has found that the echolocation calls of smaller, more maneuverable *Myotis* species were more frequently recorded over seasonal forest pools than over larger, open-canopy wetlands (R.T. Brooks, pers. comm.). Seven species of bats are state-listed in the Northeast (Table 2), including the federally listed *Myotis sodalis* Miller & Allen, which ranges into Connecticut, Rhode Island, Massachusetts, Vermont, and New Hampshire (Whitaker and Hamilton 1998).

There are two species of small mammals that actively forage in seasonal pools. *Sorex palustris* Richardson inhabit the riparian zones near streams, sphagnum swamps, emergent marshes, and seasonal pools, where they forage on aquatic and non-aquatic insects (Whitaker and Hamilton 1998), and this species is listed in three states (Table 2). *Condylura cristata* L. also specializes in wetlands, where they use their tentacles to search for earthworms, and have been captured 45 cm underwater in ponds with a minnow trap (Eadie and Hamilton 1956). Available survey information suggests *C. cristata* are common and are not listed in any state.

Brooks and Doyle (2001) assessed small mammal habitat associations at seasonal forest pools in the Northeast, and investigated shrew abundance at pools in central Massachusetts. They captured three species of shrews (*S. cinereus* Kerr [13.7% of 2124 captures], *S. fumeus* [0.4%], *Blarina brevicauda* Say [2.0%]) at their three study pools, but *Clethrionomys gapperi* (Vigors) and *Peromyscus leucopus* (Rafinesque) accounted for 60.4 and 21.1%, respectively, of all small mammal captures. There was no evidence that capture rates for any species were different between traps near the seasonal pool and in upland areas, thus these detection rates may simply reflect abundance patterns in forests in this area, and not reflect species preferences for seasonal pools.

Although several species of mid-sized mammals and large mammals are state-listed, none of those species specialize in seasonal pool habitats. Carnivores tend to have large home ranges and are habitat generalists. Thus, although most large carnivores may occasionally utilize seasonal pools, there is no indication that seasonal forest pools provide essential foraging habitat for any species (Whitaker and Hamiton 1998; DeGraaf and Yamasaki 2001).

Class Aves

There are approximately 233 species of birds that breed or migrate through the Northeast (Ehrlich et al. 1988; DeGraaf and Yamasaki 2001), of which 39% may utilize seasonal forest pools during their annual cycle (Table 1, Appendix 1). Most birds that use seasonal forest pools forage in vegetation above the pool, although some birds prey on aquatic organisms in the water. Many species of birds nest near seasonal pools, including *Aix sponsa* L. and *Anas rubripes* Brewster, although both species primarily nest near other types of wetlands (DeGraaf and Yamasaki 2001). Other birds specialize in palustrine wetlands that typically have longer hydroperiods than seasonal pools, including emergent wetlands (i.e., *Podilymbus podiceps* L., *Botaurus lentiginosus* Rackett, *Porzana carolina* L., *Rallus limicola* Vieillot, *Cistothorus platensis* Latham, *Melospiza lincolnii* Audubon) and wet meadows (*Chlidonias niger* L.), with these species probably rarely foraging or nesting near seasonal pools.

Future research needs

Available research has shown that seasonal forest pools in the northeastern United States provide essential habitat for a broad array of vertebrate species, including many species that are state- or federally listed as threatened or endangered. Although much is known about the habitat preferences of some species (e.g., herpetofauna) that use seasonal pools, much still needs to be learned about individual species' habitat use patterns during their annual cycle.

Most research on habitat associations of vertebrates at seasonal forest pools in the Northeast has focused on herpetofauna. Wetland ecologists have a well-developed understanding of amphibian community composition and habitat associations within breeding pools (Babbitt et al. 2003; Calhoun et al. 2003; Egan and Paton 2004; Babbitt

this issue; Burne this issue). Clearly, hydroperiod (Pechmann et al. 1989; Paton and Crouch 2002; Egan and Paton 2004; Babbitt this issue) and canopy closure over pools (Skelly et al. 2002, this issue) are two of the most important determinants of amphibian diversity at breeding pools.

Less is known about amphibian habitat requirements away from breeding ponds, thus there is a pressing need to quantify terrestrial habitat requirements for most species of pond-breeding amphibians (Gibbons 2003). Current state wetland regulations in the region generally have jurisdiction over only the pond basin for isolated wetlands <0.1 ha (e.g., Rhode Island), or a 30-m buffer around seasonal forest pools (e.g., certified vernal pools in Massachusetts; Colburn 1996). Yet, existing empirical evidence suggest that amphibians in the region move much greater distances than the jurisdiction boundaries of state wetland regulations, which were primarily designed to protect water resources (Semlitsch and Bodie 2003). Radio-telemetry studies in Vermont and Rhode Island have shown that ambystomid salamanders will emigrate considerable distances from breeding pools (30–460 m; Faccio 2003; Montieth 2004). Emigration distances of other amphibian species in the region are not known, thus there is need to quantify their dispersal characteristics. In addition, Regosin et al. (2003) recently documented that male *Rana sylvatica* tend to winter closer to breeding pools than females, which suggests that regulations that protect only narrow buffers around breeding pools may not protect substantial numbers of females. This type of dispersal information is needed for other amphibian species in the Northeast.

Based on my review of the available literature, there is also a need for more research on use of seasonal forest pools by other taxa, particularly mammals and birds. Based on our understanding of the foraging ecology of Chiroptera (Whitaker and Hamilton 1998), it seems quite likely that some species of bats may readily utilize the airspace over seasonal forest pools to actively forage for insects. Preliminary research conducted by Brooks (pers. comm.) suggests that bats often forage over seasonal forest pools. Given that several state- and federally listed species of bats occur in the region, biologists should consider more detailed studies of bat habitat associations at potential foraging sites, including seasonal forest pools.

Several species of small mammals apparently readily use seasonal pools and we do not have a clear understanding of how important seasonal wetlands are to these species. However, embarking on habitat use studies of these species (e.g., *S. palustris*, *C. cristata*) will be a challenge because they are rare. Thus, gathering sufficient data to develop resource selection functions may be difficult, if not impossible.

There is no compelling evidence that any species of bird in the Northeast specializes in seasonal forest pools, although temporary wetlands are utilized by over 100 species of birds during some part of their annual cycle (DeGraaf and Yamasaki 2001). Because seasonal pools in the Northeast are small, they generally account for a small percentage of the breeding territory of most species. However, due to insect productivity at seasonal pools, many species of birds may actively forage at seasonal forest pools. Species that specialize in riparian habitats may utilize edges of seasonal pools (*Dendroica petechia* L.) or small openings over pools (*Sayornis phoebe* Latham). However, most avian wetland specialists in the Northeast probably prefer other types of wetlands including swamps (e.g., *Wilsonia canadensis., Seiurus noveboracensis* L.; Miller 1999) or permanent ponds (*Podilymbus podiceps* L., *Rallus limicola* Vieillot; Ehrlich et al. 1988).

Finally, we need more information on the relationship between landscape composition and configuration and vertebrate diversity at seasonal forest pools. Several investigators have documented that harvested landscapes can affect dispersal of pond-breeding amphibians. deMaynadier and Hunter (1998, 1999) found that capture rates of wood frogs (*Rana sylvatica*) were negatively impacted by proximity to edge habitat between clearcuts and contiguous forest habitat. Guerry and Hunter (2002) found occupancy rates of seasonal pools for seven of nine species of amphibians in Maine were positively associated with forest area within 1-km of pools. Joyal et al. (2001), based on radio-telemetry research, documented that two rare species of turtles required large landscapes with a complex of small wetlands and large terrestrial buffers around wetlands to conserve the species. These types of studies on other taxa should be a top priority in other parts of the northeastern United States to gain a clearer understanding of the habitat requirements of vertebrates associated with seasonal forest pools.

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Appendix 1. Vertebrates in the northeastern United States that forage (F) or breed (B) in or near seasonal forest pools during at least one stage of their annual cycle.

Common name	Scientific name	Use
eastern spadefoot	*Scaphiopus holbrookii* Harlan	B
American toad	*Bufo americanus* Holbrook	B
Fowler's toad	*Bufo fowleri* Hickley	B
spring peeper	*Pseudacris crucifer* Wied-Neuwied	B
gray treefrog	*Hyla versicolor* LeConte	B
American bullfrog	*Rana catesbeiana* Shaw	F
green frog	*Rana clamitans* Latreille	B
mink frog	*Rana septentrionalis* Baird	F
wood frog	*Rana sylvatica* LeConte	B
northern leopard frog	*Rana pipiens* Schreber	B
pickerel frog	*Rana palustris* LeConte	B
western chorus frog	*Pseudacris triseriata* Wied-Neuwied	B

Appendix 1. Continued.

Common name	Scientific name	Use
marbled salamander	*Ambystoma opacum* Gravenhorst	B
Jefferson salamander	*Ambystoma jeffersonianum* Green	B
blue-spotted salamander	*Ambystoma laterale* Hallowell	B
spotted salamander	*Ambystoma maculatum* Shaw	B
red-spotted newt	*Notophthalumus viridescens* Rafinesque	B
four-toed salamander	*Hemidactylium scutatum* Schlegel	B
northern watersnake	*Nerodia sipedon* Linnaeus	F
red-bellied snake	*Storeria occiptomaculata* Storer	F
eastern gartersnake	*Thamnophis sirtalis* Linnaeus	F
eastern ribbonsnake	*Thamnophis sauritus* Linnaeus	F
ring-necked snake	*Diadophis punctatus* Linnaeus	F
eastern racer	*Coluber constrictor* Linnaeus	F
smooth greensnake	*Opheodrys vernalis* Harlan	F
milksnake	*Lompropeltis triangulum* Lacepede	F
northern copperhead	*Agkistrodon contortrix* Palisot de Beauvois	F
snapping turtle	*Chelydra serpentina* Linnaeus	F
spotted turtle	*Clemmys guttata S*chneider	F
bog turtle	*Clemmys muhlenbergii* Schoepff	F
wood turtle	*Clemmys insculpta* LeConte	F
painted turtle	*Chrysemys picta* Schneider	F
Blanding's turtle	*Emydoidea blandingii* Holbrook	F
Virginia opossum	*Didelphis virginiana* Kerr	F
little brown myotis	*Myotis lucifugus* (LeConte)	F
northern long-eared bat	*Myotis septentrionalis* (Trouessart)	F
Indiana myotis	*Myotis sodalis* Miller and Allen	F
eastern small-footed myotis	*Myotis leibii* (Audubon and Bachman)	F
silver-haired bat	*Lasionycteris noctigagans* (LeConte)	F
eastern pipistrelle	*Pipistrellus subflavus* (F. Cuvier)	F
big brown bat	*Eptesicus fuscus* (Palisort de Beauvois)	F
red bat	*Lasiurus borealis* (Muller)	F
hoary bat	*Lasiurus cinereus* (Beauvois)	F
masked shrew	*Sorex cinereus* Kerr	F
water shrew	*Sorex palustris* Richardson	F
smoky shrew	*Sorex fumeus* (Miller)	F
northern short-tailed shrew	*Blarina brevicauda* (Say)	F
star-nosed mole	*Condylura cristata* (Linnaeus)	F
eastern cottontail	*Sylvilagus floridanus* (Allen)	F
New England cottontail	*Sylvilagus transitionalis* (Bangs)	F
snowshoe hare	*Lepus americanus* Erxleben	F
eastern chipmunk	*Tamias striatus* (Linnaeus)	F
gray squirrel	*Sciurus carolinensis* Gmelin	F
red squirrel	*Tamiasciurus hudsonicus* (Erxleben)	F
beaver	*Castor canadensis* (Kuhl)	F
muskrat	*Ondatra zibethicus* (Linnaeus)	F
meadow jumping mouse	*Zapus hudsonius* (Zimmerman)	F
woodland jumping mouse	*Napaeozapus insignis* (Miller)	F
white-footed mouse	*Peromyscus leucopus* (Rafinesque)	F
southern red-backed vole	*Clethrionomys gapperi* (Vigors)	F
meadow vole	*Microtus pennsylvanicus* (Ord)	F
southern bog lemming	*Synaptomys cooperi* (Baird)	F
northern bog lemming	*Synaptomys borealis* (Richardson)	F
porcupine	*Erethizon dorsatum* (Linnaeus)	F
american marten	*Martes americana* (Turton)	F
fisher	*Martes pennanti* (Erxleben)	F
short-tailed weasel	*Mustela erminea* Linnaeus	F
long-tailed weasel	*Mustela frenata* Lichtenstein	F
mink	*Mustela vison* Schreber	F

Appendix 1. Continued.

Common name	Scientific name	Use
river otter	*Lontra canadensis* (Schreber)	F
coyote	*Canis latrans* Say	F
gray wolf	*Canis lupus* Linnaeus	F
red fox	*Vulpes vulpes* Linnaeus	F
gray fox	*Urocyon cinereoargenteus* (Schreber)	F
black bear	*Ursus americanus* (Pallas)	F
raccoon	*Procyon lotor* (Linnaeus)	F
striped skunk	*Mephitis mephitis* (Schreber)	F
lynx	*Lynx canadensis* Kerr	F
bobcat	*Lynx rufus* (Schreber)	F
white-tailed deer	*Odocoileus virginianus* Zimmerman	F
moose	*Alces alces* (Linnaeus)	F
great blue heron	*Ardea herodias* Linnaeus	F
green heron	*Butorides virescens* (Linnaeus)	F
turkey vulture	*Cathartes aura* (Linnaeus)	F
canada goose	*Branta canadensis* (Linnaeus)	F
wood duck	*Aix sponsa* (Linnaeus)	B
gadwall	*Anas strepera* Linnaeus	F
American wigeon	*Anas americana* Gmelin	F
American black duck	*Anas rubripes* Brewster	B
mallard	*Anas platyrhynchos* Linnaeus	F
blue-winged teal	*Anas discors* Linnaeus	F
northern shoveler	*Anas clypeata* Linnaeus	F
northern pintail	*Anas acuta* Linnaeus	F
green-winged teal	*Anas crecca* Linnaeus	F
hooded merganser	*Lophydytes cucullantus* (Linnaeus)	B
sharp-shinned hawk	*Accipter striatus* Vieillot	F
cooper's hawk	*Accipter cooperii* (Bonaparte)	F
northern goshawk	*Accipter gentilis* (Linnaeus)	F
red-shouldered hawk	*Buteo lineatus* (Gmelin)	F
broad-winged hawk	*Buteo platypterus* (Vieillot)	F
red-tailed hawk	*Buteo jamaicensis* (Gmelin)	F
ruffed grouse	*Bonasa umbellus* (Linnaeus)	F
wild turkey	*Melegris gallopavo* Linnaeus	F
king rail	*Rallus elegans* Audubon	F
virginia rail	*Rallus limicola* Vieillot	B
sora	*Prozana carolina* (Linnaeus)	B
American coot	*Fulica americana* Gmelin	F
spotted sandpiper	*Actitis macularia* (Linnaeus)	F
common snipe	*Gallinago gallinago* (Linnaeus)	B
American woodcock	*Scolopax minor* Gmelin	B
ring-billed gull	*Larus delawarensis* Ord	F
mourning dove	*Zenaida macroura* (Linnaeus)	F
great horned owl	*Bubo virginianus* (Gmelin)	F
northern saw-whet owl	*Aegolius acadicus* (Gmelin)	F
common nighthawk	*Chordeiles minor* (Forster)	F
whip-poor-will	*Caprimulgus vociderus* Wilson	F
chimney swift	*Chaetura pelagica* (Linnaeus)	F
belted kingfisher	*Ceryle alcyon* (Linnaeus)	F
red-bellied woodpecker	*Melanerpes carolinus* (Linnaeus)	F
yellow-bellied sapsucker	*Sphyrapicus varius* (Linnaeus)	F
downy woodpecker	*Picoides pubescens* (Linnaeus)	F
hairy woodpecker	*Piocoides villosus* (Linnaeus)	F
northern flicker	*Colaptes auratus* (Linnaeus)	F
pileated woodpecker	*Dryocopus pileatus* (Linnaeus)	F
olive-sided flycatcher	*Contopus cooperi* (Nuttall)	F
eastern wood-pewee	*Contopus virens* (Linnaeus)	F

Appendix 1. Continued.

Common name	Scientific name	Use
yellow-bellied flycatcher	*Empidonax flaviventris* (Baird and Baird)	F
acadian flycatcher	*Empidonax virescens* (Viellot)	F
alder flycatcher	*Empidonax alnorum* Brewster	F
willow flycatcher	*Empidonax trailii* (Audubon)	F
least flycatcher	*Empidonax minimus* (Baird and Baird)	F
eastern phoebe	*Sayornis phoebe* (Latham)	F
great crested flycatcher	*Myiarchus crinitus* (Linnaeus)	F
eastern kingbird	*Tyrannus tyrannus* (Linnaeus)	F
warbling vireo	*Vireo gilvus* (Vieillot)	F
red-eyed vireo	*Vireo olivaceus* (Linnaeus)	F
gray jay	*Perisoreus canadensis* (Linnaeus)	F
blue jay	*Cyanocitta cristata* (Linnaeus)	F
American crow	*Corvus brachyrhynchos* Brehm	F
fish crow	*Corvus ossifragus* Wilson	F
common raven	*Corvus corax* Linnaeus	F
purple martin	*Progne subis* (Linnaeus)	F
tree swallow	*Tachycineta bicolor* (Vieillot)	F
northern rough-winged swallow	*Stelgidopteryx serripennis* (Audubon)	F
bank swallow	*Riparia riparia* (Linnaeus)	F
cliff swallow	*Petrochelion pyrrhonata* Vieillot	F
barn swallow	*Hirundo rustica* Linnaeus	F
black-capped chickadee	*Poecila atricapilla* (Linnaeus)	F
tufted titmouse	*Baelophus bicolor* (Linnaeus)	F
white-breasted nuthatch	*Sitta carolinensis* Latham	F
carolina wren	*Thryothorus ludovicianus* (Latham)	F
sedge wren	*Cistothorus platensis* (Latham)	F
marsh wren	*Cistothorus palustris* (Wilson)	F
veery	*Catharus fuscescens* (Stephens)	F
wood thrush	*Hylocichla mustelina* (Gmelin)	F
American robin	*Turdus migratorius* Linnaeus	F
gray catbird	*Dumetella carolinensis* (Linnaeus)	F
European starling	*Sturnus vulgaris* Linnaeus	F
cedar waxwing	*Bombycilla cedrorum* Vieillot	F
tennessee warbler	*Vermivora pergrina* (Wilson)	F
nashville warbler	*Vermivora ruficapilla* (Wilson)	F
northern parula	*Parula americana* (Linnaeus)	F
yellow warbler	*Dendroica petechia* (Linnaeus)	F
yellow-rumped warbler	*Dendroica coronata* (Linnaeus)	F
palm warbler	*Dendroica palmarum* (Gmelin)	F
northern waterthrush	*Seiurus noveborecensis* (Gmelin)	F
common yellowthroat	*Geothlypis trichas* (Linnaeus)	F
hooded warbler	*Wilsonia citrina* (Boddaert)	F
wilson's warbler	*Wilsonia pusilla* (Wilson)	F
yellow-breasted chat	*Icteria virens* (Linnaeus)	F
eastern towhee	*Pipilo erythrophthalumus* (Linnaeus)	F
song sparrow	*Melospiza melodia* (Wilson)	F
swamp sparrow	*Melospiza georgiana* (Latham)	F
white-throated sparrow	*Zonotrichia albicollis* (Gmelin)	F
dark-eyed junco	*Junco hyemalis* (Linnaeus)	F
northern cardinal	*Cardinalis cardinalis* (Linnaeus)	F
red-winged blackbird	*Agelaius phoeniceus* (Linnaeus)	F
rusty blackbird	*Euphogus carolina* (Muller)	F
common grackle	*Quiscalus quiscula* (Linnaeus)	F
brown-headed cowbird	*Molothrus ater* (Boddaert)	F
American goldfinch	*Carduelis tristis* (Linnaeus)	F