Can Golf Courses Be Designed To Enhance Amphibian Movements To Breeding Sites?

1999 Annual Report

1 November 1999

Dr. Peter Paton
Assistant Professor
Department of Natural Resources Science
University of Rhode Island
Kingston RI 02881
(401) 874-2986
(401) 874-4561 (fax)
email: ppaton@uri.edu

ABSTRACT

Objectives:

1. Determine the pre-construction population size for amphibians breeding at ponds within the boundaries of a golf course being constructed and a proposed golf course (construction will start in August 2000)
2. Determine pre-construction travel corridors and movement patterns for amphibians at the proposed golf course site.
3. Quantify amphibian community structure in ponds at existing golf courses in southern New England.
4. Experimentally create potential travel corridors and determine if amphibians use them.

Amphibian movement chronology and community structure has been monitored at two ponds and the surrounding landscape within the boundaries of a proposed golf course on the Univ. of Rhode Island campus since mid-February 1998. A total of 13,131 amphibian captures representing 11 species were documented, with six species of reptiles (61 capture events) and 8 species of mammals (1,475 captures) also detected.

In 1998, we found that the young of some species (Green Frog, Pickerel Frog, Spotted Salamander, and Red-spotted Newt) dispersed in random directions across the landscape, while other species exhibited habitat selection and avoided edges between wooded habitat and a turf field (Wood Frog, Spring Peeper, Gray Tree Frog, American Toad). Movement data for metamorph amphibians (i.e., newly transformed young) gathered in 1999 generally supported the patterns observed in 1998. In addition, we did find that adults of some species readily moved across a 68 m wide turf field (Pickerel Frog, Green Frog), while adults from other species were rarely observed crossing this expanse of turf grass (Wood Frog, Spotted Salamander, Spring Peeper, Gray Tree Frog).

Experiments conducted in 1998 showed that amphibians preferred to move through wooded habitats rather than turf, and grass height did not affect frog movement patterns. Data collected in 1998 and 1999 investigating movement patterns of amphibians across the landscape generally verified this relationship, as species richness and abundance was much greater in a contiguous forest patch, than near the ecotone between woods and a turf field.

Surveys of 59 ponds at 32 golf courses in southern New England found that Green Frogs and Bullfrogs dominated most of the ponds (e.g., found in 73% of the ponds surveyed) at golf courses in the region. This is because these species prefer water bodies that are permanently flooded, as their young take 1-3 years to undergo metamorphosis and disperse from the pond. In contrast, the young of other species of pond-breeding frogs and salamanders only remain in the pond for less than 6 months, and their young are out competed by Green Frog and Bullfrog. A simple management solution may be to modify the hydrology of a pond to increase species richness.

During 1998 and 1999, baseline data were gathered at a pond used by a large number of breeding frogs and salamanders, which was adjacent to golf course under construction during the summer and fall of 1999. Ten species of amphibians visited this pond during 1998 and 1999, with breeding populations of Wood Frog (over 1000 breeding adults), Spotted Salamander (42 breeding adults), and Marbled Salamander (64 adults). We will continue to monitor this pond to determine what affect construction activities have on amphibian populations in the region.

Proposed research for 2000: Future funding for this research project during the 2000 field season will be used support three lines of investigations: (1) we will continue monitoring natural

movement patterns amphibians at the URI study site (as in 1999, this research will focus on adult movements to/from breeding sites, which was missed during the 1998 field season); (2) we will continue to quantify amphibian population size at a breeding pond adjacent to a golf course constructed in 1999, (3) we will conduct a series of experimental habitat manipulations at the proposed URI golf course to further refine our knowledge of habitat characteristics of amphibian movement corridors, including creating potential travel corridors in a contiguous forest patch near some breeding ponds.

INTRODUCTION

RESEARCH OBJECTIVES IN 1999

This report summarizes research conducted during the 1999 field season at the University of Rhode Island. One objective of the research focused on study was investigating the movement patterns of amphibians to/from breeding ponds, specifically investigating the potential effects of turf and edges on movement patterns. This research was initiated in 1998 (Paton 1999) and represents one of the longest running studies investigating this question on North America. This research took place on the proposed Kingston Reserve Golf Course on the University of Rhode Island campus. Therefore, these data will provide baseline information on pre-construction movement patterns and population size. This golf course is now slated to begin construction in August 2000. In addition, we surveyed ponds on golf courses throughout New England to begin to assess amphibian biodiversity on existing golf courses. Finally, we continued monitoring amphibian movements near Beaver River Country Club, which is a golf course under construction near the URI campus.

Specific research questions addressed by this study in 1999 included: (1) Do amphibians exhibit habitat preferences for movement corridors. More specifically, is there evidence that grass substrates represent a barrier to amphibian movements or do amphibians prefer forested areas over grassy areas for travelling?, (2) Is there any evidence that topographic features or habitat features affect amphibian dispersal from breeding ponds, (3) Is there random directional movement away from breeding ponds, or are movements non-random?, (4) What are pre-construction population sizes, community structure, and the relative abundance of amphibians at the proposed Kingston Reserve golf course?, (4) What is amphibian biodiversity on existing golf courses in southern New England, primarily focusing on courses in Rhode Island and Massachusetts, and (5) gather baseline data on amphibian community structure near the Beaver River Country Club, which initiated construction in May 1999. At the end of this report, I discuss plans for next year's fieldwork in 2000.

INTRODUCTION

Compared to other vertebrates, the populations of amphibians that breed in seasonal ponds fluctuate dramatically between years (Doty 1978, Gill 1978, Wilbur 1980, Taylor and Scott 1997, Semlitsch et al. 1996, Cortwright 1998). Amphibians have complex life cycles and their populations can be regulated by factors that affect any life stage (Wilbur 1972, 1980, 1984; Jackson et al. 1989; Petranka 1989; Berven 1990). Because these species breed at discrete spatial scales, it appears that source-sink population dynamics of local amphibian metapopulations typically sustain local populations over time (Gill 1978, Larson et al. 1984, Wilbur 1984, Berven and Grudzien 1990, Sjögren 1991, Gulve 1994, Taylor and Scott 1997). Therefore, potential barriers that impede movements of amphibians can have significant negative impacts on their populations and their genetic structure (Murphy 1963, Berven and Grudzien 1990, Reh and Seitz 1990, Taylor and Scott 1997, Semlitsch and Bodie 1998); adults tend to be extremely site faithful to their breeding ponds, while juveniles disperse among breeding sites (Wilbur 1980, 1984). In addition, their population dynamics are also regulated by the hydrological regime of a pond (Doty 1978, Semlitsch and Wilbur 1988, Pechmann et al. 1989, Berven 1990, Semlitsch et al. 1996). The larvae of some species require water in the pond for only part of the year (e.g., wood frogs *Rana sylvatica*, spotted salamanders *Ambystoma maculatum*) (Berven 1990, Windmiller 1996), while other species need to the pond to be flooded year-round since they take at least two years to undergo metamorphosis (e.g., bullfrog *Rana catesbeiana*) (Klemens 1993).

Ecologists have increased their research emphasis on amphibians with complex life histories that breed in seasonal ponds because of a number of recent extripations (Barinaga 1990, Blaustein and Wake 1990, Wake 1991, Pechmann et al. 1994, Blaustein et al. 1994, McCoy 1994). Yet, we still know surprisingly little amphibian long-term population dynamics (Pechmann et al. 1994, Semlitsch et al. 1996), habitat characteristics of breeding and wintering sites (Roberts and Lewin 1979, Gates and Thompson 1981, Laan and Verboom 1995, Rowe and Dunson 1995, Jarman 1995), habitat characteristics of movement corridors (Dodd and Cade 1998, Gibbs 1998, deMaynadier and Hunter 1998, Rosenberg et al. 1998), potential dispersal barriers (Berven and Grudzien 1990, Gibbs 1998), or the potential for restoration of extirpated populations. Few quantitative studies have monitored seasonal pond-associated amphibians for over 10 years to quantify long-term population trends (but see Pechmann et al. 1991, Taylor and Scott 1997, Semlitsch et al. 1996, Cortwright 1998); therefore strong empirical evidence showing severe population declines is limited. In southern New England, there is only one ongoing long-term amphibian monitoring program; R. Shoop and T. Doty (1978, unpubl. data) have quantified adult salamander populations in the spring and fall in one pond from 1970-1978 and 1993-1998 on the Alton Jones campus of the University of Rhode Island. This pond provides valuable baseline data to assess natural population fluctuations in southern New England. The Alton Jones campus is located on the one of the largest relatively undisturbed tracts of land in the state, as it is adjacent to the state-owned Arcadia Management Area of Rhode Island Department of Environmental Management.

Certain species of amphibians are obligate breeders in seasonal ponds, that is they require these temporary ecosystems for population persistence. There are at least six species of amphibians in southern New England which breed only in seasonal ponds, of which wood frogs (Berven 1990), gray tree frog (*Hyla versicolor*) and spotted salamander (Windmiller 1996) occur in Rhode Island (Klemens 1993). A fourth obligate species is found in Rhode Island, marbled salamander (*Ambystoma opacum*), but it breeds only in the fall (Taylor and Scott 1997). At least six other species are facultative breeders in seasonal ponds in Rhode Island (e.g., spring peeper *Pseudocris crucifer*, red-spotted newt *Notophtalmus viridescens*, green frog *R. clamitans*, bullfrog *R. catesbeiana*, pickerel frog *R. palustris*, and American toad *Bufo americanus* [Klemens 1993]).

Little research has been conducted on amphibian use of seasonal or permanent ponds in Rhode Island, with the exception of Whitford and Vinegar (1966) and Doty (1978). Research in Massachusetts and Connecticut gives insights into the ecology of species associated with these seasonal ecosystems in southern New England (e.g., Shoop 1965, 1974; Pierce and Harvey 1987; Jackson 1990; Klemens 1993; Jarman 1995; Windmiller 1996). Most studies have focused on the biotic and abiotic characteristics of breeding ponds (Gates and Thompson 1981, Jackson 1990, Jarman 1995, Rowe and Dunson 1995). However, few published studies, to my knowledge, have focused the characteristics of the terrestrial upland habitats used by amphibians during the winter months (but see Bellis 1965, Windmiller 1996, Semlitsch 1998). For example, spotted salamanders are fossorial and wood frogs hibernate under various types of substrates, making it difficult to determine habitat use patterns away from breeding ponds (Downs 1989, Kleeberger and Werner 1983, Windmiller 1996). Radioactively-tagged animals have been followed to a limited extent (Shoop 1965, Madison and Shoop 1970), and more recently radio transmitters have been used to follow salamanders (Windmiller 1996, Semlitsch 1998). Experiments suggest that spotted salamanders are capable of dispersing over 800 m from breeding sites (Whitford and Vinegar 1966, Shoop 1968, Gordon 1968). Dispersal studies of wood frogs suggest winter home ranges are usually small (e.g., 77 m^2; Bellis 1965), although some juveniles may move as far as 2.5 km from their hatching site to a subsequent breeding pond (Berven 1990, Berven and Grudzien 1990). A recent meta-analysis by Semlitsch (1998) suggests that a buffer zone extending 165 m from the wetland edge would protect 95% of most amphibian populations.

Although both wood frogs and spotted salamanders are still widely distributed throughout southern New England, both species have disappeared from a number of urban areas (Klemens 1993, Jarman 1995, Windmiller 1996). Reasons for these localized population declines are uncertain, but are probably related to loss of habitat (Petranka 1994, Gibbs 1998), exotic species introductions (Bradford et al. 1993, Drost and Fellers 1996), disease (Laurance et al. 1996), increased automobile mortalities (Van Gelder 1973, Mader 1984), and the toxic effects of pollutants on local populations (Vertucci and Corn 1996). Both wood frog and spotted salamanders eggs and larvae are known to be adversely affected by low pH, high metal concentrations, and dissolved organic carbon (Gascon and Planas 1986, Pierce and Harvey 1987, Jackson 1990). The impact of mortalities from automobiles on both species is unknown; that is, it is uncertain whether or not automobile deaths result in additive or compensatory mortality. Road mortalities of wood frogs can have significant impacts on populations in certain areas (Fahrig et al. 1995); tunnels have been built in Massachusetts to allow safe passage of spotted salamanders to their breeding ponds (Jackson and Tyning 1989).

If concerted efforts are initiated to maintain all components of biological diversity in southern New England, including amphibians associated with seasonal ponds, then more needs to be learned about the effects of human-altered landscapes on amphibian populations. Windmiller (1996) quantified the effects of habitat fragmentation on the movements of spotted salamanders near Boston, and found that forest patch size, homogeneity, and forest habitat characteristics within 300 m of breeding ponds were the most significant determinants of breeding population size. Southern New England is facing increasing urbanization pressure, which results in fewer agricultural areas, and more roads, residential areas, and golf courses. Little is known about impacts of these types of habitat conversions on amphibian populations (see Hobbs 1992, Jarman 1995). Recent work by Windmiller (1996), Gibbs (1998) and DeMaynadier and Hunter (1998) suggest that amphibian movements are sensitive to habitat fragmentation, and certain habitats may act as dispersal barriers to amphibians. However, the exact impacts of specific human-altered landscapes are uncertain.

STUDY AREA AND METHODS

We studied amphibian movement patterns at a complex of seven ponds in North Woods north of the University of Rhode Island Kingston campus. Ponds were of varying sizes in a 4.5 ha section of the area at the northern edge of the proposed Kingston's Reserve Golf Course (Fig. 1). These seven ponds were bordered on the east by extensive forested woodlands (primarily Red Maple and various oaks), and to the west by 80 m of forest and then 68 m wide turf field. Two of the smaller ponds in the complex (hereafter named Trench and Gene's Truck, Fig. 1) were encircled with drift fence/pitfalls (0.5 m tall silt fencing with 2 #10 coffee cans taped together for traps) to monitor the pre-construction population dynamics of amphibians in the area (Gibbons and Semlitsch 1982, Dodd and Scott 1994). In 1999, these ponds were monitored daily (i.e., Trench [16 total traps]: 21 Feb- 30 Sept; and Gene's Truck [24 total traps]: 21 Feb – 30 Sept; Table 1) to determine amphibian community structure, population size, and fecundity. Each individual captured received a unique toe-clip representing their original capture location, so that movements of animals could be monitored (Hero 1989). Gray Tree Frogs and Spring Peepers were not toe-clipped since they are arboreal species, and toe-clipping would affect their tree climbing abilities. Data presented in this annual report include captures up to 20 August.

Is there random directional movement away from breeding ponds, or are movements seemingly non-random? Also, is there any evidence that topographic features or habitat features affect amphibian dispersal from breeding ponds?

We monitored natural movements of adult, juvenile, and metamorphosing amphibians (i.e., newly transformed) out of two small ponds the study area. This area is scheduled to be converted into a golf course in August 2000. Ponds were completely encircled in 0.5 m silt fence, with pitfalls (i.e., two #10 coffee cans buried flush with the ground) located every 25' on the inside and outside of the pond perimeter. In addition, we placed a straight-line ~500' drift fence/pitfalls (32 total pitfall traps) 100 m to the east of the pond complex in mixed forest woodland (hereafter referred to as Woods array, which was run from 23 Jan – 30 Sept, with 32 total pitfall traps [16 on inside and 16 on outside]; Fig. 1a), and ~600' of drift fence 100 m to the west of pond at the ecotone of the woods and turf grass plot complex (hereafter known at Field array: run from 10 Feb – 30 Sept, with 38 total pitfall traps, Fig. 1; Table 1). We also surveyed a third straight-line array on the west side of a 175 m wide turf field, next to the Amtrak national railroad corridor, run from 10 Mar – 30 Sept (Railroad array). This latter array was put in place to assess the effects of a wide turf field and another type of potential barrier (the train track corridor) on amphibian movements. We monitored natural movement patterns of amphibians to/away from ponds using these two arrays, with arrays checked every morning starting at 06:00 AM. Unmarked animals captured at Woods and Field received a unique toe clip (individuals all received the same toe clip that was unique each year) so their movements across the landscape could be monitored. Data presented in this annual report include captures up to 20 August.

We also used a silt fence to monitor movements of amphibians at the southwestern corner of the junction of Beaver River Road and Route 138 (Figure 1b). The array was originally established in 1997 as part of another study supported by the URI Agricultural Experimental Station. This array was closed in November 1998 and re-opened in May 1999. We re-opened this array because the land was acquired over the winter and construction initiated on a golf course approximately 150 m west of the array. Therefore, we thought this would be unique opportunity to assess the potential impact of golf course construction on pond-breeding amphibians. Because it was not re-opened until May, we missed quantifying adults population sizes for Wood Frog and Spotted Salamander, however we were able to measure metamorph productivity for both species in 1999.

To quantify amphibian community structure at ponds on golf courses in southern England (Rhode Island, Massachusetts, and Connecticut), we sampled 59 ponds at 28 golf courses and 1 commercial turf field (Table 3). Based on conversations with superintendents at each course, we attempted to sample every available pond at each course. A crew of 2-3 biologists would sample each pond by dip-netting for tadpoles and salamander larvae. All samples were collected during daylight hours from 06:00 – 15:00, with most samples collected early in the morning. Each pond was sampled with 30 sweeps of a 0.5 m diameter, small mesh dip-net. Data collected at each pond included estimates of size (length and width in meters), depth, vegetation characteristics at each pond, and distance from pond edge to the nearest woods.

RESULTS

Amphibian use of seasonal ponds

A total of 14,667 animal captures were recorded at pond arrays (13,131 amphibians, 89.5% of captures; 1,475 mammals, 10.0% of captures; and 61 reptiles, 0.4% of captures; Figure 2; both mammals and reptiles will be discussed in greater detail below). Capture rates were much greater in the Woods array (32.35 amphibians per 100 trap nights) compared to the Field array (22.02 per 100 trap nights) (Figure 3). Comparisons between Woods versus Field will be discussed in much greater detail below, as those two arrays are the focus of the rest of this section. Capture rates were significantly lower in the Railroad array compared to either Woods or Field, with only 0.96 animals per 100 trap nights. This suggests that both the Amtrak Railroad tracks and large expanses of turf (over 150 m) can be significant barriers to amphibians moving across the landscape.

As is typical in New England (Klemens 1993), movement of adult amphibians exhibits a bimodal pattern (Figure 4). During spring (March through early June), and again in the fall (September through October), adults, both frogs and salamanders, tend to be the dominant life stage moving across the landscape. However, during the summer (June through August), metamorphs that have recently transformed and are emigrating from breeding ponds to winter habitat are the most abundant life stage that we captured in our traps. This pattern holds true for virtually all species we monitored in North Woods.

Are movements to/away from breeding ponds random or non-random?

One of the primary questions that conservation biologists are investigating is the effect of anthropogenic habitat manipulation on animal populations. For amphibian populations, if wintering habitat is lost near a breeding site, how does the loss affect movement patterns? One might assume that metamorphs movement patterns would be random once they leave the pond, that is equal numbers of individuals would radiate out in all directions from the breeding site in all directions. However, in 1998 we found that some species exhibited non-random dispersal (Paton 1999). In 1999, drift fences remained in the same locations as 1998 to determine if dispersal patterns remained consistent between years

Selected Species accounts

A total of 11 species of amphibians have been captured in pitfall traps in North Woods over the past two years. This represents most species that could potentially breed in ponds in southern New England (species missing included Marbled, Jefferson and Blue-spotted Salamanders, Eastern Spadefoot and Fowler's Toad; both Jefferson and Blue-spotted have never been documented in Rhode Island). Based on field research in 1998 (Paton 1999), we found that several species (Green Frog, Pickerel Frog, and Spotted Salamander) apparently emigrated from breeding ponds at random directions. In contrast, American Toads, Gray Tree Frogs, Spring Peeper, Wood Frogs, and Red-spotted Newts exhibited habitat preferences, as they had a higher probability of being captured in the Woods array compared to the Field array. We continued this research in 1999 to determine if similar patterns held true in a subsequent year.

Wood Frog: In 1998, 24.2 times more metamorphs were captured in Woods compared to Field, while in 1999 the pattern was virtually identical with 24.3 times more individuals captured in the Woods arrays (Figure 5). This suggests that metamorph Wood Frogs are radiating out non-randomly from breeding ponds across the landscape. Adult Wood Frogs were also much more likely to immigrate across wooded habitats rather than turf, as well as emigrate through contiguous habitat rather than across an ecotone (Figure 6). These data show that Wood Frogs appear to be sensitive to habitat fragmentation.

Spotted Salamander: In 1998, there was little difference in capture rates of metamorphs between Woods and Field. The pattern was similar in 1999, although (1) many fewer metamorphs were produced in 1999 due to a severe drought (Figure 7), so few animals were captured, (2) about twice as many metamorphs were captured in Woods compared to Field, although this difference was not statistically different due to low capture rates. We initiated research too late (May) in 1998 to quantify immigration rates of adult Spotted Salamander or Wood Frogs, but were able in 1999 to measure adult movements across the landscape. Although metamorphs did not appear to be sensitive to fragmentation, adult spotted salamanders did exhibit non-random movements as none immigrated across turf fields, while they readily moved across contiguous forested habitat (Figure 8). These results suggest that metamorphs movements are not affected by landscape context, however movements of adults is more habitat specific. In addition, it is more likely that there is suitable wintering habitat for adults to the east of the breeding ponds than to the west, which is another reason why more adults immigrated through the Woods array.

Pickerel Frogs: In 1998, we found no difference in capture rates of emigrating animals between Woods and Field (Figure 9). However in 1999, metamorph capture rates were actually 2.6 times greater at the Field array than at the Woods array. Adult Pickerel Frogs were one of the few species that did immigrate towards breeding ponds by moving across a large expanse of turf (68 m wide), but capture rates were 4.6 times higher in the forested habitat (Figure 10). These results suggest that both adults and metamorphs can move through fragmented landscapes. More wintering habitat for this species probably exists to the east of breeding ponds, but some adults were apparently capable of overwintering to the west of the ponds.

Green Frog: In 1998, capture rates of metamorphs were equivalent in Woods and Field arrays. In 1999, more metamorphs were likely to be captured in the Woods array (Figure 11), although capture rates were much lower in 1999, which was due to the drought. Adult Green Frogs were one of the only species whose movements did not appear to be affected by landscape context (Figure 12). Adult capture rates of immigrating animals were similar in both Woods and Field arrays.

American Toad: In 1998, we were surprised to find that capture rates of metamorph toads were much greater in the Woods array than the Field Array (Figure 13). We believed beforehand that toads should be capable of moving across a gradient of landscapes and therefore capture rates should be equivalent between Woods and Field. In 1999, we also found capture rates were greater, 3.3 times, in the Woods array compared to Field. This suggests that metamorphs of this species are sensitive to habitat fragmentation.

Red-spotted Newt: Although previous researchers have suggested that this species will avoid edges (Gibbs 1998), our research in 1998 found more metamorph newts were captured at the Field array (Figure 14). Unfortunately, there was apparently little production by newts in 1999, presumably due to the severe drought, and only 4 metamorphs were captured in 1999 (Figure 14). Therefore, there was little data to determine if patterns were similar in 1999. In addition, there was little movement of adults in 1999 (Figure 15), making verification of patterns observed in

1998 virtually impossible. During 1998, adults were more likely to be captured in the Woods when immigrating to the ponds, while emigrating animals were more likely to be captured at the Field array. These results suggest that this species is not as sensitive to habitat fragmentation as Gibbs (1998) suggests, and they will move across fragmented landscapes.

Summary of amphibian movements across the North Woods landscape: Based on two years data, capture rates were twice as great in contiguous forested habitat (40.4 animals per 100 traps nights; Woods array) compared to an ecotone between a turf field and deciduous forested habitat (22.2 animals per 100 trap nights; Field array) (Figure 15). A total of 11 species have been captured in arrays in North Woods. Five species (Red-spotted Newt, Pickerel Frog, Green Frog, Four-toed Salamander, and Bullfrog) have similar capture rates in both Woods and Field arrays. Therefore, golf course superintendents might expect to have the species moving across fairways without specific habitat manipulation. In contrast, other species (Wood Frog, Spring Peeper, Red-backed Salamander, Gray Treefrog, American Toad) appear to be sensitive to habitat fragmentation and superintendents might have to manipulate habitat to encourage these species to move across fragmented landscapes such as golf courses. These results generally concur with field research conducted in 1998 (Paton 1999).

Reptile movements in North Woods:

Reptiles were relatively uncommon in North Woods, with only 61 captures over two years. We captured a total of 6 species, with movements primarily confined to April through August and some movements into October (Figure 16). Captures rates were generally too low to compare movements across the landscape at Woods versus Field arrays.

Mammalian movements in North Woods:

Ten species of small mammals were captured during fieldwork in 1998 and 1999 (Figure 17). Capture rates were slightly higher in the Woods array compared to the Field arrays, although this difference was not as great as documented for amphibians. Three species had similar capture rates in the Woods and Field arrays (Short-tailed Shrew, Star-nosed Mole, and Jumping Mouse), while the other species had different capture rates between the two arrays. The only two species with enough captures to suggest differences in habitat use patterns were (1) Meadow Vole, with a higher capture rate at the Field array, which would be expected because they prefer open, grassy habitats, and (2) masked shrew, which were captured more often in contiguous forested habitat at the Woods array.

Small mammals were active from February through December, with the highest capture rates during the summer from June through August (Figure 18).

Monitoring the effects of golf course construction on pond-breeding amphibians:

The data presented in Table 2 represent baseline information on amphibian community structure prior to golf course construction at Beaver River CC, Rhode Island. Because there was such a severe drought in 1999 in Rhode Island, productivity was low at this array in 1999 (Table 2). For example, only 90 metamorph toads were found in 1999, compared to over 1100 in 1998. No Spotted Salamander young were produced at this pond in 1999, while 19 Marbled Salamander metamorphs left the pond in 1999. Only 32 Wood Frog young were produced from this pond, compared to 254 in 1998. The potential impacts of golf course construction will not be realized until next field season. However, we did note far fewer adult Marbled Salamanders emigrated to this pond in 1999 compared to 1998 (5 vs. 64, respectively), although this could have been due in part to the severe drought experienced in 1999.

Surveys of Golf Courses

We surveyed 59 ponds at 32 golf courses during the summer of 1999, of which 78% (46 of 59) had amphibians detected (Table 3). The vast majority of ponds (73%) either had Bullfrog (56%) or Green Frog (53%) tadpoles (Figure 19). Pickerel frogs were much less common, as they were detected in only 10% of ponds surveyed, American Toads were only in one pond on the Beaver River Country Club, Rhode Island, under construction (this pond had fish in it), and Spotted Salamander larvae were found in only 1 pond sampled at Laurel Lane Golf Course in Rhode Island.

These results are not surprising since most ponds tend to be permanent water bodies (have water year-round) as many are primarily irrigation reservoirs. Both Bullfrogs and Green Frogs have tadpoles that have to overwinter before undergoing metamorphosis, therefore they tend to be found in permanent bodies of water. In contrast, Wood Frogs, Spring Peeper, Gray Tree Frog, and Spotted Salamander young transform within 6 months of hatching, and consequently only need ponds with fluctuating water levels to survive.

DISCUSSION

Surveys of golf courses throughout southern New England show that amphibians will use ponds on golf courses. However, species richness at golf course ponds is relatively low compared what could potentially breed at these sites (Klemens 1993). Species that are typically found in seasonally-flooded ponds (e.g., Wood Frogs, Spotted and Marbled Salamander, Spring Peeper, Gray Treefrog). This is because ponds on golf courses often are permanently flooded because they often provide irrigation water for the course. Ponds that always have water provide ideal habitat for species whose larvae have to overwinter 1-3 years before undergoing metamorphosis (e.g., Bullfrog and Green Frog). This is why 73% of the ponds we surveyed on golf courses throughout the region either had Bullfrog or Green Frog tadpoles. Bullfrog tadpoles can be voracious predators and can out compete the young of other pond-breeding amphibians (e.g., Wood Frog; Klemens 1993). One potential management strategy for superintendents to increase amphibian species richness at golf course ponds is to modify the hydrology of ponds. If ponds were to be drained completely every year, in the early fall (mid-September-early November), that would eliminate Bullfrog/Green Frog production from the pond and allow other species (Spring Peeper, Wood Frog, Spotted Salamander, Gray Treefrog) the opportunity to successfully breed in the pond. This latter management strategy assumes that other pond-breeding species exist near the pond to be managed, and will readily disperse to the pond.

Research conducted over the past 1.5 years suggests that some species will be less affected by the habitat fragmentation that occurs at golf courses (e.g., fairways interspersed among forest patches), while others species tend to be relatively sensitive to habitat fragmentation. We found that adult Green Frogs and Pickerel Frogs will travel across a 68 m (220') wide turf field, suggesting that most fairways do not present a travel barrier for these species. Yet, adults of other species (e.g., Spotted Salamander and Wood Frog) were not captured attempting to cross the turf field, suggesting that a 68-m wide corridor of grass can be a barrier for some pond-breeding amphibians. On the other hand, a 175-m (560') wide turf field apparently impeded virtually all amphibian movements, as we found few organisms crossing such a large expanse of turf. In fact, captures rates were at least 20 times lower in the Railroad array compared to the Field or Woods array. The proximity of the national railroad corridor also presented a substantial travel barrier to amphibians attempting to head east from Hundred Acre Pond, which is another reason why few species or individuals were captured at the Railroad array.

Experiments conducted in 1998 found that grass height (0.25 to 1 inch tall) had little affect on amphibian movement, as frog did not select or avoid any grass height (Paton 1999). In 1998, we did find that frogs were much more likely to seek forest/shrub cover, rather than travel in open grass areas when given the opportunity. This is probably why capture rates were about 2 times greater in the Woods array compare to the Field array. This pattern was observed consistently in both 1998 and 1999 on the proposed Kingston Reserve Golf Course at URI (Figure 1a). This suggests that golf course superintendents interested in maximizing amphibian species diversity on golf courses should (a) maximize forest/shrub cover at the edge of fairways, (b) minimize fairway widths, (c) provide shrub/forest cover to potential amphibian breeding ponds. This latter recommendation will be the focus of experimental research during field research in 2000 near URI. We will manipulate forested habitats to determine if amphibians will readily use forested/shrub habitats for travel corridors.

Our results have consistently shown over 1998 and 1999 emigration and immigration movements of both adults and young amphibians to breeding ponds appears to be non-random, at least for certain species. This result suggests the possibility that amphibians have the potential to adapt to habitat manipulations such as golf course construction. As I stated in last year's annual report (Paton 1999), it is important to point out that the North Woods study site only 25 years ago was a landfill for the town of South Kingston. In fact, the area is currently an EPA Superfund Site. Therefore, the ponds in the area, such at Trench and Gene's Truck Pond, are artificial wetlands that obviously have been colonized by a broad array of amphibians (see Table 1). This shows that restoration efforts, such as golf course designs, have a great deal of potential to become effective in enhancing wildlife populations such as amphibians.

Data gathered by the Beaver River Country Club, where construction was initiated in May 1999, will provide useful empirical information on the effects of golf course construction on amphibian populations. During the 2000 field season, we will begin to assess what impacts, if any, the construction had. If there were impacts, they would be on wintering individuals, therefore we might expected significant declines in population abundance. However, amphibian populations can vary dramatically among years (Pechmann et al. 1994, Semlitsch et al. 1996), therefore it might be difficult to tease apart direct affects of the construction. We also are gathering baseline information on the relative abundance, movement patterns, and community structure on the proposed Kingston Reserve Golf Course, which should give us remarkable insights into the impacts of golf course construction on amphibian populations.

FUTURE RESEARCH

In 2000, this research project will be used support three types of investigations

First, we will continue monitoring natural movement patterns amphibians at the proposed URI study site. Data gathered in 1998 and 1999 suggest relatively consistent patterns, with some species and age classes sensitive to habitat fragmentation, while others were not. However, data gathered during 1999 was hampered by a severe drought, therefore productivity was relatively low because ponds dried earlier than in most years. We hope to document greater productivity at breeding ponds in 2000 to gather more information on dispersal patterns of metamorphs and adults across this fragmented landscape. We will also initiate a fourth straightline drift fence array to the north of the ponds in old-field habitat, something that logistical constraints did not allow us to do in 1998.

Second, during the winter of 1999/2000, we are proposing to conduct a series of small scale clear-cuts to create a number of potential travel corridors. Forest cutting will take place to the east of breeding ponds adjacent to the Woods arrays. This is an area where substantial amphibian movements have been documented in 1998 and 1999. Cutting will be designed to create potential travel corridor ~5 to 25 m wide. Amphibian movements will be monitored daily throughout the year to determine if they are used by amphibians, or if habitat characteristics do not affect movements. Pitfall traps at both fences will be situated to determine if animals prefer to move in areas with a dense understory or in areas with no understory. This research was proposed for 1999 (Paton 1999), but due to uncertainties with golf course construction, we were unable to implement this phase of the research. The political climate has changed and it is almost certain the golf course will be constructed on this land now, therefore we can go forward with these habitat manipulations.

Experiments conducted during 1998 found that most frogs probably prefer to travel in forested corridors compared to grass habitats. This suggests that amphibians would prefer to cross a narrow corridor of grass compared to wider corridor. However, we know of no research that has investigated the effects of corridor width on movements. East of the Woods array is a dirt road in the forest that parallels the Wood array and is approximately 200 m east of the pond complex. Based on capture rates in Woods, large numbers of amphibians probably cross this road. We propose to place a drift fence array on the west side of the road. The gap in the forest canopy caused by this road varies from 5-20 m. We propose to remove the understory and overstory along sections of this road, then monitor movements of adult amphibians across the road to see if width of the open corridor affects movement patterns. Pitfall cans and the drift fence array will be strategically placed to determine where amphibians crossed the opening.

Third, we will continue to monitor amphibian community structure in a breeding pond near the Beaver River Country Club, which initiated construction in May 1999. This research, coupled with baseline data gathered near URI, should give superintendents and engineers/planners interested in building golf courses useful information design criteria for golf courses.

ACKNOWLEDGEMENTS

Fieldwork during the 1999 field season was primarily conducted by Kelly Radcliffe, Chris Monti, Eileen LaRosa, and Erik Endrulat. This research would not have taken place without their dedicated assistance. We also thank all the golf course superintendents who graciously allowed on their golf courses, assisted the crew with finding ponds to survey, and lent the crew golf carts for the day to conduct their research; their assistance was vital. Finally, we thank the superintendent, Ray Grandchamp, and owners of the Beaver River Club for assistance with conducting research on their property.

Budget for the 2000 field season

Budget line item	Cost
I. Clearcut habitat at proposed Kingston Reserve Golf Course to create potential travel cooridors.	
	$1,800
II. Monitoring amphibian movements in North Woods (natural movements and experimental arrays) 15 Feb to 1 Oct:	
1 technicians (5hr/day X $10/hr X 228 days X 7.65% (FICA)	$12,272
Supplies (field equipment/rental [silt fence, fence installation equipment rental, pitfall cans])	$1,000
III. Monitor array at Beaver River Country Club under construction	
1 technicians (2 hr/day X $10/hr X 228 day X 7.65% FICA)	$4,560
Mileage to Beaver River ($.31/mile X 12 miles/day X 228 days)	$848
PI summer salary	$1,000.00
Total Direct Costs (TDC)	**$21,480**
Indirect Costs (16% TDC)	**$3,437**
Total Costs	**$24,917**

Table 1. Summary of sampling effort in North Woods

	1998				1999			
	Start	Stop	Days	Trapnights	Start	Stop	Days	Trapnights
Woods	21 May	17 Dec	210	6300	23 Jan	20 Aug	209	6525
Field	28 May	17 Dec	203	7105	10 Feb	20 Aug	191	4986
Railroad	26 Jun	31 Oct	129	3612	10 Mar	20 Aug	163	2934
G. Truck	15 Feb	31 Oct	258	4128	21 Feb	20 Aug	180	4680
Trench	28 Mar	31 Oct	217	5642	21 Feb	20 Aug	180	2880
Total				26,787				22,005

Table 2. Summary of vertebrates captured at Beaver River array in 1998 and 1999.

	1998				1999			
SPECIES	Adult	Juvenile	Metamorph	Total	Adult	Juvenile	Metamorph	Total
Amphibians								
Am. Toad	41	58	1195	1294	3	27	90	120
Green Frog	10	10	321	341	2	30	234	266
Bullfrog	2	15	4	21				
Pickerel Frog	5		57	62			18	18
Wood Frog	1481	16	254	1751	4	9	32	45
Spring Peeper	9		1	10	1			1
Four-toed Salamander	1			1				
Marbled Salamander	64	3	57	124	5	5	19	29
Spotted Salamander	42	1	49	92				
Red-backed Salamander	157	20	13	190	27	13		40
Reptiles								
N. Water Snake		1		1				
Garter Snake	2	1		3	2	5		7
Ribbon Snake		1		1	1			1
Ring-necked Snake	1			1				
Painted Turtle	2			2		1		1
Small mammals								
Red-backed Vole	1			1	19			19
Jumping Mouse	6		1	7				
Star-nosed Mole	5		1	6	1			1
Masked Shrew	30	9	4	44	10			10
Short-tailed Shrew	96		14	110	85	1		86
Water Shrew					2			2
Meadow Vole	22		2	24	86		1	87

Table 3. Summary of amphibians detected at golf courses in southern New England: + = present.

COURSE	POND NAME	Species					
		Am. Toad	Bullfrog	Green Frog	Rana spp.	Pickerel Frog	Spotted Salamander
ALLENDALE CC	#12		+	+		+	
	IRRIG POND		+	+			
BALLYMEADE CC	EAST POND		+				
	WEST POND		+	+			
BEAVER RIVER CC	VET	+	+	+			
BOULDER HILLS	#8		+	+			
	Clubhouse pond			+			
CC OF NEW BEDFORD	POND		+				
DEDHAM CC	#7/8		+				
EAST GREENWICH CC	#5			+			
	#8						
FALL RIVER CC	#1						
	#3						
GLOCESTER	POND		+	+		+	
HIDDEN HOLLOW CC	#1		+				
	#6		+				
LAUREL LANE	#11		+	+	+		+
	#13		+	+			
	#6		+	+	+		
LEDGMONT	IRRIGATION POND		+				
MELODY HILL	POND		+	+		+	
MIDVILLE CC	POND						
MISQUAMICUT CLUB	#11		+		+		
	#13				+		
	#14		+	+	+		
	#16						
MONTAUP CC	#6			+			
	#14						
NEWPORT CC	#1						
PAWTUCKET CC	DUCKWEED POND		+	+		+	
	CLUBHOUSE POND						
PEQUABUCK GC	#1			+			
	#2		+	+			

COURSE	POND NAME	Am. Toad	Bullfrog	Green Frog	Rana spp.	Pickerel Frog	Spotted Salamander
POTAWAMUT CC	NORTH POND		+	+			
	SOUTH POND		+				
PT. JUDITH CC	#16			+			
	#17		+				
	D		+	+			
RHODE ISLAND CC	BIG ECHO			+			
	LITTLE ECHO			+			
SEGREGANSETT	B/W HOLES 4+5			+			
	DRAINAGE POND		+	+			
THE ALPINE CC	POND			+		+	
THORNEY LEA	#1		+	+			
	#3		+	+			
	#5						
TITLEIST AND FOOTJOY WORLDWI	POND		+	+			
TUCKAHOE TURF FARMS	CHARIHO HS POND		+	+			
VALLEY CC	B/W HOLES 17+12					+	
	#14						
WANNAMOISETT CC	#1		+				
WARWICK CC	NO RR Ties Pond			+			
	1/4 RR Ties						
WAUNTAUP CC (Agawam Hunt)	NE		+	+			
	Fountain						
	SE						
WIDOW'S WALK GC	#17		+				
	#4		+				

Figure 1a. Kingston Reserve study site on URI campus.

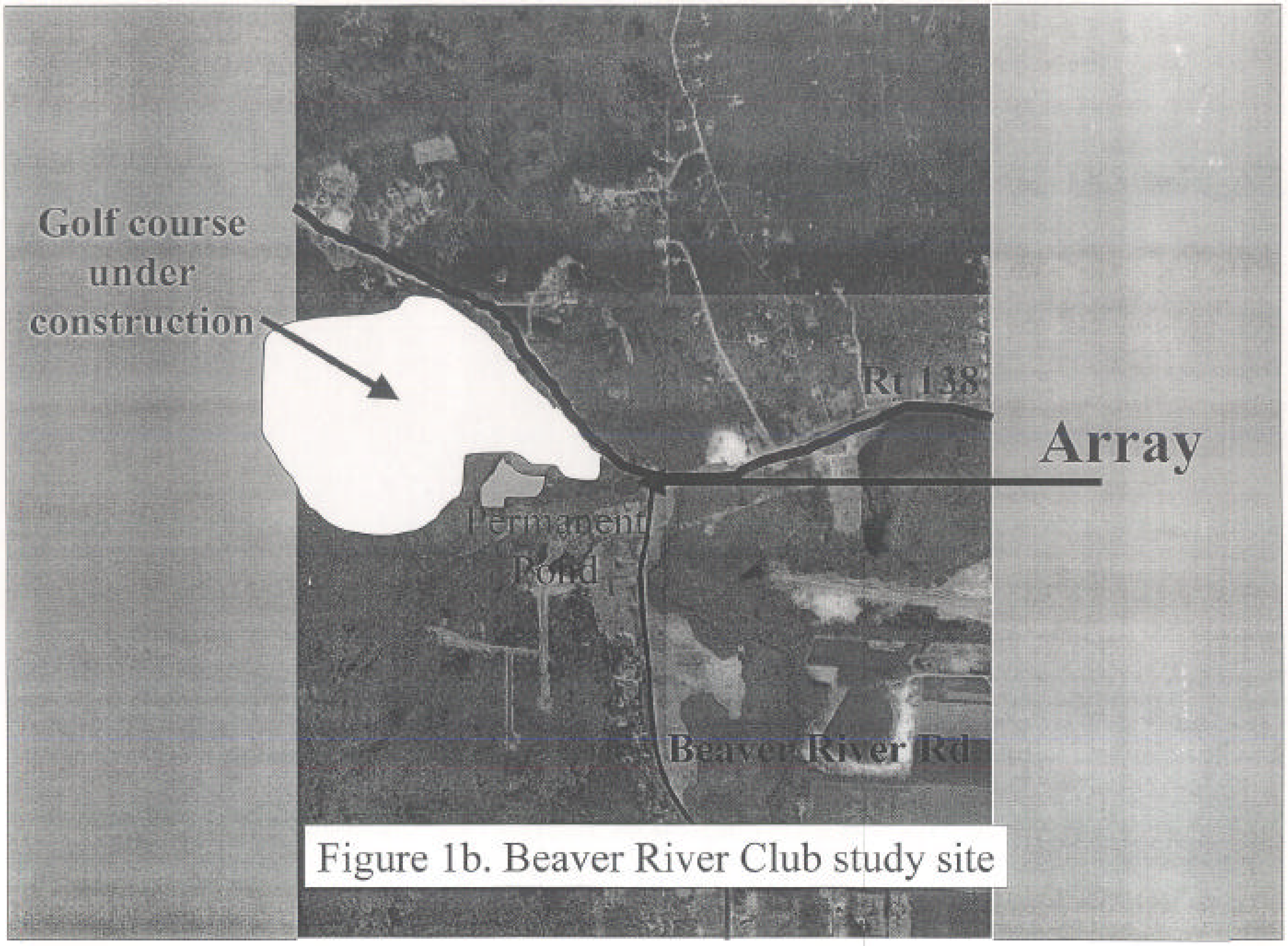

Figure 1b. Beaver River Club study site

Figure 2. Total number of animals captured in 1998 & 1999 in North Woods

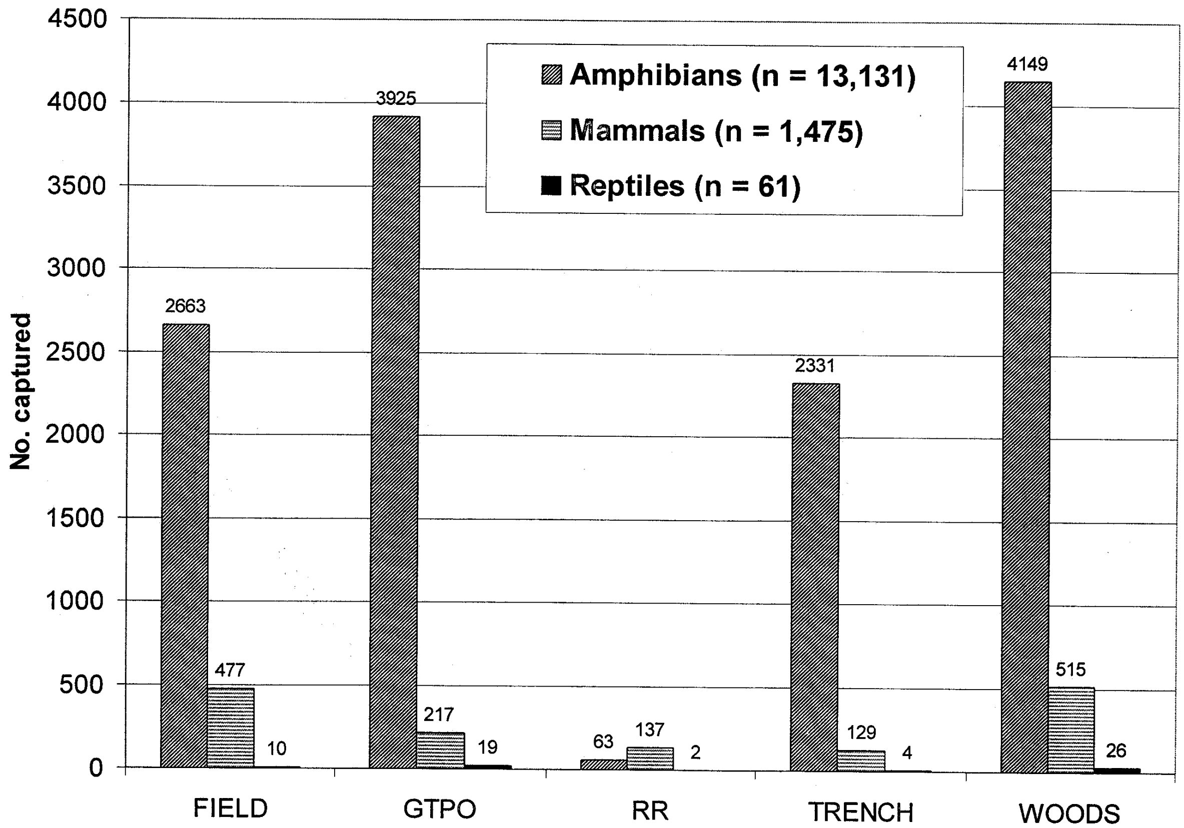

Figure 3. Amphibian capture rates in North Woods, based on 1998 & 1999 captures.

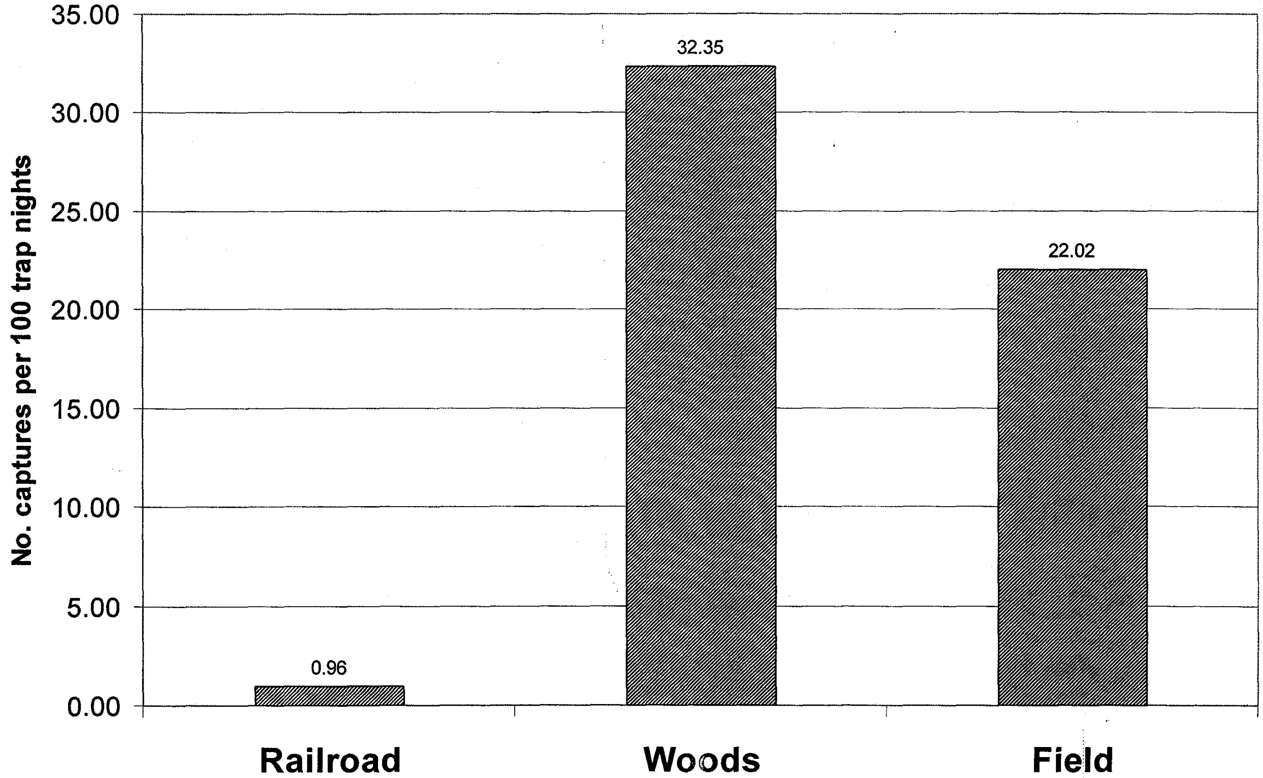

Figure 4. Movement chronology of adult and metamorph amphibians captured in North Woods in 1998 & 1999

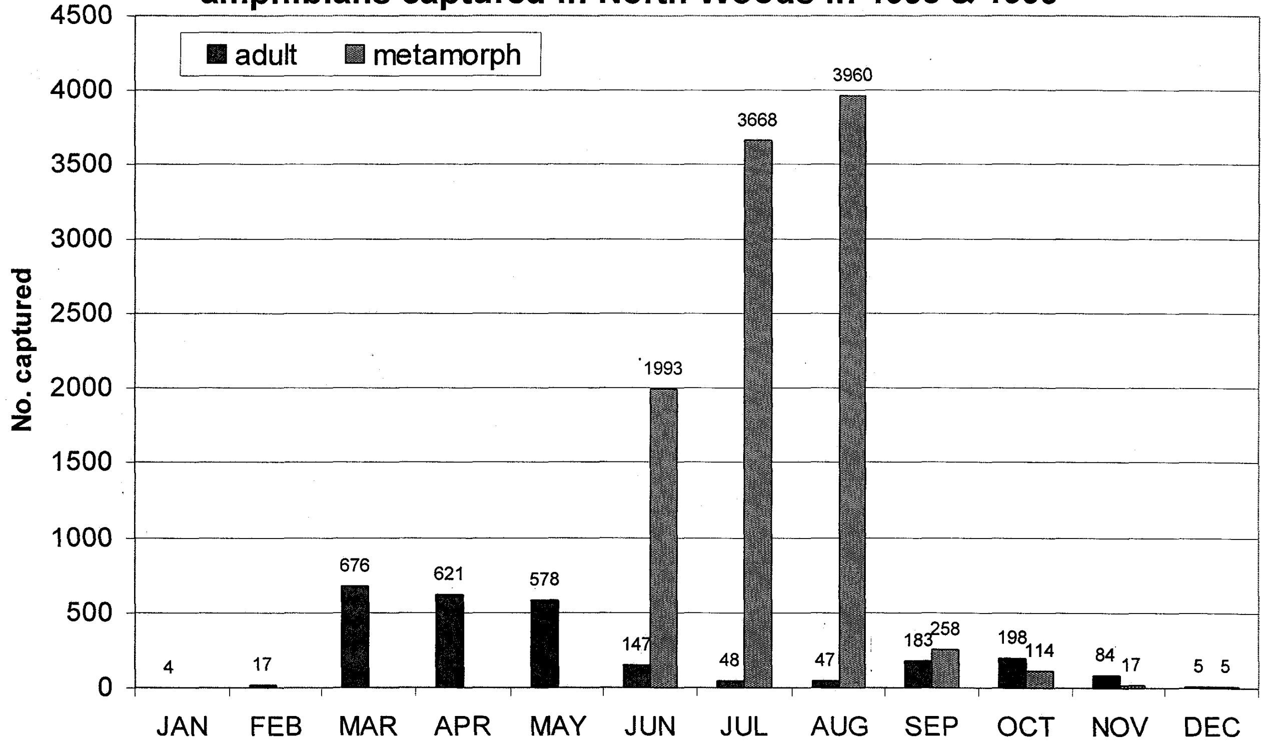

Figure 5. Wood Frog metamorph captures emigrating from breeding ponds

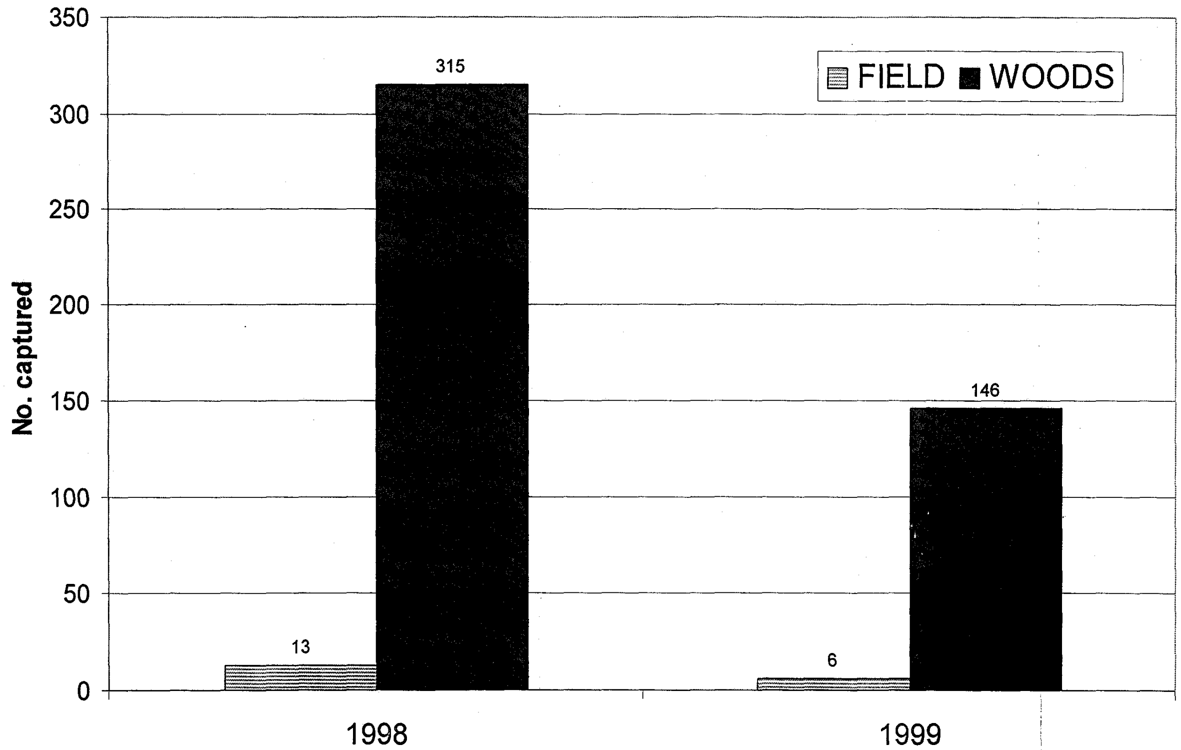

Figure 6. Summary of adult Wood Frog captures immigrating (Outside) and emigrating (inside) from breeding ponds in North Woods.

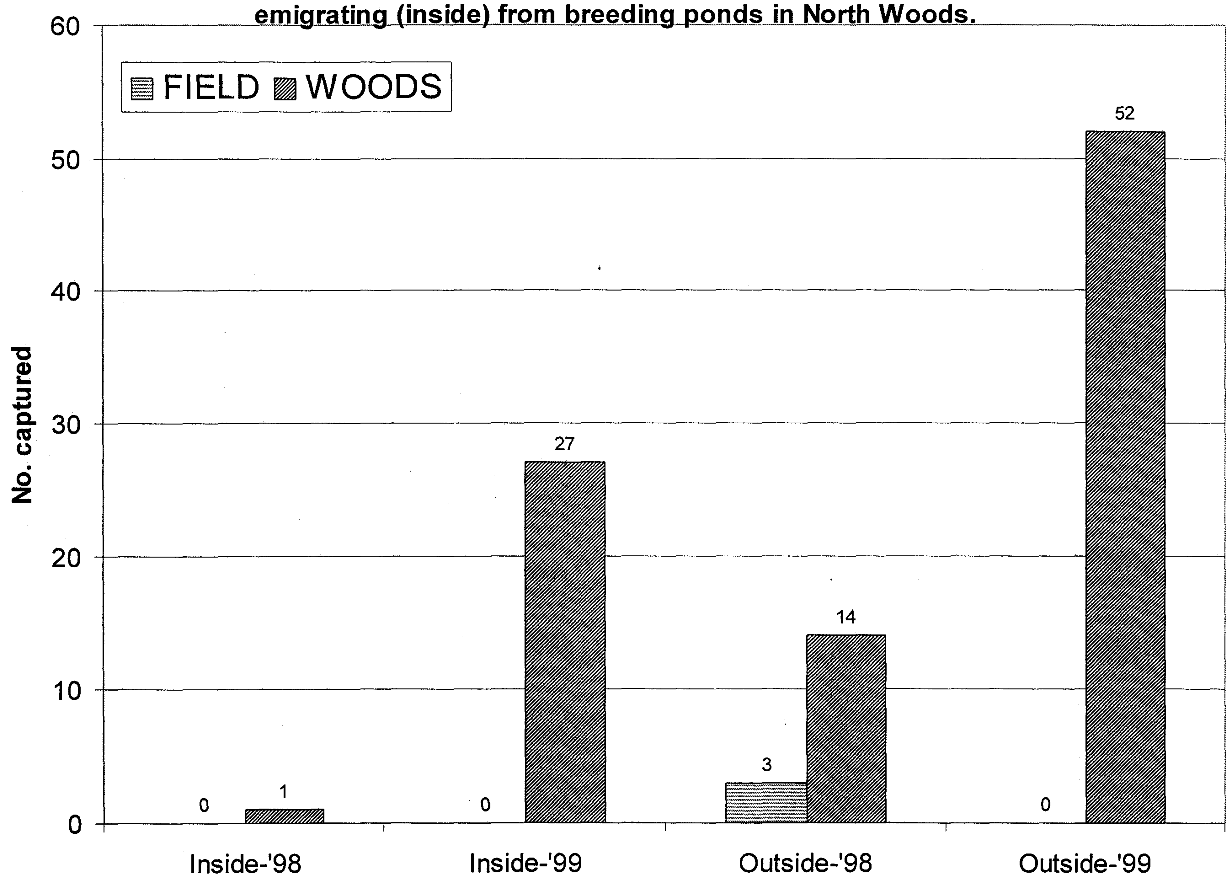

Figure 7. Summary of metamoph Spotted Salamander movements emigrating from breeding ponds in North Woods.

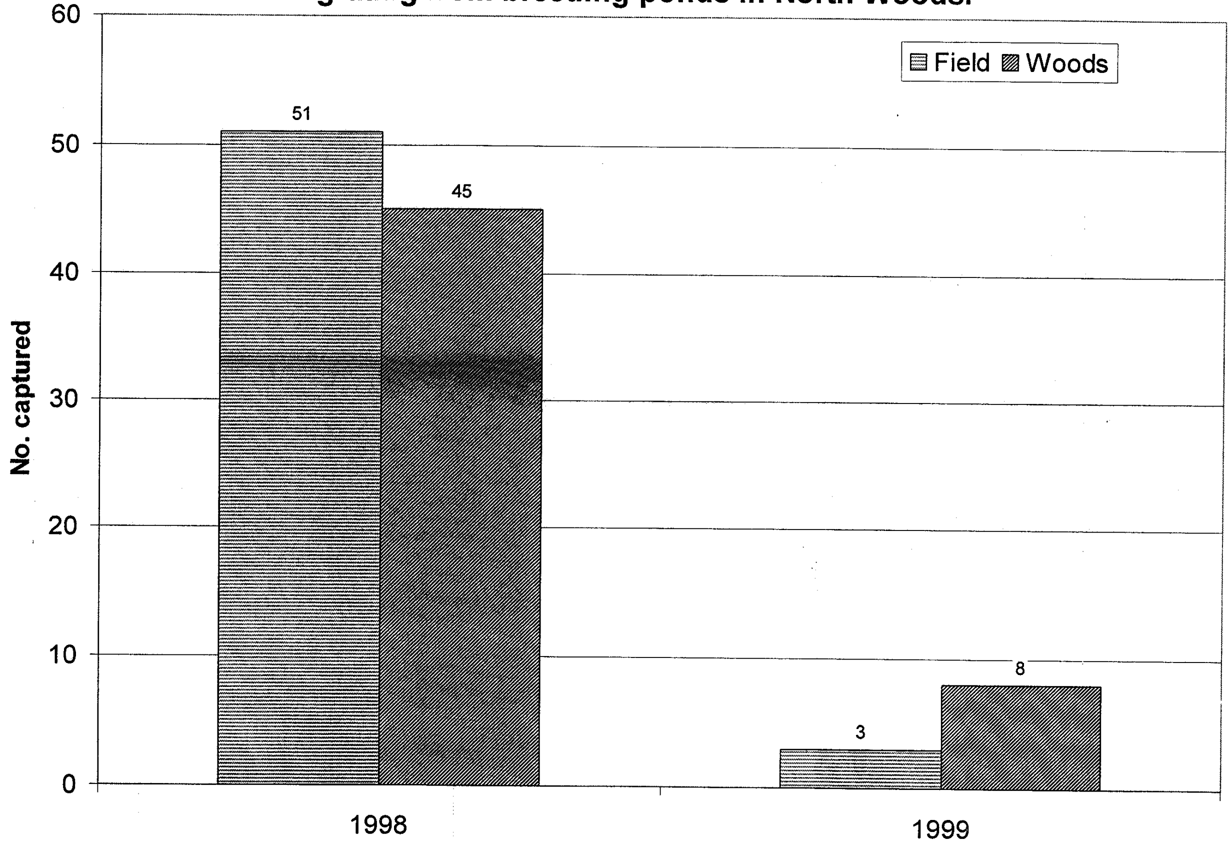

Figure 8. Summary of adult Spotted Salamander movements immigrating (outside) and emigration (inside) from breeding ponds in North Woods.

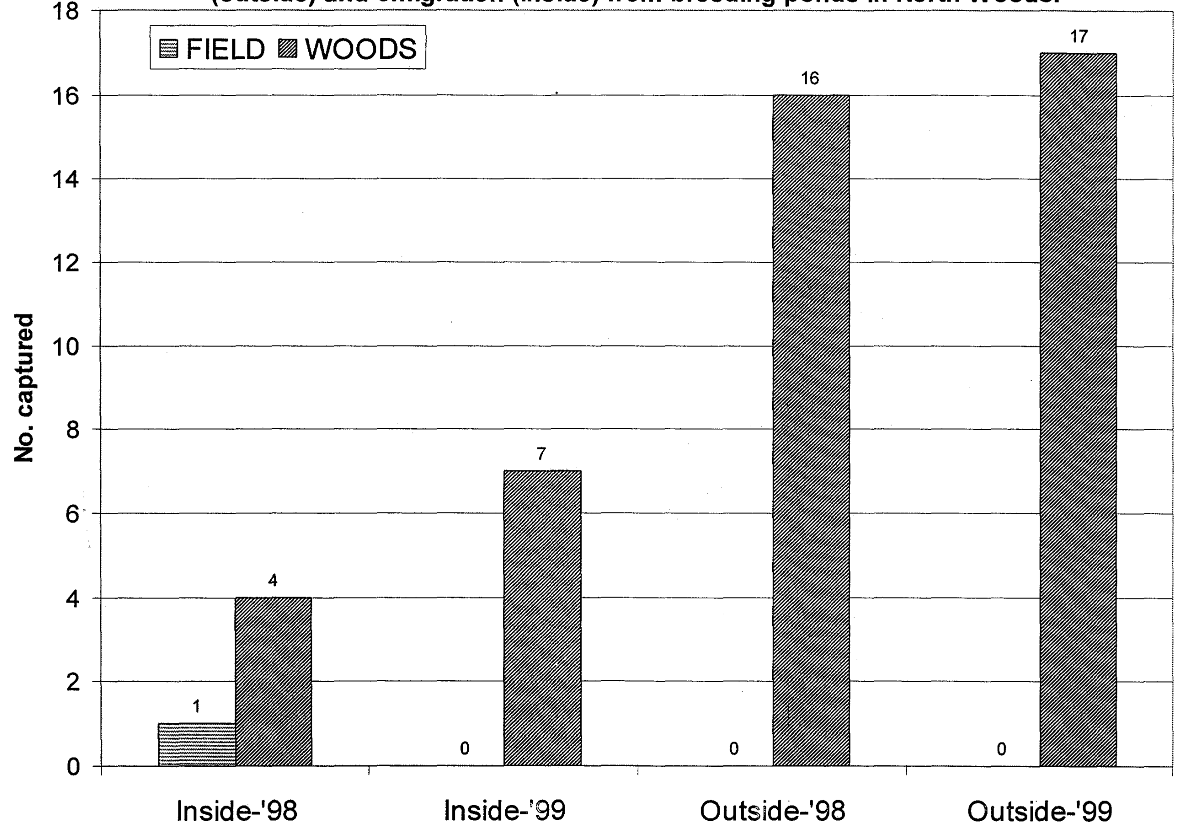

Figure 9. Summary of metamorph Pickerel Frog movements emigrating from breeding ponds

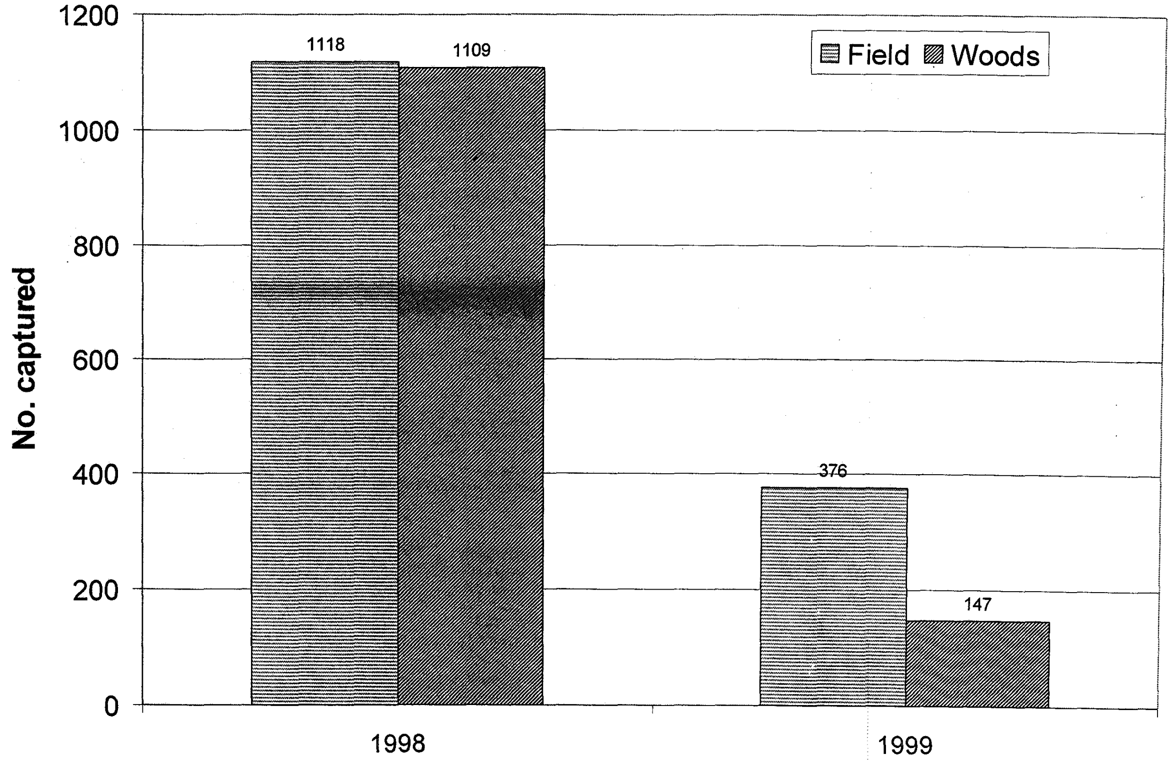

Figure 10. Summary of adult Pickerel Frog movements immigrating (outside) and emigrating (inside) from breeding ponds in North Woods.

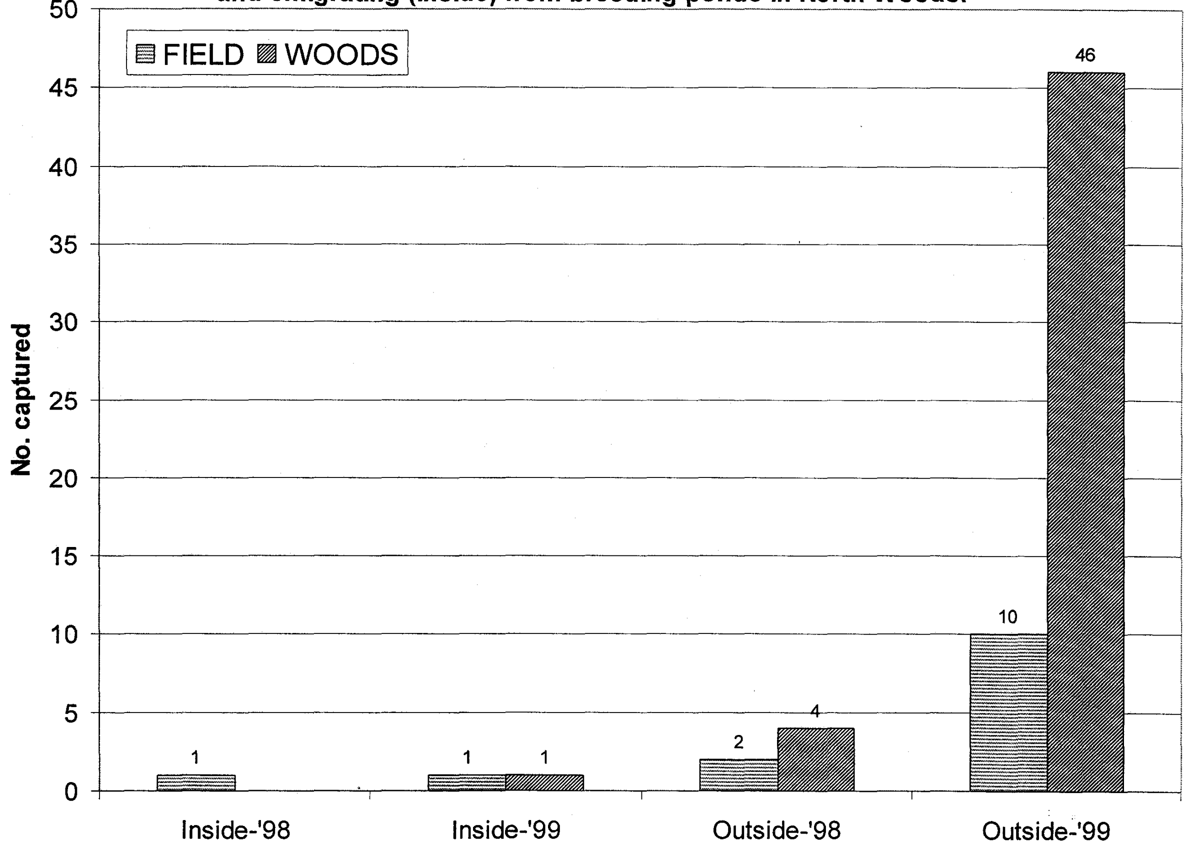

Figure 11. Summary of metamorph Green Frog movements emigrating from ponds

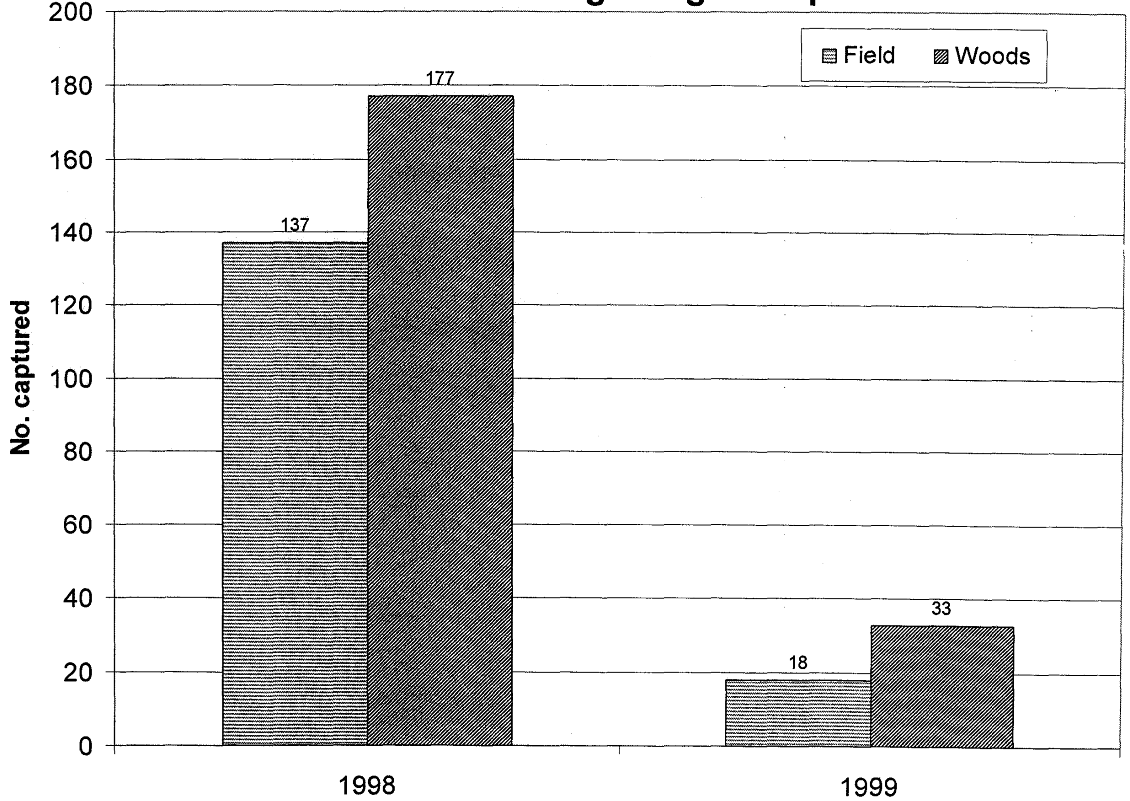

Figure 12. Summary of adult Green Frog movements immigrating (outside) and emigrating (inside) from breeding ponds in North Woods.

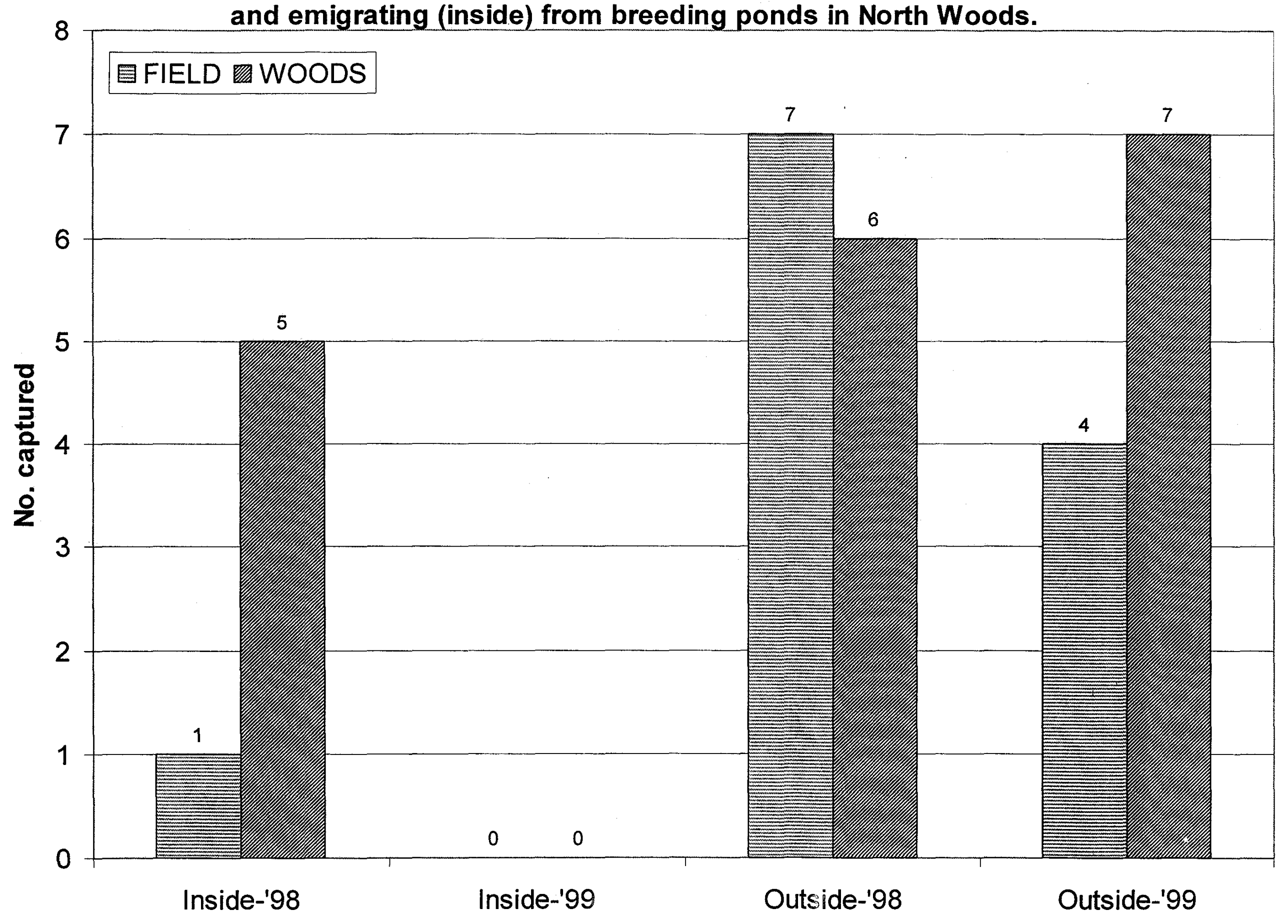

Figure 13. Summary of metamorph American Toad emigration from breeding ponds.

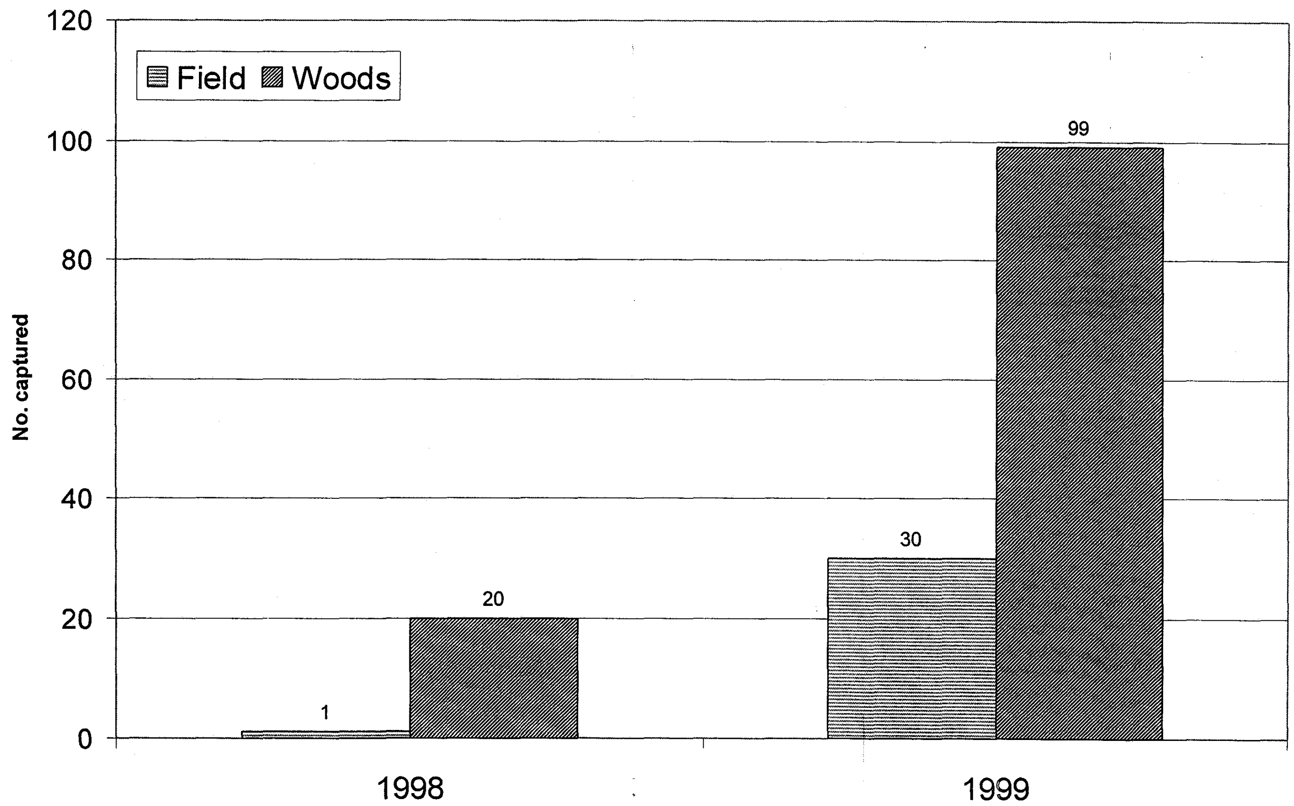

Figure 14. Summary of metamorph Red-spotted Newt emigration from breeding ponds

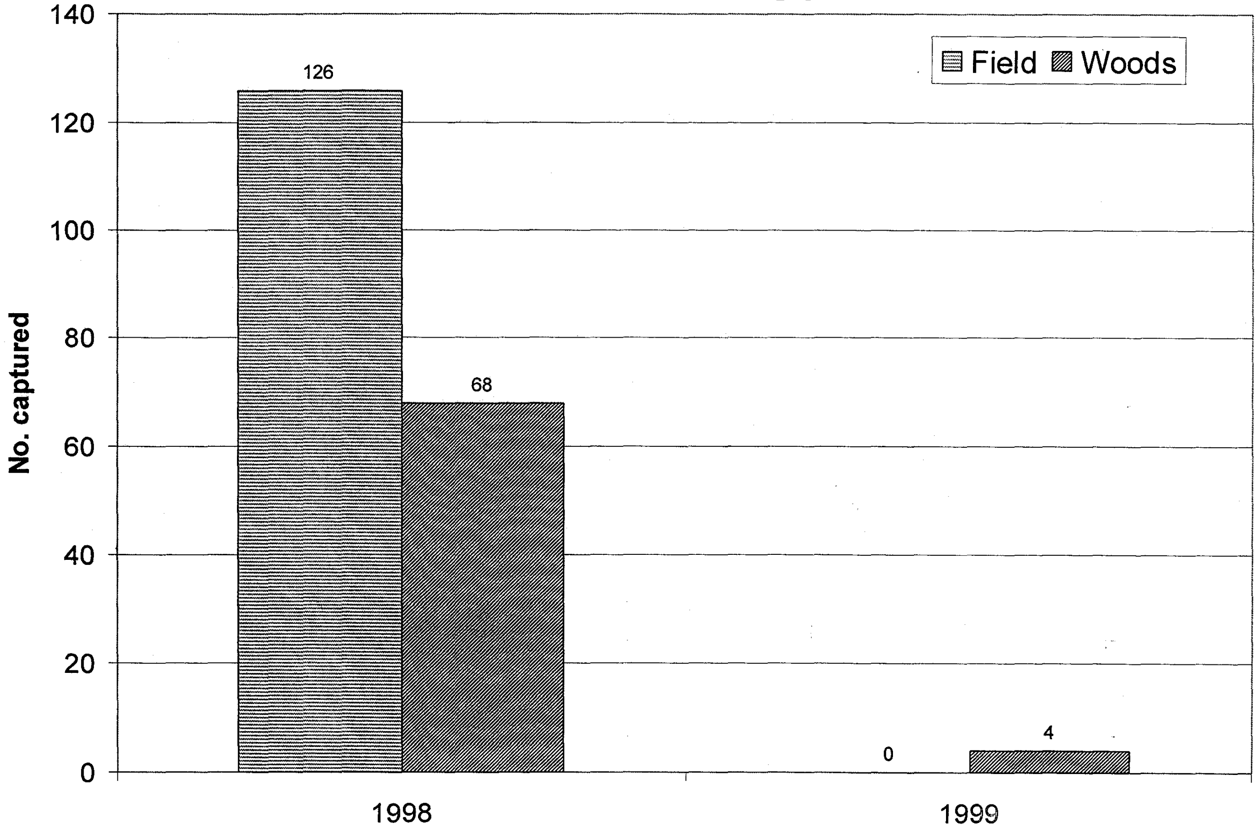

Figure 15. Summary of "eft" Red-spotted Newt immigrating (outside) and emigrating (inside) from breeding ponds in North Woods.

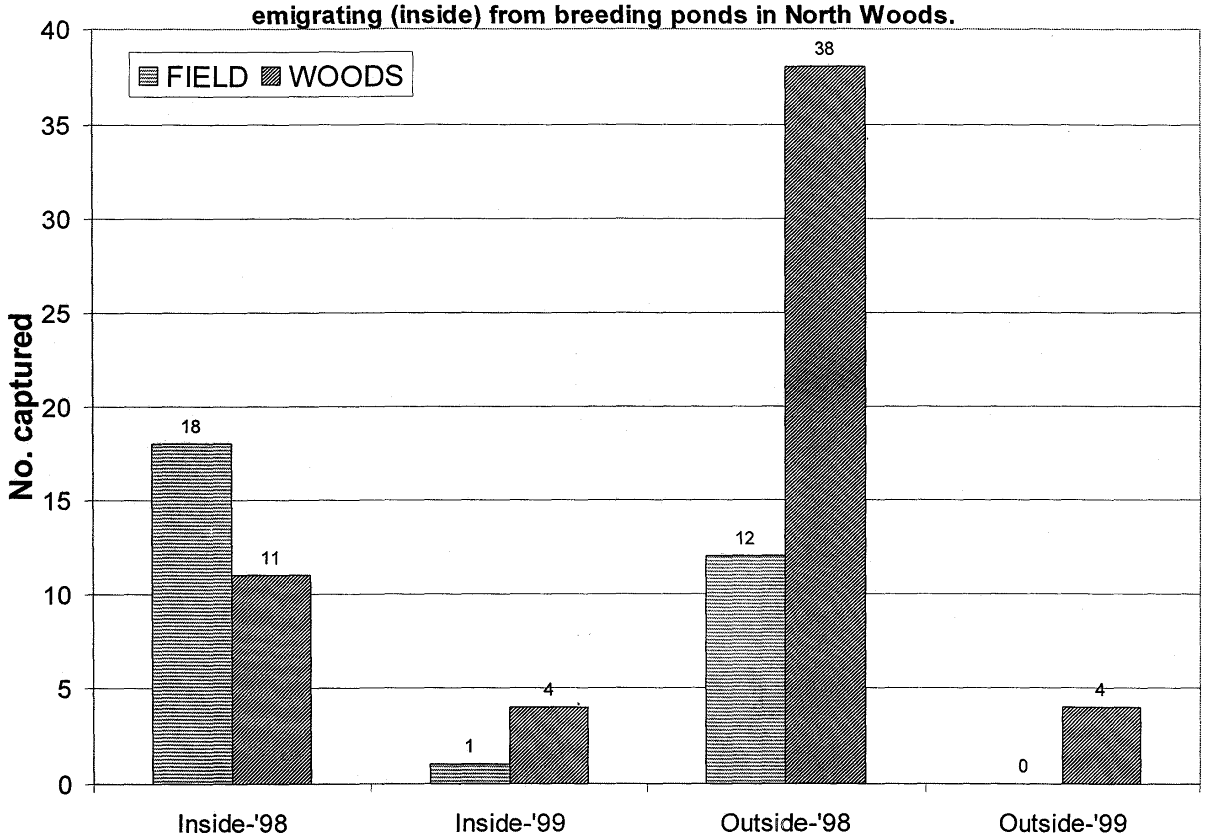

Figure 15. Summary of amphibian capture rates in Woods versus Field arrays.

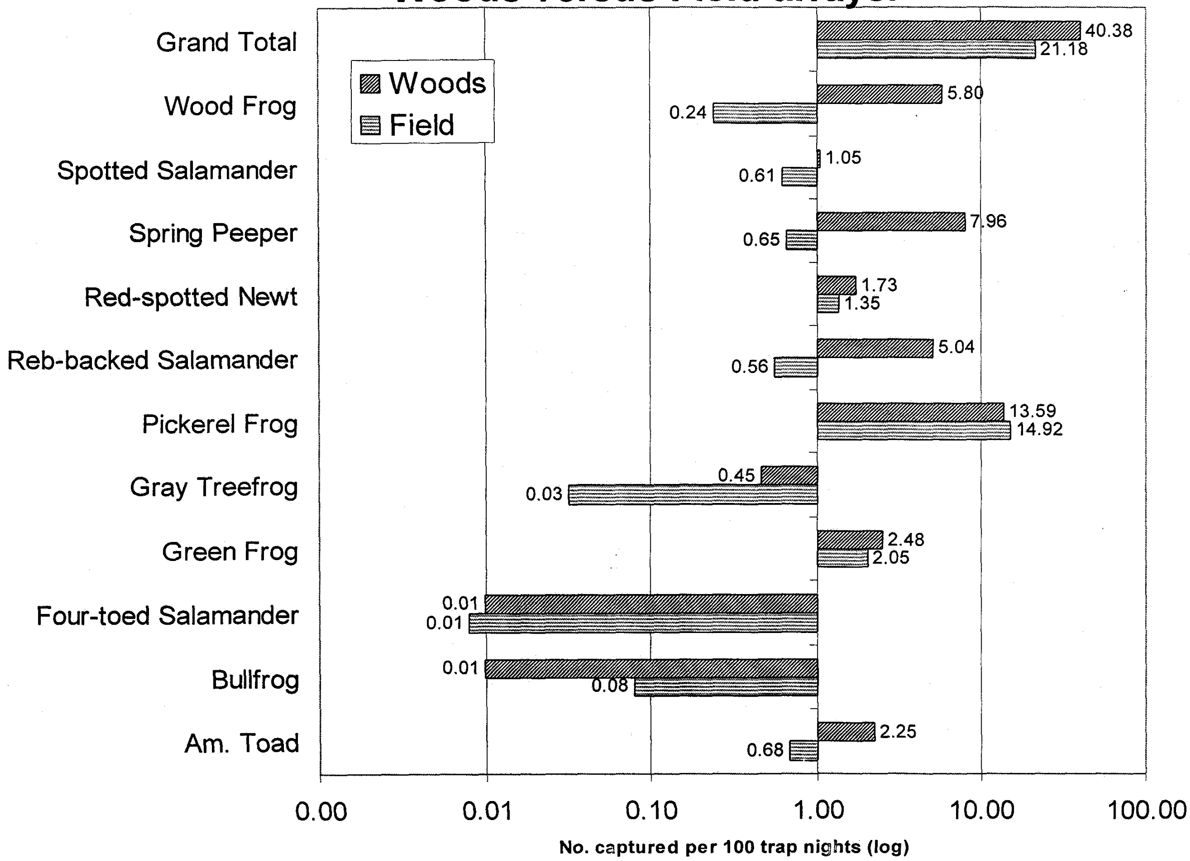

Figure 16. Summary of reptiles movement chronology in North Woods

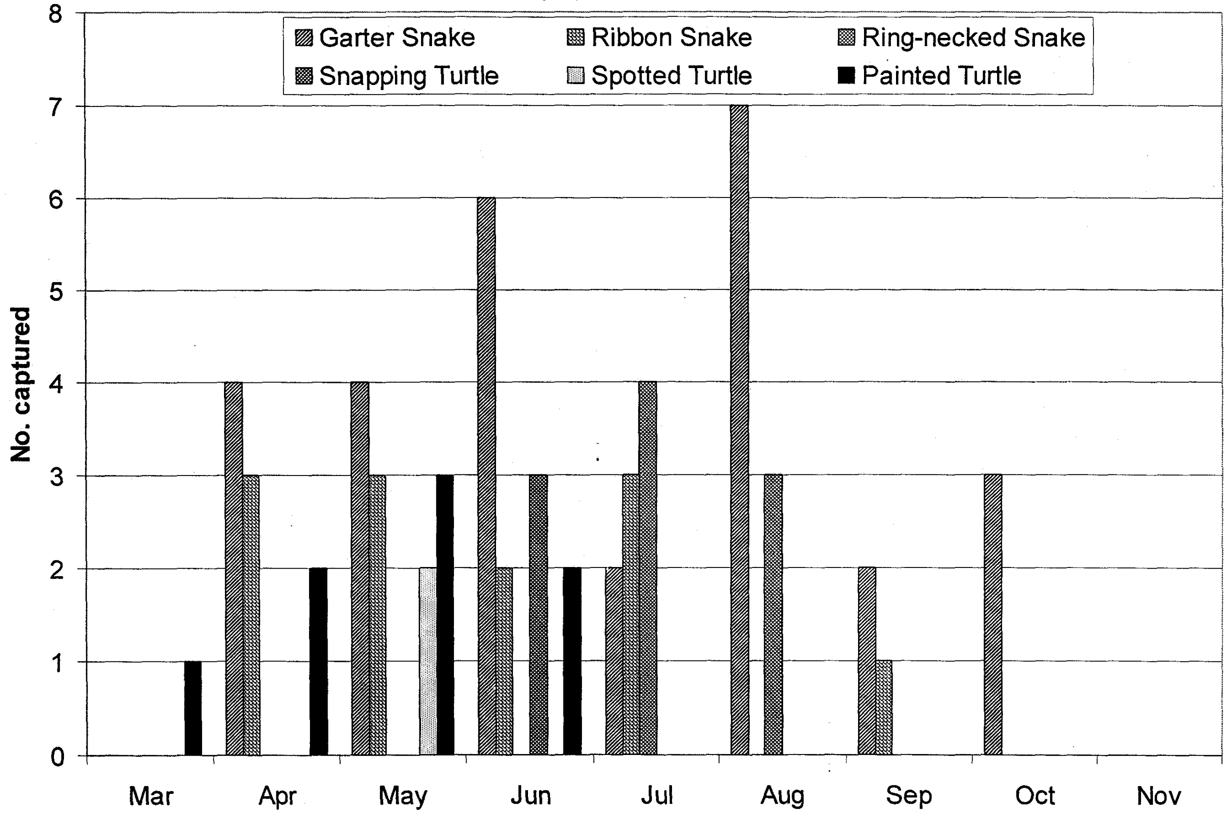

Figure 17. Summary of mammalian capture rates in Field versus Woods arrays

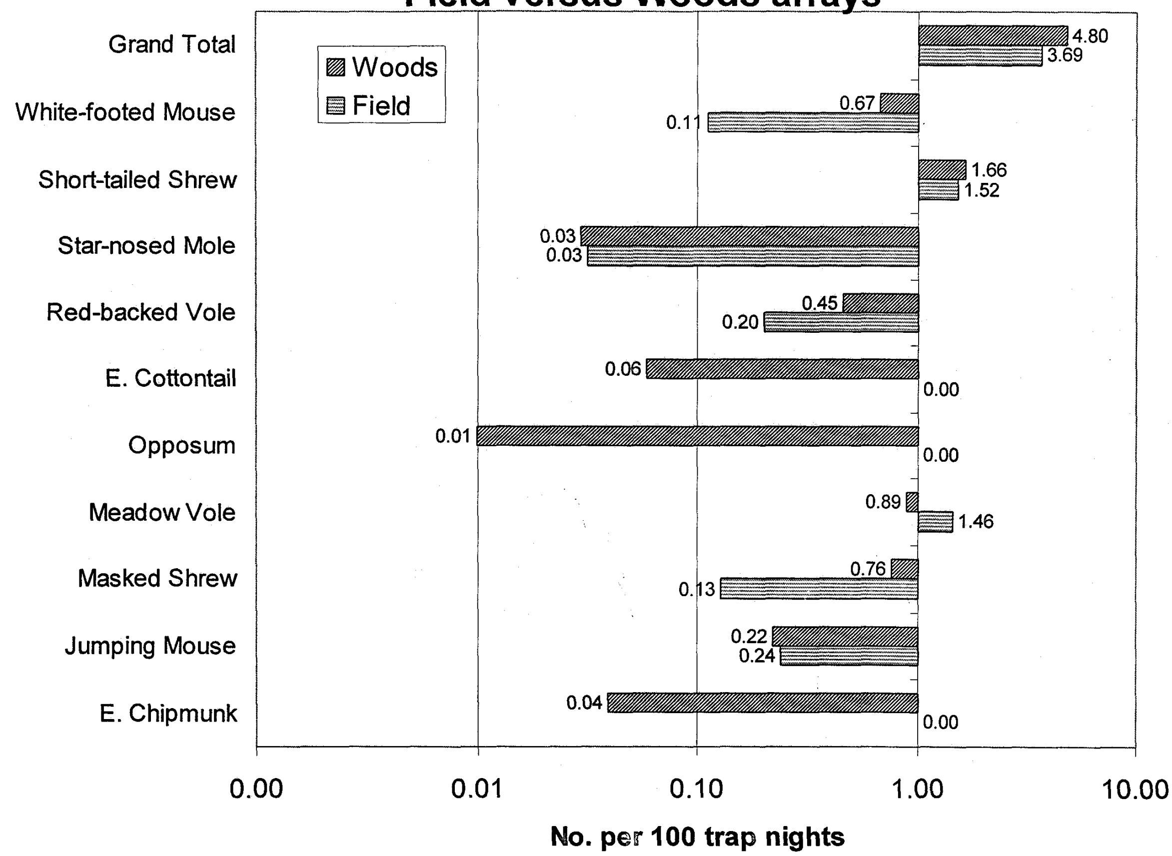

Figure 18. Summary of mammals captured in North Woods

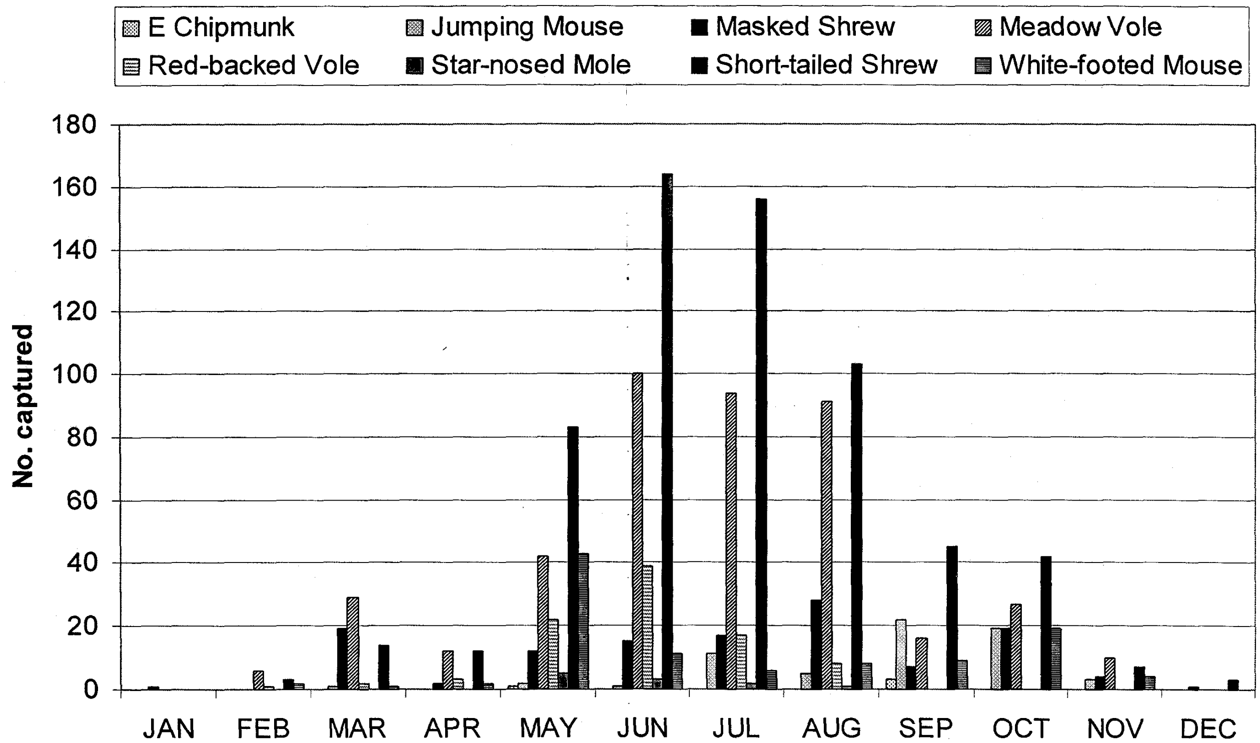

Figure 19. Summary of amphibian species captured in ponds on golf courses in southern New England.