Can golf courses be designed to enhance amphibian movements to breeding sites?

1998 Annual Report

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Executive Summary

(1) Amphibian movement chronology and community structure was monitored in three ponds in the middle of the proposed golf course construction site starting mid-February 1998. A total of 7,911 amphibian captures representing 11 species were recorded since project initiation. In addition, two species of snakes and 7 species of mammals were detected.

(2) Experimental evidence showed that frogs prefer to move through wooded habitats rather than turf areas (G = 3.6, $P = 0.058$) or barren areas (G = 9.2, $P = 0.002$). This preliminary finding suggests that dispersal corridors from ponds to upland wintering areas will be more effective if designed to include woodlands. However, other research showed that amphibians will readily cross turf.

(3) Experiments with various grass heights (0.25", 0.5", 1.0", and ~2-5") found no evidence that grass height affected frog movement patterns (G=3.7, $P = 0.29$). This suggests that varying grass height is not a management option to increase frog use of a potential movement corridor.

(4) Frogs readily crossed a 68 m (225') wide, mowed grass field, but there was little evidence of amphibian movement across a 175 m (575') wide grass field. This preliminary evidence suggests that the vast majority of fairways do not represent a dispersal barrier for most species of frogs in New England.

(5) One of the most important scientific findings of this summer's research was that we documented non-random migration of metamorph frogs (e.g. newly transformed young) away from our monitored ponds. We established two 200-m long drift-fence arrays ~100 m to the east (habitat = woodlands) and west (habitat = woods and turf fields) of monitored ponds. Several species (Green Frog, Pickerel Frog, and Spotted Salamander) radiate out at random directions from breeding ponds. On the other hand, American Toads, Gray Tree Frogs, Spring Peeper, Wood Frogs, and Red-spotted Newts exhibited habitat preferences, most species were more likely to move through wooded habitats. This suggests that among some species of frogs, metamorphs have an innate genetic predisposition to migrate in specific directions. This has very important implications for management strategies.

(6) *Proposed research for 1999:* Future funding for this research project during the 1999 field season will be used support three types of investigations: (1) we will continue monitoring natural movement patterns amphibians in the North Woods study site (this research will focus on adult movements to/from breeding sites, which was missed during the 1998 field season); (2) a series of experiments will be conducted in the North Woods area to further refine our knowledge of habitat characteristics of amphibian movement corridors, and (3) we propose to initiate a large-scale quantitative survey of the habitat characteristics of breeding sites used by amphibians on golf courses on southern New England, including habitat characteristics of potential movement corridors.

This report briefly summarizes research conducted during the 1998 field season at the Kingston campus of the University of Rhode Island. This study was designed to investigate the movement patterns of amphibians to/from breeding ponds, specifically focusing on the potential effects of turf grass on movements. Research at URI in 1998 focused on the habitat characteristics of movement corridors for amphibians.

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 extinction events (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 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..

Specific research questions addressed by this study in 1998 included: (1) Does grass height affect movements of amphibians, that is can golf course managers manipulate grass height to facilitate amphibian movements to breeding sites?, (2) 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?, (3) Is there any evidence that topographic features or habitat features affect amphibian dispersal from breeding ponds, and finally (4) Is there random directional movement away from breeding ponds, or are movements non-random?

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. Three of the smaller ponds in the complex (hereafter named Tran-A, 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). These ponds were monitored daily (i.e., Tran-A Pond [10 total pitfall traps, 5 on inside and 5 on outside]: 12 Feb. to 5 Aug; Trench [16 total traps]: 15 Feb - 5 Aug; and Gene's Truck [24 total traps]: 26 May-5 Aug) 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.

Figure 1. Distribution of Drift Fence Arrays during the 1998 near the Kingston Campus of the University of Rhode Island. Drift fences were constructed from 0.5 m tall silt fencing, with pitfall traps (two #10 coffee cans) placed on the inside and outside of arrays at 10 m intervals. The inside of Woods and Field refers to the side of the fence nearest Trench and Gene's Truck Pond. See Table 1 for capture rates at each of these sites.


Railroad Array
Field Array
Trench Pond
Gene's Truck Pond
Woods Array
0 200 400 600 Feet
Habitat Types
Turf
Ephemeral Pond
Old Field / Shrub
Deciduous Hardwood
Road Border
Shrub / Sapling
Red Maple
Excavated Area
Barren Moss
Roads

Adults and juveniles captured entering/leaving these ponds were also used for the following experiments.

Does grass height affect movements of amphibians?

We constructed two square pens (50' on each side) on a 4-ha section of bent grass, which is used by the Turf Grass Group at URI for a variety of experiments. Grass in this area is typically mowed to <0.25" tall to mimic typical golf greens. The perimeter of our experimental pens was encircled with 0.5-m tall silt fence. The pens were subdivided into 4 quarters (25' per side). Each quarter (randomly selected) was mowed to a grass height that mirrored height typically found on golf greens, fairways, and roughs (0.25", 0.5", 1", and >1.0" [ranging from 2-5"). All experiments were conducted on rainy nights, when amphibians were likely to move. During the experiment, an individual amphibian (a Wood frog, American Toad, Green Frog, Bullfrog, or Pickerel Frog) was placed in the center of the array underneath an inverted coffee can. Attached to the coffee can was a 100' rope that went through a pulley attached to a 3' tall tripod directly above the can, and then >50' out of the array. Once an animal was placed in the can, the observer moved away from the array and allowed the animal to settle for 30 seconds. The trial began when the can was lifted off the animal, and the animal was allowed to move for 3 minutes. The observer then determined the quarter where the animal moved and how far it had moved. Each animal was marked with a small patch of red reflective tape to aid in finding it with a flashlight. Habitat preferences were analyzed with a log likelihood ratio test statistic.

Do amphibians exhibit habitat preferences for movements?

We used Wood Frogs, Green Frogs, Pickerel Frogs, and American Toads for this experiment. We construct pens with silt fencing measuring 25' wide by 50' long, with enclosures located at the ecotone of two habitats, with 50% of the enclosure in one habitat type and 50% in another. Habitat comparisons included forest versus mowed grass field, and forest versus a barren, sandy substrate. A pitfall trap was placed in each corner of the pen. A single frog was placed in the center of the array underneath a coffee can with the rope system described above attached. Trials lasted for 5 minutes. All experiments were conducted on rainy/humid nights, and animals had red reflective tape attached. The final habitat and distance moved were recorded at the end of the trial. We used a log likelihood ratio test statistic to determine habitat selection.

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 three small ponds the study area. This area is scheduled to be converted into a golf course in the near future. 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 22 May-5 Aug, with 32 total pitfall traps [16 on inside and 16 on outside]; Fig. 1), 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 28 May - 5 Aug, with 38 total pitfall traps, Fig. 1). We also initiated a third straight-line array on the west side of a 175 m wide turf field, next to the Amtrak national railroad corridor. 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 so their movements across the landscape could be monitored.

RESULTS

Amphibian use of seasonal ponds

A total of 3,917 animal captures were recorded at pond arrays (Table 1) and 4,534 animal captures at straight-line arrays that we monitored in North Woods (Table 2). The majority of captures (93.6%) were 11 species of amphibians, with four species of reptiles (n = 20 individuals) and 7 species of mammals (n = 520 individuals) captured in pitfall traps. Productivity information is available for each of the ponds, but are not presented in this annual report. As would be expected, small ponds (e.g., Tran-A: 66 m^2: capture rate = 0.08 individuals per trap night) have relatively few animals using them compared to moderately-sized pond (Trench: 326 m^2: capture rate = 0.44 individuals per trap night) or medium-sized ponds (Gene's Truck: 1,410 m^2: capture rate = 0.51 per trap night). We do not have any data on very large ponds, >1 ha or 10,000 m^2, because of the logistical constraints in monitoring such large ponds. However, there are large ponds (> 50 m diameter) in North Woods that could be monitored to determine overall community structure.

As would be expected based on the amphibian community structure at other woodland ponds in southern Rhode Island (Paton and Crouch, unpubl. data), adult Wood Frogs were the most abundant adult amphibians followed by Green Frog, Pickerel Frog, American Toad, Red-backed Salamander, Spring Peeper, Spotted Salamander, Gray Tree Frog, Red-spotted Newt and Bullfrog (Table 1). This represents virtually the entire amphibian community that could be expected in this habitat type in southern New England, so this area is ideal to monitor the effects of golf course construction on a broad suite of amphibians. Yet, not all species were found here, including Marbled Salamanders, Fowler's Toads (usually found in more sandy substrates closer to the coast), and Eastern Spadefoot (extremely rare in Rhode Island, only know from <10 site farther to the west).

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, we found this was not the case, at least for some species.

We had relatively high capture rates of amphibians at both the Woods and Field arrays (Fig. 1), although species richness, total captures, and capture rates were higher in the forested habitat (i.e., Woods array: 9 species, 2,484 captures, capture rate = 0.56 individuals per trap night, Table 2) than at the ecotone between woods and the turf field (Field array: 8 species, 1,962 captures, capture rate = 0.39 individuals per trap night). We found that Green Frogs, Pickerel Frogs, and Spotted Salamanders were caught in equal proportions at the Woods and Field arrays ($P \geq 0.05$; Table 2), which suggests that these species radiate randomly from breeding sites. However, American Toads, Gray Tree Frogs, Spring Peepers, Wood Frogs, and Red-spotted Newts all exhibited non-random radiation from breeding ponds ($P < 0.05$). Red-backed

Salamanders are a terrestrial breeder, and the animals we captured at the Woods array were adults presumably near their breeding territory. Species that prefer to winter in wooded swamps (e.g., tree frogs, peepers, wood frogs) headed towards the woodlands (that is, significantly higher capture rates at the Woods array), whereas Red-spotted Newt metamorphs migrated toward the turf fields (significantly higher capture rates at the Fields array) and the bottomlands beyond the turf fields. This finding suggests that among certain species of amphibians, metamorphs may have a genetic predisposition to migrate in specific directions towards their preferred wintering habitat. This appears to be true for American Toads, Gray Tree Frog, Spring Peeper, Wood Frogs and Red-spotted Newts. Or, there could be some habitat cues of habitat preferences that the animals are keying in on that we are currently unaware.

Effects of grass height on amphibian movements

In experiments with four grass heights, we found movements were random with respect to grass height ($G = 3.7$, $P = 0.29$; Table 3). This suggests that grass height, at least in the height range we quantified that is typical of current golf courses practices in North America, does not hinder or enhance amphibian movements. This is true for the species we sampled, but we did not have the opportunity to investigate any salamanders or some frogs (Spring Peepers, Gray Tree Frogs, and Wood Frogs), whose movements could be affected by grass height.

We had some minor problems with this experiment. We experienced a drought from mid-June to the present (early August) in Rhode Island. These experiments were to take place on rainy nights or nights with high humidity, when amphibians (especially adults and juveniles) usually move. However, since we had few rainy nights, we had few experimental animals to work with (since adults/juveniles were not captured at other arrays) and we few nights which provided suitable environmental to conduct the experiments. Therefore, sample sizes for this experiment were lower than originally proposed.

Is there evidence for habitat selection during movements?

We conducted experiments to determine if amphibians (frogs in this case) preferred forested habitats to either turf or barren areas. In both cases, the evidence shows that wooded habitats were preferred over barren ground ($G = 9.2$, $P = 0.002$, Table 4) or turf ($G = 3.6$, $P = 0.058$, Table 5). This suggests that travel corridors from breeding sites to wintering areas designed to have wooded habitats connecting the two areas would be preferred over areas with that have grassy habitat bisecting breeding and wintering habitat.

In addition, we found little evidence that amphibians, reptiles, or mammals would readily cross 174 m (570') of turf (although we did have one young marked Pickerel Frog move from the Field array to the Railroad array). Capture rates at the Railroad array (Fig. 1) were at least 6.5 to 9.3 times lower than the Field and Woods array, respectively (Table 2). However, amphibian readily crossed ~70 m of turf (i.e., the outside of Field array), which is 2-3 times wider than most fairways in New England. This implies that many typical fairways may not represent a travel barrier to many species of amphibians in southern New England. Unfortunately, there is no potential upland habitat to the west of the Field array that represents wintering habitat, which is why relatively more animals might not be on the outside of the Field array.

DISCUSSION

At least four preliminary lines of evidence gathered from this study suggests that golf courses can be designed to provide effective movement corridors for amphibians to move between breeding and wintering habitat. First, we found that frogs readily moved across a 70 m (220') wide turf field, suggesting that most fairways do not present a travel barrier to amphibian populations. On the other hand, a 175 m (560') wide turf field apparently impeded amphibian movements, as we found few organisms crossing such a large expanse of turf. Yet, few golf courses would ever have such an immense expanse of turf. Second, experiments with a variety of grass heights, typically found on golf courses (0.25-1"), found no evidence that frogs preferred or avoided any grass height we sampled (Table 3). Third, experiments with captive frogs suggest that all species prefer to seek cover in forested habitats compared to open habitats (either turf fields or barren habitats). This indicates that preferred movement corridors might be forested habitats over grasslands, but that grasslands do not necessarily completely impede movements. Therefore, golf course designers might consider incorporating wooded corridors connecting breeding ponds to wintering sites (i.e., forested blocks of habitat) for amphibians. This latter concept needs further investigation. Fourth, our results suggest that movements from breeding ponds of both adults and young amphibians appear 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.

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.

Recent research by Gibbs (1998) suggested that certain species of amphibians avoid edge habitat and were unwilling to utilize edge habitats (Table 6). I calculated a permeability index for amphibian movements by comparing capture rates on the insides of the Woods and Field arrays. It is evident that for some species (e.g., Wood Frog and Red-backed Salamander) I found similar results to Gibbs findings, that is these species tended to avoid edge habitat. However, I found radically different results for Spotted Salamander, Red-spotted Newt, and Pickerel Frog. I documented that the metamorphs of all of these species readily used edge habitats (i.e., the juxtaposition of a turf field and wooded area). This preliminary finding suggests that these taxa will adapt to habitat fragmentation to a greater extent than Gibb's data seems to indicate. The reasons for differences between our two studies remain unclear, but must have to do with the types of edges he studied (roads vs. woods in Gibb's case compare to turf field vs. woodsin this investigation) and the duration of his study (he only capture 307 animals vs. over 3,400 for our research). Amphibians seem to be willing to cross turf, but this question still need further research. Specifically, this study was started in June after most adults amphibians had entered and left breeding ponds. Therefore, we are awaiting the results from next spring's research, when we can determine movement patterns of adults across the turf compared to movements through the woods.

FUTURE RESEARCH

(1) Future funding for this research project during the 1999 field season will be used support three types of investigations: First, we will continue monitoring natural movement patterns amphibians in the North Woods study site (this research will focus on adult movements to/from breeding sites, which was missed during the 1998 field season); second, a series of experiments will be conducted in the North Woods area to refine our knowledge of habitat characteristics of amphibian movement corridors, and third, we propose to initiate a quantitative survey of the habitat characteristics of breeding sites used by amphibians on golf courses on southern New England, including habitat characteristics of potential movement corridors.

(2) Due to budget constraints during the 1998 field season (e.g., the final contracting between URI and USGA was not signed until late July 1998), we were unable to start full-scale field efforts until June. Therefore we missed the primary pulse of movements for most adult amphibians to/from the breeding ponds (e.g., Wood Frogs move from mid-Feb to mid-April, Paton and Crouch, unpubl. data), and were only able to monitor movements of metamorphs away from breeding ponds. Therefore, using funding from this year's budget, we will continue to monitor natural movement patterns of adult amphibians to/from the breeding ponds in the spring of 1999.

by amphibians. We will ask golf courses in the region if we can survey ponds for amphibians using a combination of nocturnal calling surveys (used to assess the presence of breeding frogs) and diurnal/nocturnal dip net surveys (used to assess the presence of breeding adult salamanders & frogs, and to sample amphibian young to assess productivity). Ponds to be surveyed will be selected based on the surrounding habitat matrix, with sampling concentrated at (A) ponds surrounded only by grass, (B) ponds surrounded only by shrubs, (C) ponds surrounded by a forest overstory with no understory, and (D) ponds surrounded by forests with an overstory and understory.

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Funding for 1999 will be used to support monitoring of amphibian movements in the North Woods study area during the summer and fall of 1999. We are especially interested in which species readily travel across the 70 m turf field towards the ponds, that is which species will be captured in the Field Array. Also, we are curious about differences in community structure between the Woods and Field array. 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.

(3) Since our experimental evidence suggests that amphibians seek cover in forested area over open habitats, such as grasslands, we are interested in the specific micro-habitat characteristics of forested areas affect movements. Data gathered at the Woods Array suggest that microhabitats may play an essential role in amphibian movements (e.g., one trap with little understory had a much higher capture rate than adjacent traps). We propose to conduct experimental habitat manipulations, with five 10 m wide by 30 m long strips of habitat perpendicular to the inside (the side facing the ponds) of Woods and Field array having the entire understory removed manually. 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.

(4) Experiments conducted this summer 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.

(5) We need more information on ponds used by amphibians on golf courses in southern New England. A broad scale survey of ponds on golf courses in the region will allow us to quantify habitat characteristics of breeding ponds and to also assess potential movement corridors used

Budget for the 1999 field season

Budget line item	Cost
I. Monitoring amphibian movements in North Woods (natural movements and experimental arrays) 15 May to 1 September:	
2 technicians (5hr/day X $8.50/hr X 110 days X 1.0765 (FICA)	$10,065.28
Field equipment/rental (silt fence, fence installation equipment rental, pitfall cans)	$2,000.00
II. Quantifying habitat characteristics at Golf Courses	
2 technicians (4 hr/day X $8.50/hr X 5 day/wk X 12 wks X 1.0765)	$4,392.12
Mileage for fieldwork ($.325/mile X 80 mile/day X 60 days)	$1,560
Field equipment (nets, boots etc)	$650.00
PI summer salary	$2,000.00
Total Direct Costs (TDC)	**$20,667.40**
Indirect Costs (16% TDC)	**$3,306.78**
Total Costs	**$23,974.18**

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Table 1. Summary of animal captures in three ponds up to 6 October 1998.

Species	Tran-A			Trench			Gene's Truck		
	Inside	**Outside**	**Total**	**Inside**	**Outside**	**Total**	**Inside**	**Outside**	**Total**
Amphibians									
American Toad	4	6	10	8	11	19	20	18	38
Bullfrog	0	0	0	4	0	4	2	4	6
Green Frog	16	16	32	138	218	356	94	262	356
Pickerel Frog	1	2	3	158	336	492	208	383	592
Gray Tree Frog	0	0	0	2	7	9	7	6	13
Spring Peeper	0	0	0	12	37	49	7	2	9
Wood Frog	21	17	38	498	77	575	782	116	901
Spotted Salamander	3	3	6	2	4	6	67	8	75
Red-spotted Newt	0	3	3	7	61	68	3	13	16
Red-backed Salamander	22	30	52	5	18	23	7	11	18
Reptiles									
Eastern Garter Snake	0	0	0	0	0	0	4	1	5
Ribbon Snake	0	1	1	0	0	0	0	0	0
Mammals									
Masked Shrew	4	10	14	0	1	1	3	3	6
Short-tailed Shrew	3	24	27	14	20	34	5	35	40
M. Jumping Mouse	0	0	0	0	3	3	1	3	4
Meadow Vole	0	0	0	0	1	1	0	8	8
Star-nosed Mole	0	2	2	0	0	0	0	0	0
White-footed Mouse	0	1	1	0	1	1	5	2	7
Total no. of animals	**74**	**112**	**186**	**847**	**789**	**1636**	**1217**	**878**	**2095**
Total trap nights			**2360**			**3728**			**4108**
No. animals/trap night			**0.079**			**0.439**			**0.510**

Table 2. Summary of animal captures in three straight-line drift fence arrays up to 6 October 1998.

Species	FIELD ARRAY			WOODS ARRAY			RAILROAD ARRAY				
	Inside	Outside	Total	Inside	Outside	Total	Inside	Outside	Total	G*	P
Amphibians											
American Toad	12	16	28	43	29	72	4	7	11	9.5	0.002
Bullfrog	0	10	10	0	1	1	0	0	0	N/A	
Green Frog	142	64	106	179	20	199	1	4	5	2.1	0.14
Pickerel Frog	1134	203	1336	1091	34	1125	3	15	18	0.4	0.5
Gray Tree Frog	0	0	0	9	2	11	0	1	1	7.7	0.005
Spring Peeper	4	2	6	82	6	88	0	1	1	44.5	0.001
Wood Frog	13	7	20	323	14	337	0	1	1	181.6	0.001
Spotted Salamander	48	9	57	41	3	44	0	0	0	0.28	0.60
Four-toed Salamander	0	1	1	0	0	0	0	0	0	N/A	
Red-spotted Newt	110	16	126	68	69	137	0	0	0	5.0	0.025
Red-backed Salamander	6	4	10	129	142	271	0	0	0	70.7	0.001
Reptiles											
Eastern Garter Snake	0	1	1	0	2	2	0	0	0		
Ribbon Snake	0	1	1	0	1	1	0	1	1		
Ring-necked Snake	0	0	0	3	2	5	0	1	1		
Snapping Turtle	0	2	2	0	0	0	0	0	0		
Mammals											
Masked Shrew	8	2	10	19	19	38	0	0	0		
Short-tailed Shrew	61	42	103	45	58	103	13	20	23		
Meadow Jumping Mouse	12	11	23	3	5	8	0	0	0		
Meadow Vole	12	6	18	6	6	12	7	5	12		
Star-nosed Mole	1	1	2	0	5	5	0	0	0		
White-footed Mouse	1	0	1	1	6	7	0	0	0		
Eastern Cottontail Rabbit	0	0	0	2	4	6	0	0	0		
Cumulative Total	**1564**	**398**	**1962**	**2047**	**437**	**2484**	**28**	**60**	**88**		
Total trap nights			**4978**			**4416**			**1456**		
No. of animals/trap night			**0.394**			**0.5625**			**0.060**		

*Log likelihood ratio test statistic: compares total number of animals captured on the inside of Woods and Fields to an expected 50:50 capture ratio

Table 3. Number of frogs selecting a particular grass height for travelling after a 3-min trial experiment. Trials conducted only at night.

	Grass height					
	0.25"	0.5"	1.0"	>1.0"	*G*	*P*
Observed	14	29	21	29	3.7	0.29
Expected	23.25	23.25	23.25	23.25		

Table 4. Number of frogs selecting either woods or barren habitat when placed at the edge. Trials were conducted only at night.

	Habitat			
	Woods	Open	*G*	*P*
Observed	19	2	9.2	0.002
Expected	11.5	11.5		

Table 5. Number of frogs selecting either woods or turf habitat when placed at the edge. Trials were conducted only at night.

	Habitat			
	Woods	Turf	*G*	*P*
Observed	17	5	3.6	0.058
Expected	11	11		

Table 6. Relatively permeability to edges of amphibians during pitfall trapping in North Woods on the Kingston campus of the University of Rhode Island. This study (Paton) is compared to data collected by Gibbs (J. Wildl. Manage. 62:584-589) at two types of edges near New Haven, CT. Permeability was calculated as the ratio of total captures at drift fences at an edge to captures at a drift fence in the forest interior. Indices below 0.5 suggest the species avoids edge habitat.

	Paton*		Gibbs**		
	Numbers	Index	Residential	Road	Overall
Spotted Salamander	48/41	1.17	0.6	0.2	0.4
Red-spotted Newt	110/68	1.62	0.1	0.1	0.1
Red-backed Salamander	6/129	0.05	1.3	0.6	1.0
Wood Frog	13/323	0.04	0.4	0.2	0.3
Green Frog	142/179	0.79			
Pickerel Frog	1134/1091	1.04	1.2	0.3	0.8
American Toad	12/43	0.28			
Spring Peeper	4/82	0.05			
Gray Tree Frog	0/9	0.00			
All species	1469/1965	0.75	0.9	0.3	0.6

*Captures represented are only individuals moving away from breeding ponds (inside of arrays); Field array over Woods array

*Gibbs captured a total of 307 individuals compared to 9,394 for this study