even insects. It contained a breakdown of all habitat types such as desert, prairie, or woodland, and if the woodland was deciduous or coniferous. It also broke down the water features of the site, by number of ponds and pond acreage, number of lakes and lake acreage, and the amount of wetland area. The model also incorporated the address, state, and zip code and contact name fore each site.

A series of reports can now be generated based on the *Resource Inventory Information* logged into the *Managed Land Database Information.* For example reports dealing with geographic regions, address information, land and water acreage, and habitats were developed. This kind of information is very useful and beneficial to the Audubon Cooperative Sanctuary Program and its members. I

Developing Methods to Enhance Amphibian Diversity on Golf Courses: Effects of Golf Course Construction on Amphibian Movements and Population Size

University of Rhode Island

Peter Paton

Start Date: 1998
Number of Years: 3
Total Funding: $72,000

Objectives:

1. *Determine the pre-construction population size for amphibians breeding at ponds within the boundaries of a proposed golf course.*
2. *Determine pre-construction travel corridors and movement patterns for amphibians at this same site.*
3. *Quantify population size and movement patterns following construction on the golf course.*

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 seven species of mammals were detected.

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 would readily cross turf.

Experiments with various grass heights (0.25, 0.5, 1.0, and 2.5 inches) 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.

Frogs readily crossed a 68 m (225 ft.) wide, mowed grass field, but there was little evidence of amphibian movement across a 175 m (575 ft.) 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.

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 to the 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.

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. I

Pesticides and Nutrients in Surface Waters Associated with Golf Courses and Their Effects on on Benthic Macroinvertebrates

University of Maryland

William Lamp

Start Date: 1998
Number of Years: 2
Total Funding: $54,896

Objectives:

1. *Measure the concentration of pesticides and nutrients residing in the water column of streams associated with golf courses.*

2. *Measure the concentration of pesticides reding in the sediments and sediment porewater of streams associated with golf courses.*
3. *Assess the impact of golf courses on stream macroinvertebrate communities.*
4. *Determine the sublethal impacts of selected pesticides on benthic macroinvertebrates.*

Golf courses provide citizens with a convenient recreational opportunity while preserving green space and natural settings. Yet, their intensive management necessitates the use of pesticides and fertilizers, thus provoking concerns of environmental damage. One of the overall goals of this project is to determine if surface waters, and their sediments, associated with golf courses are contaminated by pesticides and/or fertilizers. Potential contamination can occur especially in association with high runoff events such as storms. However, because contamination varies with time, a second overall goal was to develop the use of stream macroinvertebrates and their communities as long-term indicators of water quality. This will allow us to determine if pesticides and/or fertilizers are impacting stream macroinvertebrate communities.

Water samples for nutrient level measurement have been collected and analyzed once or twice every month since March 1998. In addition, we have collected water from five run-off events and have analyzed this water for nutrients. Water and sediment samples for pesticide analysis have also been collected five times following run-off events. The water samples have been filtered and processed using solid phase extraction. The sediment samples are being stored using methods required to maintain the integrity of any pesticides. We are now in the process of analyzing the samples using gas chromatography and mass spectrometry. These samples are being analyzed using protocols developed at USDA.

Macroinvertebrates associated with natural leaf packs are collected using artificial leaf pack samplers. Five leaf packs, each consisting of dried leaves (standardized by leaf taxa and dry weight) and connected to a brick with a strap, are placed in the stream 21 days prior to the sampling date to allow for colonization by benthic macroinvertebrates. On the sampling date, the leaf packs are collected and water quality parameters measured. In the laboratory, invertebrates in each sample are sorted, preserved, and identified to family level. Community comparisons, using taxonomic diversity and invertebrate density, are being performed by calculating various community statistics for each golf course and site.

During 1997 and 1998, invertebrates were collected five times. During 1997, these samples yielded 24,555 individuals representing 46 families of invertebrates. The most abundant types of invertebrates collected were members of the families Chironomidae (midge flies), Simuliidae (black flies), Hydropsychidae (net-spinning caddisflies), Elmidae (riffle beetles), and Capniidae (winter stoneflies). No significant differences were seen in either taxonomic richness (P=0.59) or invertebrate density (P=0.65) when comparing upstream with downstream sites, illustrated in Figures 14 and 15. Of the physical and chemical parameters measured, only turbidity

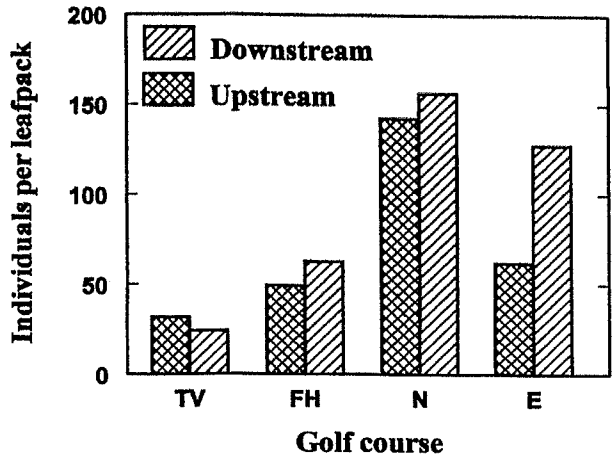

Figure 14. Average invertebrate diversity for all sample dates (1997) at upstream and downstream locations on four golf courses, TV, FH, N, and E.

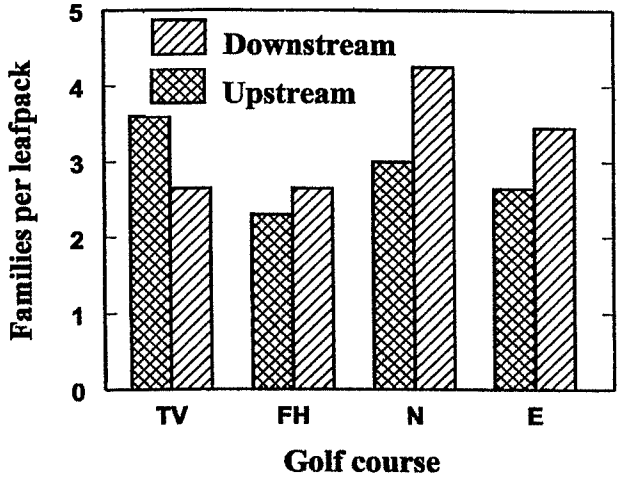

Figure 15. Average taxonomic diversity for all samples (1997) for upstream and downstream locations on four golf courses,TV, FH, N, and E.

showed a trend across all golf courses; water from sites upstream from the courses were more turbid than water collected downstream from the courses.

Based on this preliminary analysis, golf course management practices are not significantly impacting the invertebrate community. However, when one analyzes the trends seen in the invertebrate density and taxonomic diversity data, there is an increase in these two population indices at the downstream sites at three of the four courses, albeit, they are not significant increases. We will collect additional data and perform further analyses over the next year.

Area golf courses routinely use five fungicides: Daconil 2787, Bayleton, Aliette, Banol, and Subdue. Furthermore, the application of nitrogen and phosphorus is commonplace on area golf courses. Therefore, laboratory and field studies are being used to determine if pesticides and/or fertilizers influence consumption and decomposition of coarse particulate organic matter (CPOM).

Specifically, field studies are being conducted to measure the decomposition and consumption of organic matter in our streams associated with golf courses. Mesh bags containing predetermined amounts of leaf material are left in the field for various amounts of time during which the leaves are allowed to decompose or subjected to consumption by benthic macroinvertebrates. At the end of the study period, the bags are removed from the stream and the remaining leaf matter is weighed. Using this information, we can determine if golf courses are influencing the organic matter processing via alterations in decomposition of the leaf matter by periphyton or consumption of the matter by benthic macroinvertebrates.

Laboratory studies are being conducted to measure the decomposition of maple leaf discs in the presence of the five fungicides listed above. We will try to determine if the presence of these fungicides inhibits decomposition of organic matter by fungi and bacteria. In addition, laboratory studies will look at the effect of the presence of these fungicides on the consumption of maple leaf discs by stoneflies. It has been shown that consumers of organic matter are really using the periphyton growing on the organic matter as an energy source. Therefore, we are trying to determine if the presence of these pesticides has a sublethal affect on invertebrates through altering their consumption of organic matter, possibly due to altering periphyton growth on organic matter.

Golf Course Maintenance and Amphibian Conservation

Frostburg State University

Dr. James Howard

Start Date: 1997
Number of Years: 3
Total Funding: $105,036

Objectives:

Laboratory Studies:

1. *To test the relative toxicity of the most commonly used pesticides (insecticides, fungicides and herbicides) with three diverse taxa of amphibians.*
2. *To develop a more complete and biologically realistic testing protocol including: a) multiple species; b) short term acute and long term chronic tests; c) multiple life history stages; d) multiple indicators of biological impact; and e) an environment that provides the opportunity to detoxify or potentiate chemicals with more biological realism.*

Field Studies:

1. *To access the feasibility of "stocking" wetlands in order to establish breeding populations of desired amphibian species.*
2. *To evaluate the relative success of small temporary wetlands versus a larger permanent body of water stocked with the same amphibians.*

Laboratory study. The toxicity of three pesticides (carbaryl, chlorpyrifos, and imidacloprid) was investigated using American toad tadpoles (*Bufo americanus*). These trials were completed by August and the data analyzed by October. Effects on survival, growth, and time to metamorphosis analysis were consistent with previous results obtained using chorus frogs (*Pseudacris triseriata*). Concentrations of pesticide had a significant effect on survival. Prior to initiation of the *Bufo* trial, the LC_{50} (concentration of pesticide needed to kill 50% of test organisms) was determined for each pesticide. The estimated LC_{50}s in parts per billion were 468,000 for imidacloprid, 63,167 for carbaryl, and 1,316 for chlorpyrifos. All tadpoles placed in high (0.5 x LC_{50}) concentrations died during the trial whereas survival of tadpoles at all other concentrations was above 95 percent. Subsequent analyses were performed only on medium (0.1 x LC_{50}), low (0.01 x LC_{50}) concentrations and controls. Growth of tadpoles was significantly ($P < 0.05$) decreased by chronic exposure to 0.1 x LC_{50} concentrations of carbaryl and chlorpyrifos (Figure 16). Significant differences between control tadpoles and those raised in medium concentrations were observed in time to metamorphosis (measured as day front limbs emerge). Tadpoles in medium concentrations of all pesticides took an average of three days longer to reach metamorphosis when compared with controls. Sublethal effects on time to metamorphosis and growth would be expected to have negative effects on population persistence.

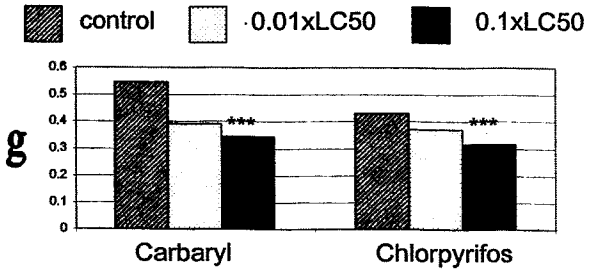

Figure 16. The effects of carbaryl and chlorpyrifos on average growth per tadpole (g) after three weeks. Treatments marked * are significantly different from controls.**