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.

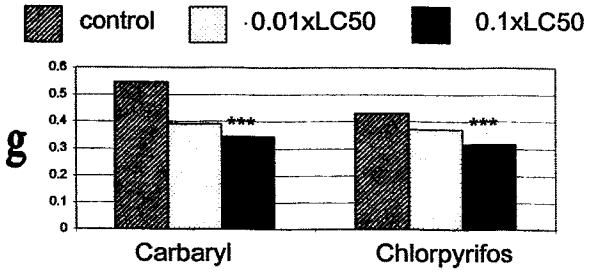

Figure 16. The effects of carbaryl and chlorpyrifos on average growth per tadpole (g) after three weeks. Treatments marked * are significantly different from controls.**

Water and sediment samples collected during the *Pseudacris* larval trials were analyzed for chlorpyrifos by The Institute of Wildlife and Environmental Toxicology. Results indicate that pesticide is rapidly absorbed by the sediment. For example, chlorpyrifos was added to a tank at a concentration of 112 ppb, and 24 hours later the concentration in water was 23 ppb. At termination of the experiment (after 4 repeated applications of pesticide), the concentration of chlorpyrifos in the sediment was 443 ppb. Because many frog tadpoles feed in the substrate and are detritivores, this pathway may be a more important contributor than pesticide residues in the water column.

In summary, Larval trials on *Bufo* were completed and data indicates that pesticide concentrations have effects on survival, growth, and time to metamorphosis of tadpoles which are significant and similar to previous trials on the genus *Pseudacris*. Sediment analysis indicates that pesticide added to the water column becomes concentrated in the sediment. Larval trials using *Rana* are in progress.

Field Studies. In March of 1998, egg masses of *Ambystoma jeffersonianum* (Jefferson salamander) and *Pseudacris triseriata* (chorus frog) were translocated into each of the six experimental ponds. Estimates indicate that 90.7 percent of *A. jeffersonianum* and 64.5 percent of *P. triseriata* larvae had successfully hatched. After larvae metamorphosed, individuals were captured by pitfall traps, funnel traps, or time constrained searches. Captured individuals were marked via toe clipping and/or freeze branding for identification in subsequent seasons. Experimental ponds, as well as ponds located on the Rocky Gap Golf Course, have been monitored for natural colonization by local amphibian species. Egg masses found have been identified to species, total number of eggs was estimated, and location of deposition within experimental ponds has been mapped. Larvae that have been dipnetted have also been identified to species.

In the spring and summer of 1998, the following species (in addition to the introduced species) had colonized experimental ponds: *Rana clamitans* (green frog), *Rana sylvatica* (wood frog), *Bufo americanus* (American toad), *Pseudacris crucifer* (spring peeper), *Hyla veriscolor* (gray treefrog), and *Notophthalmus viridescens* (red-spotted newt). Egg masses and/or larvae of the following species were found on ponds associated with the golf course at Rocky Gap: *Rana catesbeiana* (bullfrog), *R. clamitans*, *B. americanus*, and *P. crucifer*.

Although the species composition of experimental and golf course ponds seem similar, several important distinctions should be clarified. The absence of *R. catesbeiana* colonization in experimental ponds should aid in the colonization of smaller species of frogs because *R. catesbeiana* has been implicated in the local extirpation of smaller species due to predation. In addition, ponds associated with the golf course are not colonized as ubiquitously by smaller frog species as experimental ponds are. For instance, not only have we failed to find evidence of *H. versicolor* breeding in golf course ponds, but larvae of *P. crucifer* only were found in one golf course pond while all experimental ponds have contained them. The design of our experimental ponds may promote colonization success of some species. Nearly 60 percent of egg masses were deposited on narrow pond shelves designed to support vegetation that, in part, provides structure for the oviposition of amphibian egg masses. Similarly, the one golf course pond constructed with a shallow shelf on its perimeter is the only course pond that has shown evidence of *B. americanus* and *P. crucifer* colonization.

In summary, egg masses of two species of amphibians have been translocated into experimental ponds at Rocky Gap State Park. Hatching success has been monitored in the egg masses and metamorphosed individuals of both species have been captured and marked for future identification. Experimental ponds, as well as golf course ponds, have been monitored for natural colonization of amphibian species. We have detected six amphibian species that use experimental ponds for breeding and we have detected four species that use golf course ponds for breeding. More importantly, the species composition of our ponds suggests that golf course ponds lack the colonization of smaller species of frogs. However, they support the colonization of a large species (i.e., *R. catesbeiana*) that prey on (and could extirpate) smaller species.

Avian Community Response to a Golf Course Landscape Unit Gradient

Clemson University

David H. Gordon

Start Date: 1998
Number of Years: 3
Total Funding: $60,188

Objectives:

1. *Determine the composition and species richness of avian communities occupying a gradient of golf course landscape units located along the South Atlantic Coast during the breeding season.*
2. *Determine the composition and species richness of avian communities for habitat types found on golf course landscape units located along the South Atlantic Coast during breeding season.*
3. *Examine the influence of landscape context and characteristics of golf course landscape units on the composition and species richness of avian communities.*
4. *Produce a set of outreach products including a technical publication with management and design recommendations, a brochure, and color poster targeted at golf course stakeholder groups.*

David Gordon is assessing the value of golf course landscapes to avian communities. The results of the assessment will be used to produce a technical manual with management and design recommendations, as well as a brochure and color poster targeted at golf course stakeholder groups. The study will