Bolstering amphibian communities on golf courses

With proper management, out-of-play areas can become a home for amphibians.

One of the central tenets of conservation biology is that the protection of biodiversity must be balanced with land use. Considering that the average golf course consists of 150 acres (including 51 acres of rough, 24 acres of nonturfgrass landscape and 11 acres of water bodies) and that golf courses in the United States comprise more than 2.2 million acres (9), we believe that applying biological principles for the management of amphibian communities to golf course habitats can allow golf courses to serve as wildlife sanctuaries.

In natural ponds, enough amphibian eggs survive through metamorphosis to maintain the populations. **Photo courtesy of T. Biebighauser**

Aquatic habitat

The first consideration for supporting pond-breeding amphibians is the aquatic environment, a feature of most golf courses. Although the aquatic environment is often used by amphibians for only a small portion of their life cycle — weeks to months for most species — the environmental conditions will influence which species survive and how many will transform into juveniles that migrate into the terrestrial environment to be recruited into the adult population. In natural ponds, 3% to 5% of the amphibian eggs laid survive through metamorphosis, which allows for sustainable populations (16). Therefore, removing factors that reduce survival unnaturally can help promote healthy, diverse and persistent amphibian communities.

Eliminating fish

Eliminating fish from ponds is critical because fish eliminate most amphibian species (exceptions include bullfrogs) through predation on eggs, larvae and juveniles and through competition for food resources (6,7). Fish, especially stock fish from hatcheries, can carry diseases associated with amphibian mortality (22). Removing fish by draining ponds or by repetitive netting can allow amphibian communities to recover (21).

One way to eliminate fish invasions into ponds or from accidental or purposeful release is to main-

Photo by Daniel Leach

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Ponds that dry for a short part of the year eliminate the threat of predators like bullfrogs and fish. **Photo courtesy of T. Biebighauser**

tain temporary ponds that dry for a short portion of the year. Pond drying increases amphibian diversity, eliminates fish and reduces insect predators and large competitors like bullfrogs. Many pond insects are voracious predators that can eat amphibians 10 to 20 times their size, and large numbers of insect predators or large-bodied overwintering insect larvae can significantly reduce amphibian populations. Pond drying also eliminates amphibian species with long larval periods that exceed one year, like bullfrogs, which have been associated with amphibian declines, especially where they have been introduced.

The timing of pond drying should mimic the natural cycle, or hydroperiod, of filling and drying. Premature drying in the spring or early summer will reduce the number of amphibian species with longer larval periods, like salamanders and newts, and should be avoided. Drying ponds for short periods or biannually in the late summer or fall will be adequate to exclude fish predators and reduce the number of insect predators and bullfrogs. Pond drying also promotes the natural oxidation of sediments and release of essential nutrients, which will help support healthy amphibian communities.

Southern leopard frogs are associated with both forests and grasslands. **Photo courtesy of National Park Service**

Chemical contamination

Because golf courses are routinely treated with chemicals and fertilizer, wetlands on golf courses are potentially exposed to contaminants. Contaminants also can be carried aerially or through precipitation or in groundwater. Contaminants and chemical mixtures can be directly lethal to amphibians and to critical components of their food web (like algae, zooplankton and insects).

Indirect effects are as important as direct effects and include changes in the food web such as decreases in food resources or numbers of predators. Insecticides and herbicides reduce food resources, causing starvation of larvae or tadpoles even though environmental concentrations of contaminants may not be directly lethal. Reduced food resources can increase mortality and lead to reproductive failure, increasing the potential for extinction of species at the pond.

There is increasing evidence that sublethal chemical exposure can make amphibians more susceptible to disease and parasites, which, in the long run, will compromise population stability (3). Many contaminants also have endocrine-disrupting properties, which affect sexual development and reproduction.

The ideal is to minimize the potential for exposure to contaminants by increasing no-spray zones or vegetative buffers, which help filter contaminants so that increased concentrations will not reach the aquatic environment. Using chemicals only when necessary rather than proactively also should improve water quality for pond-breeding amphibians and other species that live in golf course aquatic habitats.

Diverse amphibian communities

The way both the aquatic and terrestrial environments are managed is key to the type of amphibian community that can be supported. Amphibian communities are distinguished to some extent by the types of pond communities they use: forest or grassland. The surrounding landscape will influence the amount of light a pond receives, production of food resources (such as algae, the food base of the community), the temperature of the water and the length of time the pond holds water. These factors will influence what type of species can be expected to successfully use a pond.

Some amphibian species (spotted salamanders, wood frogs) are associated with forests, others (northern leopard frogs, chorus frogs) with grasslands, and still others are found in both (American toads, southern leopard frogs, newts). Knowing which species inhabit a particular type of pond allows you to make informed management decisions that will support all or most species naturally found in similar communities in your region (consult a state or regional amphibian guide book or local expert). It also indicates that a diversity of pond types is essential for bolstering a full complement of amphibian species. The least

diverse communities likely contain only bullfrogs, which often results when fish are present in permanent ponds. The bullfrog has become a pest species worldwide, causing amphibian extinctions and reducing the abundance of native amphibian populations. Designing and constructing aquatic environments that support diverse amphibian communities can be accomplished through periodic drying of wetlands in late summer to eliminate or reduce fish and bullfrog populations and through reduced chemical contamination. These techniques increase support for amphibians in a critical portion of their life cycle and could help buffer populations from declines in areas of rapid habitat loss and alteration.

Terrestrial habitat

Most amphibian species spend the majority of their time on land. Some species enter ponds only one night a year to lay eggs and then spend the remaining 364 days in the surrounding forest. After metamorphosis, juvenile amphibians leave the pond to find food and refuges from the summer heat and overwintering sites in terrestrial habitats.

Ponds are often used for breeding by a single population, which is faithful to that pond, and migrates to and from the pond each breeding season. They also appear to be faithful to the terrestrial habitat surrounding the pond. Individuals migrate in and out of the pond in the same place each year, and they travel several hundred meters away from ponds into the forest (462-939 feet [142-289 meters]; estimates for 32 species (19)) or fields, depending on species preference. This distance varies among species and sometimes between the sexes (15).

Therefore, the breeding pond and its surrounding natural vegetation form a *core habitat* that is essential for completion of the amphibian life cycle. Efforts to bolster amphibians must consider the core habitat a single management unit. The alteration, destruction or truncation of this habitat could compromise the ability of some amphibians to persist by decreasing the quality or quantity of resources or forcing individuals to migrate through habitats that increase risks of mortality (for example, roads with heavy traffic, mowed fairways, parking lots). A population dynamic model has shown that any truncation of terrestrial habitat around breeding ponds leads to higher probabilities of local population extinction (5). Population models have also indicated that protecting the terrestrial portion of the juvenile and adult population is more critical to species' persistence than protecting the aquatic larval population. Thus, more attention should be focused on the quantity and quality of terrestrial habitats for amphibians.

Amphibians appear to select a number of important macro- and micro-habitat features in the terrestrial environment. For example, during the summer, green frogs repeatedly leave the breeding pond (averaging 117 feet [35.6 meters] from the pond edge) (8) to forage for food to support breeding. Later in the year, green frogs migrate to small creeks and spring seeps where they overwinter, indicating that protected areas for terrestrial amphibian populations must include specific critical habitats as determined for the particular set of species.

Complementation and connectivity of habitats

We also need to maintain the complementation between aquatic and terrestrial habitats so that each is readily available for its respective life-history function. This means that the terrestrial core habitat required by metamorphosing juveniles and adults after breeding should be directly adjacent to the pond. Separation of aquatic and terrestrial habitats by fairways, roads or buildings would likely disrupt or potentially stop natural migrations and lead to population declines.

Why is connectivity among populations

Green frogs repeatedly leave the breeding pond to forage for food. **Photo by D.L. Drake**

Spotted salamanders are forest-dwelling amphibians that are reluctant to travel across grassland or pasture. **Photo courtesy of *USGA TERO***

important for amphibians? In a pioneering metapopulation study (4), red-spotted newt populations varied tremendously in their ability to produce offspring. Most populations produced few, if any, offspring and were considered declining or "sink" populations. A few populations produced many young and were considered "sources" for colonists to sink populations. The source populations producing numerous offspring changed over time.

The important point is that if most populations cannot replace dying adults with an equal number of new offspring, the populations could become extinct, especially if they suffer from drought, fish predation, disease or chemical pollution. Such populations can only be "rescued" if they are supplied with colonists migrating from source populations. The critical issue for managing terrestrial habitat is whether immigrants from source populations can readily move overland to colonize sink populations. Two factors determine the probability of an individual successfully immigrating: geographic distance between the adjacent populations and habitat resistance to overland movement.

Several independent studies have shown that individual amphibians can travel overland for no more than approximately 1.0 mile (~ 2 kilometer). If this is true for all amphibians, populations (pond-patches) that make up a metapopulation need to be within this distance. The distance between wetlands in a natural landscape like the South Carolina coastal plain is, on average, about 0.3 mile (471 meters) (18). Thus, ponds or streams on or near golf courses should not be separated by more than an average distance of about 650 to 1,650 feet (~200-500 meters).

The habitat between ponds must not contain barriers to overland travel of amphibians. Species vary tremendously in their ability to travel through terrestrial habitats. Forest-dependent species like spotted salamanders are often reluctant to cross more than 328 feet (100 meters) of grassland or pasture, whereas the American toad and green frogs readily travel across mowed grass and suburban landscapes. Maintaining corridors of natural vegetation between ponds (on or off course property) will facilitate amphibian movement and ensure that populations do not become permanently isolated or go extinct.

Management recommendations

The success of a management program to bolster amphibians depends on three elements:

- Potential or existing course layout, design and construction
- Routine monitoring and management of all land uses within the property
- Capacity to seek new information and to inform others

Many superintendents will find it natural to apply this program to amphibians because it is also the approach for creating a healthy, playable golf course. Questions to ask include:

- What amphibian species may occur in my local area?
- What aquatic and terrestrial habitats are they associated with?
- Do these habitats occur or have the potential to occur on my golf property?
- What threats do these species face, and how can I reduce or remove these threats on my property?
- What can be done to bolster amphibian populations?

The answers to these questions will help define the amphibian resources on the property and place management within a larger context focused on habitats and landscapes.

Course layout, design, and construction

Natural and created water bodies, including seasonal shallow "wet areas," are the best starting points for providing amphibian habitat, as these are sites of amphibian breeding. Wetlands and streams are functionally integrated with the uplands that surround them, and amphibians use 462-939 feet (142-289 meters) of land outward from their breeding sites as core terrestrial habitat. Every effort should be made to preserve or restore substantial acreage of existing natural upland vegetation around wetlands as core habitat by routing golf features around the upland vegetation. If necessary, a portion of the golf envelope may encroach on the upland, but most (75% or more) of the upland should be managed as native habitat (14), and the area immediately adjacent to the wetland (within 302 feet [93 meters]) should be undisturbed (15).

Connectivity

To maintain connectivity, corridors suitable for amphibian movement among core habitats should be preserved or restored with a recommended minimum width of 164 feet (50 meters). Golf

courses, with many discrete linear- and angular-shaped features arranged throughout a landscape, provide an ideal development model for providing both core habitats and corridors to connect them in the spaces between and among golf holes (Figure 1). For long-term persistence of amphibians on the course, it is important to connect core habitats not only within your property, but also to potential core habitats adjacent to your property — migrating amphibians do not recognize property lines!

Water bodies

Water bodies created on golf courses can augment existing wetlands and streams and provide more "source" populations or "stepping stones" for amphibian migration. The model for pond design for amphibians is best derived from natural wetlands in your region. In general, the best mix includes lots of small (0.25-0.5 acre [0.1-0.2 hectare]) and a few large ponds (2-5 acres [0.8-2 hectares]) with open and closed canopy and depths ranging from 6 to 24 inches (15-61 centimeters).

A diversity of wetland types creates variation in seasonal filling and drying and will support a greater diversity of native amphibians in both wet and dry years. Open-canopy pond margins should have a littoral shelf planted with native emergent vegetation with low slopes of 15:1 or less (13). The final design should include natural and created aquatic habitats no more than 220 to 550 feet (67-168 meters) apart as detailed above.

Innovative and effective stormwater designs (20) often include measures such as littoral shelves, which may do double duty in protecting amphibian habitat.

Renovation and construction

During clearing and construction, new or renovating golf courses must be especially attentive to existing amphibian populations that are using wetlands or streams and associated terrestrial core habitats. Besides the potential for direct damage to individuals, the activity may alter nutrient cycling, water quality, natural hydrology and vegetative structure. Solutions include creating and

Golf course habitat

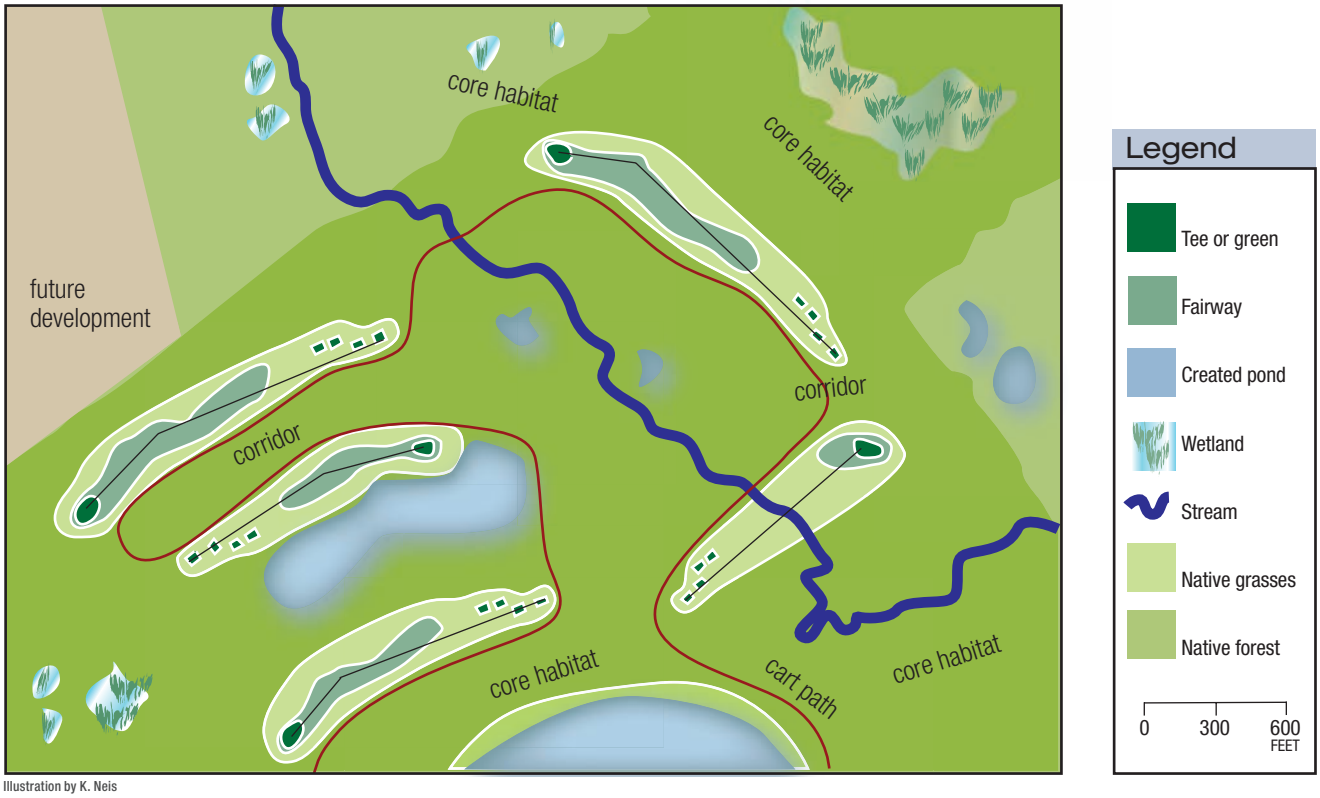

Illustration by K. Neis

Figure 1. Amphibians require adequate access from breeding ponds to their preferred terrestrial habitat (forests or grasslands). Fairways, roads or buildings can impede access to habitat and result in population decline or local extinction.

Fallen trees, limbs and leaves should be allowed to remain to maintain amphibian habitat. **Photo courtesy of T. Biebighauser**

following a comprehensive resource management plan before site work, flagging wetlands and core terrestrial habitat boundaries, minimizing site disturbance, incorporating vigilant construction management and protecting core areas.

Because stormwater is the primary vector for contaminants, protecting water resources also protects amphibian species. Measures such as effective best management practices including preventive and structural controls (20) preclude contamination of core habitats and corridors. The most effective way to protect both ground and surface water is by using a comprehensive BMP systems approach (2,20).

Management and monitoring

Management

Best management practices on the golf course are not relegated to construction but are best integrated into course design and implemented during construction and long-term management. Combining BMP and integrated pest management (IPM) programs together with efficiency in rate and timing of fertilizer application and irrigation will substantially reduce or eliminate water-quality problems (11,12) that directly affect aquatic amphibian breeding sites.

Tenets of IPM programs include the use of drought-resistant turf varieties, cultural and biological control of pests and good nutrient-management techniques (10). In addition, effective management of the maintenance area is an important part of water-quality management. The general approach is to isolate all potential contaminants from soil and water, not to discharge any material onto the ground or into surface water bodies and to minimize irrigation, fertilizer and pesticide use through the use of BMP and IPM (10).

Another layer of protection for amphibian populations is added by establishing restrictive management zones throughout the course. Management zones are areas that have distinct management practices that correspond with their position in the watershed and proximity to amphibian core habitats. Restricted practices should include "no mow, no spray" 25-foot-wide (7.6-meter) buffers adjacent to all core habitats including uplands, followed by another 25-foot-wide buffer where only organic fertilizers are allowed. All surface drainage from the course should be filtered through "management zone" vegetation or infiltrated before reaching core amphibian habitats (10).

Minimal management of terrestrial core habitats and corridors is necessary for amphibians. Although it may be essential to occasionally cut and remove dead trees or snags for safety reasons, allowing fallen leaves, limbs and trees to accumulate is a positive microhabitat feature for amphibians, especially salamanders.

Control burning is a common management practice in some regions to control invasives and to reduce fuel and fire risks in forests or prairies, but little is known about its potential effects on amphibians; burning during the coldest period of the year is likely to do the least harm. Mechanical or chemical measures to reduce or eliminate invasive exotic plants in terrestrial preserves are often necessary, but BMP and IPM programs should be followed to reduce direct and indirect impacts on amphibians.

Monitoring

Monitoring provides a means to measure the success of the management program. At a minimum, it should encompass sampling groundwater, surface water and sediment as well as amphibian populations in wetlands and ponds before and during construction and during routine maintenance to detect detrimental effects on these habitat variables. The goals of the monitoring program are to provide baseline data and data that assess biophysical conditions, and to ensure that the management programs are functioning properly.

Results of the monitoring program provide the superintendent with a useful management tool. For example, the results are used to determine the correct application rates and timing of pesticides and fertilizers and the effectiveness of course personnel training programs.

Finding diverse amphibian communities

where successful reproduction (indicated by presence of egg masses/strings), larval development and recruitment into the adult populations are occurring is another way to monitor for successful management. The presence of sustainable populations of local frogs and salamanders in all parts of their life cycle can be a biologically meaningful way to monitor terrestrial habitat and water quality. Because frogs and toads have unique calls associated with each species, calling surveys can be used to determine species presence and relative abundance. Many states have local frog call survey teams, which may be willing to help golf courses monitor their amphibian populations.

Education and outreach

Education and notification of residents and golfers of environmentally sensitive areas is an important part of the overall management strategy for surface waters and wetlands. Signs can identify areas that are ecologically sensitive or areas that golfers should avoid and also provide information about species that are of particular focus or concern. The scorecard should also identify these areas, and the starter can also notify golfers of the sensitive areas. Information should be posted in the clubhouse and other high-visibility locations.

There is great potential for outreach programs linked to local colleges, universities or conservation groups once interested citizen groups, students, professors or conservation agents are contacted. Information on amphibians can be gathered easily through a number of Web sites that are maintained by professional biologists and herpetologists (see the sidebar).

Conclusions

We believe that amphibians can provide a number of benefits to golf courses and the golfing community. Because pond-breeding amphibians occupy both aquatic and terrestrial environments, they play an integral role in most wetland, stream and adjacent forest ecosystems (16,17), and they perform a number of functions and services that are beneficial to all members of the ecosystem, including humans.

In the aquatic environment, frog and toad tadpoles consume vast amounts of algae, periphyton and plant material that would otherwise clog waterways and create algal mats. Salamander larvae consume zooplankton and aquatic insects like mosquito larvae that infest ponds, and in some regions, carry diseases like West Nile virus. Likewise, frogs, toads and salamanders consume large amounts of insect biomass, including pest species. Because they emigrate from ponds as metamorphosing juveniles, many of which do not survive, pond-breeding species help export nutrients from the aquatic environment into the terrestrial environment, often in large quantities. These nutrients are then made available to terrestrial plants and often provide food for terrestrial predators. Some researchers have found that amphibians help nutrient cycling to a degree that results in measurable differences in primary productivity where amphibians are present (1). Thus, amphibians provide a number of functions that are part of healthy ecosystems, which are inherently more stable and presumably need less active management.

The recreational needs of the human population are legitimate and important, but balancing the use of these natural resources with the conservation of biodiversity is also important. We have outlined a number of management elements that can be incorporated into existing golf courses and developed into new designs. If these recommendations are taken seriously, we believe that golf courses can become places where amphibians can thrive, regional diversity can be bolstered and amphibians can become a sentinel for a healthy ecosystem.

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Online resources

Conservation groups

Nature Serve
www.natureserve.org/

Audubon International
www.AudubonInternational.org

Amphibian information

Center for North American Herpetology
www.cnah.org/

Partners in Amphibian and Reptile Conservation
www.parcplace.org

International Union for Conservation of Nature and Natural Resources
www.amphibians.org./

AmphibiaWeb
http://amphibiaweb.org/index.html

Global Amphibian Assessment
www.globalamphibians.org/

Amphibian habitat recommendations

1. Preserve and restore existing seasonal or temporary wetlands and streams, including their natural ability to fill and dry, typically in late summer/autumn.
2. Provide created ponds without fish by regularly netting or by draining during late summer/autumn.
3. Preserve, restore and create many sizes and types of ponds, wetlands and streams with and without forest canopy and no more than 650-1,650 feet (200-500 meters) apart.
4. Include forested and grassed uplands around aquatic sites that extend 462-939 feet (142-298 meters) from the water with management for native habitat in at least the 328 feet (100 meters) closest to the water. Manage aquatic and surrounding terrestrial areas together as amphibian core habitat.
5. Augment core habitats with minimum 164-foot-wide (50-meter-wide) corridors of managed native forest and grasses between ponds.
6. Use best management practices, integrated pest management and a management plan during golf course construction and maintenance to reduce or eliminate pollutants.
7. Monitor surface and groundwater quality to assess the effectiveness of the management plan.
8. Monitor amphibian populations for successful reproduction, juvenile recruitment and a diverse group of species.
9. Adapt management as needed based on monitoring and current research.
10. Reach out to local, regional and national groups to educate and be educated on amphibians and golf.

Table 1. Summary of recommendations for bolstering amphibians on golf courses.

The research says

→ For golf courses to serve as sanctuaries for amphibians, design and management of the habitat areas must focus on the biological needs of amphibians.

→ For aquatic habitats, fish must be eliminated, and a diversity of pond types should be maintained or created to mimic natural wetlands in the region.

→ Best management practices and Integrated Pest Management should be used to buffer aquatic habitats from chemical runoff; surface and groundwater quality should be monitored.

→ All wetlands should be surrounded by a core habitat of forest and native grasses or a combination, extending 488-975 feet from the water and uninterrupted by barriers.

→ Terrestrial connectivity of wetlands is essential for overland movement of amphibians, recolonization and long-term persistence of populations.

→ Education and outreach with local, regional and national groups on amphibians and golf is essential to staying informed, modifying management strategies and maximizing the benefit to humans and wildlife.

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