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CHAPTER 19

Enhancing Amphibian Biodiversity on Golf Courses with Seasonal Wetlands

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Abstract — Ecologists recognize the value of seasonal wetlands, but these wetlands are often ignored in landscape management decisions and practices, including golf course design. We sampled the amphibians and reptiles that use wetland habitats on five golf courses for three years in the sandhills of South Carolina and Georgia, and compared these survey data to concurrent surveys at 11 nearby (off-course) seasonal wetlands. Two of the golf courses sampled had on-course seasonal wetlands, which allowed us to compare amphibian diversity on these courses to the other three golf courses that did not have seasonal wetlands. Permanent wetlands were more numerous than seasonal wetlands on the golf courses we sampled. However, greater amphibian species richness occurred at both off-course and on-course seasonal wetlands compared to golf course permanent lakes and ponds — 24 species were sampled at comparison seasonal wetlands, 18 species at the two courses with seasonal wetlands plus permanent aquatic habitats, and 11 species at the three golf courses with only permanent wetlands. Permanent golf course wetlands harbored numerous fish species and contained only the few amphibian species that can tolerate fish. Much of the difference between the species lists for golf courses with and without seasonal wetlands results from the presence of amphibian species that use fish-free wetlands on the golf courses that have seasonal wetlands. Examples include: *Ambystoma opacum* (Marbled Salamander), *Ambystoma maculatum* (Spotted Salamander), and *Gastrophryne carolinensis* (Eastern Narrow-mouthed Toad). These results demonstrate that the incorporation of seasonal wetlands into the design of the golf-course landscape would likely enhance amphibian biodiversity. Well-designed and managed golf courses, like other open space habitats, could play a pivotal role in the "new urbanism" (Song and Knapp 2003).

Key Words — Fish-Free Wetlands, Golf Course Design, Hydroperiod, Temporary Ponds, Wildlife Sanctuary

Because wetlands bring beauty and wildlife to any recreational site, builders frequently integrate them into golf course design (Peacock et al. 1990, p. 7)

The golf industry suggestion to "Play golf America" seems to have worked. In 1998 there were 569 million rounds of golf played by 26.4 million people in America (Florkowski and Landry 2002). Participation levels have remained high, with an average of approximately 500 million rounds played per year in 2002 and 2003, and as of December 2006 there were 15,990 golf facilities in the US (National Golf Foundation, NGF, www.ngf.org, accessed 3 March 2008). During the 1990s, annual increase in the number of new golf courses constructed averaged about 340 per year. At the end of 2006, there were 968 18-hole equivalents being prepared, including 283 under construction, 305 in planning and 260.5 proposed (NGF website). Roughly 70% of the new golf courses will be part of a residential community, compared to 22% of existing courses that are part of a suburban or urban setting. Assuming an average acreage for courses of 61–81 ha, golf courses account for roughly 1.21 million ha of land use in the US; by comparison, state park total acreage is roughly 4.82 mil-

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lion ha (3.52 million ha excluding Alaska), and national parks total 34 million ha. Clearly golf courses constitute an important greenspace land use in the US (Santiago and Rodewald 2004).

The Golf Course Superintendents Association of America (GCSAA) touts two of the environmental benefits of golf courses as "key sanctuaries and habitat for wildlife" and "wetlands preservation areas" (www.gcsaa.org/, accessed 3 March 2008). Few studies have examined whether golf courses can indeed be refuges for biota, although there is evidence that some species-rich habitats (e.g., forests) that have been eliminated in the surrounding landscape may be retained on golf courses (Tanner and Gange 2005; Yasuda and Koike 2006). Rough and out-of-play (ROP) areas can account for 40–70% of the total course area (Kiss 1998; Santiago and Rodewald 2004), and as such have significant conservation potential (Gange et al. 2003). The inclusion of "amphibian friendly" wetlands on golf courses should be an important goal of golf course design (Howard et al. 2002) and would serve the dual function of biodiversity protection and wetland preservation.

Seasonally flooded wetlands are extremely important habitat for many species (e.g., plants—Kirkman and Sharitz 1994; aquatic invertebrates—Taylor et al. 1989), including amphibians (Semlitsch et al. 1996). Additionally, many species of semi-aquatic reptiles and amphibians use small wetlands and surrounding uplands as linked habitats, both portions of which are vital to the organisms' survival (Burke and Gibbons 1995; Gibbons 2003). These isolated, ephemeral wetlands are an important refuge for wildlife species, particularly in agricultural landscapes where the wetlands are the last remaining unexploited habitat (Sharitz and Gibbons 1982). Thus, as more and more agricultural lands are converted to other uses such as suburban developments and golf courses (Kiss 1998; Gange et al. 2003), it is critical to maintain seasonal wetland functions and values on the new landscape. The golf course landscape may provide an ideal opportunity to combine golf course design objectives with conservation goals such as habitat protection and biodiversity enhancement (Green and Marshall 1987; Terman 1997; Kiss 1998).

Our objectives were to examine the relationship of amphibian species richness to the variety of wetlands found on golf course landscapes, and to compare the diversity and abundance of amphibians in permanent aquatic habitats to that of seasonal wetlands, among and between golf courses and at off-course reference wetlands. Based on our results, we developed recommendations for enhancing biodiversity on golf courses by increasing spatial distribution and abundance of seasonal wetlands as part of golf course landscape design.

MATERIALS AND METHODS

Our study was conducted in the Central Savannah River Area (CSRA) of the midlands of Georgia and South Carolina, where approximately 37 golf courses and 52 species of amphibians occur, of which 22 species primarily use seasonal wetlands for breeding and larval development (amphibian data compiled from species accounts in Lannoo 2005 by D. Scott). The five golf courses that participated in the study were located in Aiken County (n = 3) and Edgefield County (n = 1), South Carolina, and Columbia County (n = 1), Georgia. The age of the courses ranged from 4 to >25 yrs old at the time we sampled. Of the two youngest (<9 yrs old) and two oldest (>25 yrs) golf courses, one of each pair had a seasonal wetland and the other only permanent water; the remaining 15-yr-old course had only permanent water. Natural seasonal wetlands that were sampled for comparative purposes were located on the Department of Energy's Savannah River Site (SRS) in Aiken and Barnwell Counties, SC. The SRS wetlands were all isolated depressional wetlands, including "Carolina bays" (Sharitz and Gibbons 1982), and were chosen to represent a range of wetland size, hydroperiod, and biota (Snodgrass et al. 2000).

Wetlands sampled at golf courses included lakes, ponds, and streams, as well as single seasonal wetlands at two courses (Table 1). We sampled wetlands on and off golf courses at 2-mo intervals throughout the year to account for differences in breeding chronology; seasonal wetlands were sampled only when water was present. Each sample period consisted of four days/three nights of trapping with small-meshed minnow traps, supplemented by dip-netting, hoop-net trapping, hand collecting, and visual observations (Heyer et al. 1994). Sampling in off-course seasonal wetlands began in April 1999; golf course wetland sampling at five courses was added in late summer of 1999. Sampling continued regularly at golf course wetlands throughout 2000 until October 2001, but due to drought conditions many of the off-course seasonal wetlands were dry in these years; thus some of the comparison wetlands had a reduced trapping effort compared to the permanent aquatic habitats (Table 1). Both adult and larval amphibians were captured by our sampling efforts; small larvae that were difficult to identify were raised to larger size or metamorphosis to assist in identification. Fish were also identified and numbers of captures recorded.

At the two courses that contained a seasonal wetland, we installed a 50-m partial drift fence with pairs of 2-L can pitfall traps at 8-m intervals for a portion of one year. These drift fence capture data enabled us to determine the larval success (i.e., successful metamorphosis) of selected species and better assess the ecological value of the seasonal wetland on the golf course landscape.

RESULTS

On the three golf courses that had only permanent waters (i.e., lakes, ponds, and streams) we had 3,085 captures of 11 amphibian species and 6,677 captures of 16 fish species (Tables 2, 3). On the two courses that had a single seasonal wetland in addition to permanent waters, we had 1,618 captures of 18 amphibian species and 6,853 captures of 15 fish species. The partial drift fences at the two on-course seasonal wetlands

Table 1. Total number of habitats sampled at five golf courses in the midlands of South Carolina and Georgia, with total trap nights at on- and off-course wetlands.

Site	Pond/Lakes sampled	Creek/Streams sampled	Seasonal Wetlands sampled	Total trap nights
Course 1	4	2	0	768
Course 2	1	2	0	257
Course 3	4	3	0	579
Course 4	6	1	1	1026
Course 5	3	2	1	687
subtotal	18	10	2	3317
Bay 40			1	33
Bay 58			1	9
Caroline's Bay			1	145
Dry Bay			1	621
Ellenton Bay			1	581
Flamingo Bay			1	188
Ginger's Bay			1	60
Mona Bay			1	51
Sarracenia Bay			1	36
Bay 139			1	215
Steel Creek Bay			1	111
subtotal			11	2050

confirmed successful metamorphosis for four amphibian species. In our comparison wetlands, we had 5,976 captures of 24 amphibian species (Table 2) and 909 captures of 10 fish species (Table 3); only three of the reference seasonal wetlands contained fish at some time during our sampling (Bay 40, Steel Creek Bay, and Sarracenia Bay).

Sampling confirmed a well-known trend in amphibian ecology—wetlands that harbor fish populations are generally not suitable for a diversity of amphibian species. In the permanent waters on CSRA golf courses we found primarily three amphibian species — Bullfrogs (*Rana catesbeiana*), Green Frogs (*R. clamitans*), and Southern Toads (*Bufo terrestris*) or Fowler's Toads (*B. fowleri*), depending on location. For those courses that had solely permanent aquatic habitats, these three species accounted for 98.8% of all amphibian captures (C1–C3; Table 3). These same three species comprised only 64% of the total amphibian captures on the two golf courses that had both permanent and seasonal wetland types. On these two golf courses, we also trapped several pond-breeding species in the seasonal wetlands that were not present in the on-course permanent waters including Marbled Salamanders (*Ambystoma opacum*), Spotted Salamanders (*A. maculatum*), and Narrow-mouthed Toads (*Gastrophryne carolinensis*) (Table 2).

All golf course lakes and ponds contained numerous predatory fish species, including Largemouth Bass (*Micropterus salmoides*), Redfin Pickerel (*Esox americanus*), Mosquitofish (*Gambusia affinis*) and species of sunfish (*Lepomis* sp.) (Table 3).

The seasonal comparison wetlands that we sampled away from golf courses had greater numbers of amphibian species than permanent golf-course wetlands. Off-course seasonal wetlands generally had 2–3 additional salamander species and 2–5 additional frog and toad species (Table 2). Although the comparison wetlands we sampled are "isolated," most have been ditched in the past and several sites are connected to nearby creeks during high water; these aquatic connections permit the invasion of fish at some sites in some years (Snodgrass et al. 2000). We observed the same pattern as at the permanent waters on golf courses at three comparison wetlands in years when fish were present — a relatively depauperate amphibian fauna. At Steel Creek Bay, we captured only Greater Sirens (*Siren lacertina*), Two-toed Amphiumas (*Amphiuma means*), Bullfrog tadpoles, and a single Mole Salamander (*A. talpoideum*) in conjunction with six fish species; no amphibians were captured at Bay 40 (five fish species). The most striking example of the effect of fish on amphibian communities in these seasonal wetlands occurred at Sarracenia Bay, which was sampled in one year when fish were present and one year when fish were absent. In 1999, the fish species present at the site included *E. americanus* and Mud Sunfish (*Acantharchus pomotis*) — the only amphibian species captured was the Cricket Frog (*Acris gryllus*). After fish were killed following drying of the bay, we sampled it again in spring of 2001; no fish were present, and nine species of amphibians were captured, including the Carolina Gopher Frog (*Rana capito*).

Discussion

Species inhabiting the permanent golf-course wetlands were the "expected" species, i.e., those known to be tolerant of fish and able to use permanent waters for breeding, such as

Table 2. Amphibian captures on five golf courses, C1-C5 (three *without* seasonal wetlands and two *with* seasonal wetlands), compared to totals from eleven off-course comparison seasonal wetlands. "X" indicates species presence; the "All" column summarizes capture totals of individuals across all courses; the "seasonal" column is individual capture totals for the two courses with seasonal wetlands.

Amphibian Species	Without			With		All	Seasonal	Comparison	
	C1	C2	C3	C4	C5	Total ind.	Total ind.	Off-course	Off-course Total
Necturus punctatus		X				1	0		0
Amphiuma means						0		X	1
Siren lacertina		X		X		9	8	X	9
Siren intermedia		X				9		X	6
Ambystoma talpoideum						0		X	2193
Ambystoma opacum					X	58	58	X	131
Ambystoma maculatum				X	X	414	414		0
Notophthalmus viridescens	X			X		21	20	X	209
Plethodon chlorobryonis					X	2	2	X	18
Desmognathus auriculatus			X	X		7	5		0
Pseudotriton montanus		X	X	X		4	2	X	2
Eurycea cirrigera				X		1	1		0
Eurycea guttolineata		X				1			0
Eurycea quadridigitata								X	2
Scaphiopus holbrookii								X	320
Bufo terrestris	X	X	X	X		2058	321	X	352
Bufo fowleri					X	100	100		
Acris gryllus				X		4	2	X	41
Acris crepitans					X	9	9		
Hyla cinerea				X		3	3	X	74
Hyla gratiosa								X	1
Hyla femoralis								X	6
Hyla squirella								X	20
Pseudacris crucifer				X	X	1	1	X	187
Pseudacris nigrita								X	150
Pseudacris ornata								X	174
Gastrophryne carolinensis				X		53	53	X	718
Rana catesbeiana	X	X	X	X	X	557	288	X	9
Rana clamitans	X	X	X	X	X	1018	314	X	281
Rana sphenocephala	X		X	X	X	18	5	X	829
Rana capito								X	10
Total species (or individuals)	5	8	6	14	9	4348	1606	24	5743

Bullfrogs, Green Frogs, and Southern Toads. At the on-course seasonal wetlands, we sampled several species generally associated with shorter hydroperiod wetlands lacking fish, including Marbled Salamanders, Spotted Salamanders, and Narrow-mouthed Toads. At the off-course comparison sites, we found many species not captured on any golf course, including Mole Salamanders, Ornate Chorus Frogs, Spadefoot Toads, and Gopher Frogs, a species of special concern in SC (Buhlmann et al. 2005). Because we sampled a wider variety of habitats (e.g., streams and marshes) on golf courses, we found additional amphibian species including the Lesser Siren (*Siren intermedia*), Dwarf Waterdog (*Necturus punctatus*), and Mud Salamander (*Pseudotriton montanus*).

Seasonal wetlands are important from an ecological perspective because they retain surface water for only a portion of a year (Schalles et al. 1989). The hydroperiod, or length of time that a wetland holds water, has an overriding influence on the biota that can live and reproduce in or near the wetland, especially with regard to amphibians and other semi-aquatic taxa (Pechmann et al. 1989; Wellborn et al. 1996; Snodgrass et al. 2000; Paton and Egan 2003). Permanent lakes and ponds are at one end of a hydroperiod continuum; most water hazards on golf courses can be categorized as "permanent" and are usually inhabited by large predatory fish species (e.g., Largemouth Bass, Bluegill, Pickerel). Only those amphibian species with adaptations to avoid fish predation such as Bullfrogs can

Table 3. Fish species captured at golf course wetlands (C1-C3 without seasonal wetlands, C4-C5 with a seasonal wetland) and at three comparison seasonal wetlands (Bay 40 [40], Sarracenia Bay [SB], and Steel Creek Bay [SCB]).

Scientific Name	Common Name	Without			With		Comparison		
		C1	C2	C3	C4	C5	40	SB	SCB
Acantharchus pomotis	Mud Sunfish		21	262	2			9	
Ameiurus sp.	Catfish			64					2
Aphredoderus sayanus	Pirate Perch		13			1			
Ctenopharyngodon idella	Grass Carp	2			1	1			
Enneacanthus chaetodon	Blackbanded Sunfish		47						
Erimyzon sp.	Chubsucker			105	92	1		29	
Esox americanus	Redfin Pickerel		18		15		2	5	
Esox niger	Chain Pickerel				1				
Gambusia holbrooki	Eastern Mosquitofish	84	162	344	2105	570			698
Lepomis gulosus	Warmouth	41		6	29	8	5		9
Lepomis macrochirus	Bluegill			2	2				
Lepomis punctatus	Spotted Sunfish				1				
Lepomis sp. juveniles	Sunfish	4272	13	1001	753	1844	4		3
Micropterus salmoides	Largemouth Bass	2			6	14			
Notemigonus crysoleucas	Golden Shiner						2		
Notropis sp.	Shiner	54	9	81	252	70			
Noturus sp.	Madtom		3						
Semotilus atromaculatus	Creek Chub	87		83	415	23	3		1
Umbra pygmaea	Eastern Mudminnow				633	13			139

succeed in these habitats (see also Paton and Egan 2003). In general, most amphibian species are preyed upon heavily by fish (and Bullfrogs) and do not fare well in permanent water (Heyer et al. 1975; Gamradt and Kats 1996). Most "pond"-breeding amphibian species actually require seasonal wetlands for breeding and for the larval stage of their life cycles.

Wetland loss in the southeastern U.S. has been of concern for many years (Hefner and Brown 1985; Gosselink and Lee 1989). The loss of wetlands in the southeastern US from the 1950s to the 1970s was greater than any other region of the country, with a net annual loss of 156,000 ha per year (Hefner and Brown 1985). On the Coastal Plain of North Carolina for example, 51% of all wetland acreage had been lost by 1980 (Richardson 1991). This loss includes pocosins, a category of seasonal wetlands, approximately 70% of which have been either totally destroyed through urban or suburban development, partially altered, or are scheduled for development (Richardson 1983). In South Carolina, isolated freshwater wetlands account for over 22% of the total wetland acreage (Wagner et al. 1991), yet alteration and destruction of these types of wetlands has also been severe. A survey of the status of Carolina bays on the Coastal Plain of South Carolina found that approximately 97% have been altered or severely impacted, and fewer than 200 Carolina bays of the original thousands remain "relatively unimpacted" (Bennett and Nelson 1991).

Thus, while increasingly recognized as the most valuable wetland habitat type for maintaining amphibian diversity in the Southeast, seasonal wetlands continue to rapidly disappear and remain unprotected by most wetlands regulations (Semlitsch and Bodie 1998; Sharitz 2003). A concerted effort by golf course architects and superintendents to preserve and even create new seasonal wetlands has the potential for great conservation value. We observed enhanced amphibian diversity with just a single seasonal wetland in a golf course landscape. From a design standpoint, the incorporation of seasonal wetlands into a course layout has the potential to make a course more varied, aesthetically pleasing, and challenging. From a conservation standpoint, several isolated seasonal wetlands scattered across a habitat mosaic of forested and open areas on a course may create a biodiversity boon for amphibians. At the landscape-level scale of a golf course, the presence of numerous seasonal wetlands that vary in size and hydroperiod will likely support different groups of amphibians due to the relationship between hydroperiod and amphibian species composition (Snodgrass et al. 2000). In conjunction with permanent water hazards, seasonal wetlands of varied types will create a hydroperiod continuum across the landscape that will be used by a diverse array of species.

Pond-breeding amphibians with their complex life cycle (Wilbur 1984) have additional habitat needs beyond the wetland boundary (Gibbons 2003). It is likely that for a seasonal wetland to serve as a population source for a variety of species the wetland will need to be at least partially embedded in an unfragmented forested habitat (Paton and Egan 2003). Since rough and out-of-play (ROP) areas account for a large portion of the golf course landscape and often contain the sole remnants of forested habitat, ROP areas are a logical choice for the inclusion of seasonal wetlands. In general, ROP areas also receive fewer chemical inputs than the turfgrass areas of a course (Kiss 1998; US EPA 2005). Effects of chemicals on water quality and amphibians that inhabit golf course wetlands can be of concern (Mankin 2000; Howard et al. 2002). It is unknown whether the negative effects of pesticides, insecticides, and fungicides on amphibian eggs and larvae that have been observed under constant water conditions (Howard et al. 2002) will be any different in a variable hydroperiod seasonal wetland. Further research is needed to be certain that seasonal wetlands are indeed valuable additions to golf course landscapes and do not function as ecological traps for amphibians (sensu Kristan 2003). Placing seasonal wetlands in ROP areas that receive minimal chemical inputs would be the safest course of action at this time. However, using ROP areas for seasonal wetlands and natural habitat may be incompatible with the recent trend in course designs of devoting more of the ROP areas to residential development (estimated as 30% in Kiss 1998), a trend which may be exacerbated due to increased property value adjacent to golf courses (Do and Grudnitski 1995). We witnessed this trend, as after our sampling was completed the seasonal wetland at one course was eliminated as new houses were constructed adjacent to the course.

The creation of true variable-hydroperiod seasonal wetlands "from scratch" is largely an unknown science. Although protocols exist for restoring previously degraded wetlands (e.g., Stevens et al. 2003), little research has been conducted towards the goal of creating wetlands with variable hydroperiods that mimic natural seasonal wetlands (but see Biebighauser 2002). Given the need for and benefit of seasonal wetlands on a golf course landscape, additional studies that determine the best methods for constructing these habitats are essential.

In an urban design movement termed the "new urbanism," open spaces will be an important design element along with high density housing, mixed use neighborhoods, convenient public transit, and social gathering places (Song and Knaap 2003). Inclusion of open space in an urban setting is one of several smart growth trends that homebuyers desire (McMahon 1999). As a form of open space, well-designed and managed golf courses can have important habitat and biodiversity values, although there are limits. For example, on a gradient of pristine to heavily urbanized habitat, golf courses may only harbor half the species of woodland birds found in natural preserve areas, but they may also be more species rich than either preserves or more urbanized areas due to their habitat heterogeneity (Blair 2004). Although we observed that golf courses with seasonal wetlands had relatively enriched amphibian diversity compared to those without, the diversity was nonetheless below that observed at our comparison sites. Additional studies of amphibians along an urbanization gradient might reveal a similar pattern; i.e., species most sensitive to forest fragmentation being eliminated with decreasing forest cover (Gibbs 1998). Nonetheless, an appropriately designed golf course has the potential to play a beneficial role in an urban landscape.

Summary and Management Recommendations

Most golf course water hazards had a lower diversity of amphibians than comparison seasonal wetlands (i.e., similar sized, natural wetlands with variable hydroperiods). We observed enhanced amphibian diversity at golf courses that had just a single seasonal wetland. Consequently, we predict that incorporating more seasonal wetlands into the design of golf courses will increase the biodiversity of amphibians and other semi-aquatic animals. This idea cannot be tested until seasonal wetland habitats are implemented in golf course designs, and the amphibian populations are monitored to be certain that golf course seasonal wetlands do not function as hazardous ecological traps. However, our extensive sampling of seasonal wetlands indicates that if the wetland itself is "intact," and if there is suitable adjacent terrestrial habitat coupled with source populations, then it is likely that amphibians and other wetland species will thrive. We recommend that seasonal wetlands be incorporated into golf course designs, particularly in ROP areas where there is adjacent forest habitat. Getting these recommendations adopted will hinge on quantitative follow-up studies and successfully educating the golf community on the value of seasonal wetland habitats.

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