Response of Plant and Invertebrate Communities to Pothole Blasting in a Giant Cutgrass Marsh

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Abstract: Thousands of hectares of tidally-influenced, forested wetlands were cleared in the South Atlantic Coastal Zone and put into rice production during the eighteenth and nineteenth centuries. Many of these ricefields were abandoned in the late 1800s and were not maintained thereafter; hence, they no longer have functional dikes and provide poor habitat for waterfowl and wading birds due to colonization by dense stands of giant cutgrass *(Zizaniopsis miliacea).* Because efforts to open these extensive stands with herbicides and fire have been largely unsuccessful, in April 1997 we used an ammonium nitrate gel to blast a cluster of five potholes in a 162–ha abandoned ricefield system in Georgetown County, South Carolina. Potholes ranged from 100–175 m^2 and cost ranged form US$700 to $1,000 per pothole. Our objectives were to estimate and compare plant community characteristics and invertebrate biomass in the pothole cluster and control sites. We evaluated coverage of giant cutgrass and other vegetation 6 and 18 months post-treatment and estimated invertebrate biomass in November and March, one and two years after blasting. Giant cutgrass coverage was greatest along the edge and decreased in coverage from the edge to the middle of potholes. Giant cutgrass coverage increased in potholes during the 2-year period, but remained less dense than in other control sites. Biomass of isopods (O. *Isopoda*), amphipods (O. *Amphipoda*), and leeches (Cl. *Hirudinea*) increased from fall (November) to spring (March) in control and pothole sites. Amphipod biomass was greater in pothole than control sites each spring ($P < 0.05$). Blasted potholes in abandoned ricefields reduced emergent vegetation cover and provided open water for at least two years. In historically altered ricefield marshes with broken dikes and water control structures that cannot be repaired, blasting potholes is an option for improving the diversity of waterfowl and wading bird habitat in extensive giant cutgrass stands. However, more data from larger-scaled studies are needed to determine if open water areas will persist longer than two years, provide winter foraging and loafing sites, as well as refuge from disturbance.

Key words: giant cutgrass, macroinvertebrates, potholes, South Carolina, *Zizaniopsis miliacea.*

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More than 8,200 ha of freshwater wetlands were converted from gum-cypress (*Nyssa* sp.-*Taxodium* sp.) swamps to managed ricefields during the eighteenth and nineteenth centuries along the Pee Dee/Waccamaw River system in Georgetown County, South Carolina (Hilliard 1975). When rice production became unprofitable in the late nineteenth century, ricefields in tidal freshwater wetlands were abandoned. In later years many of these impoundments, although no longer planted in rice, were refurbished to provide excellent habitat primarily for wintering, migratory waterfowl. Water levels in these impoundments can be manipulated to favor desirable food plants and vegetation cover, and for this purpose sometimes elaborate management systems have been devised. This habitat base still provides for much recreational waterfowl hunting activity in the region.

Dikes and water control structures of former ricefields were destroyed due to neglect and storms. Reestablishment of these structures and dikes is not feasible because such work does not comply with regulations in Section 404 of the Clean Water Act (Federal Register 2002:2078). Most abandoned ricefields with broken dikes in the South Atlantic Coastal Zone (SACZ) are now dominated by emergent, nearly homogeneous stands of giant cutgrass that thrive under the unmanaged twice daily tidal fluctuations These giant cutgrass marshes typically provide habitat for few species of waterbirds or waterfowl (Chabreck 1967, Gordon et al. 1998).

Giant cutgrass, also known as southern wildrice, generally is considered undesirable and a potential nuisance (Payne 1992). It is a monoecious perennial that can grow up to 3 m tall and form dense stands (Aulbach-Smith and Kozlowski 1996). Once established, these dense stands exclude the growth of many desirable food plants and reduce the availability of what foods might be present. The range of giant cutgrass extends from Texas and Oklahoma in the west, to Florida and Maryland in the east. It occurs in both tidal and nontidal marshes in freshwater systems, occasionally occurring in slightly brackish areas (Tiner 1993).

Wetlands featuring a 50:50 ratio of emergent hydrophytes to open water (hemimarsh), provide the necessary mix of components for excellent macroinvertebrate production (Baldassare and Bolen 1994) and provide greater invertebrate biomass than systems with >50% emergent vegetation coverage such as giant cutgrass marshes. When openings are interspersed in marshes dominated by emergent vegetation, detritus accumulates and is available to invertebrates (Payne 1992). Openings, including potholes, have been created in marshes using mechanical equipment (e.g., backhoes, dredges) or explosives to blast soil from the marsh bed. Blasting to create potholes in dense stands of emergent vegetation (Scott and Dever 1940, Provost 1948) produces open water habitats necessary for invertebrate production.

Attempts to control giant cutgrass or create persistent openings in stands of it have met with only limited success. Mechanical means such as mowing or disking, burning, application of herbicides, and combinations of these techniques are all enhanced by the ability to selectively manipulate the water level in the target areas (Wood et al. 1996). To diversify and enhance habitat where water level manipulation was not possible, we examined the efficacy of creating openings within giant cutgrass marsh with an array of ammonium nitrate-diesel fuel gel pack explosives.

Study Site

Our study was conducted in a 162-ha freshwater tidal marsh in northern Georgetown County, South Carolina. The marsh was bordered by the Pee Dee River on the west and north and Jericho Creek on the east; the Pee Dee River and Jericho Creek converged at the southern tip of the marsh. The marsh was an unmanaged remnant of the agrarian rice culture that ended in the late 1800s. The original dikes of the ricefields had deteriorated so the fields were open to twice daily tidal inundation, and the area was dominated by homogeneous stands of giant cutgrass. Three 0.4-ha abandoned ricefields within the marsh system were selected and randomly assigned to either the treatment or control group. Ricefields were 275 m apart and separated by the original ditch/dike system. Soils and topography were similar among ricefields.

Methods

Given the inability to manipulate water levels in our study site, we evaluated blasting as a means of opening the giant cutgrass dominated marsh. We hypothesized that potholes established by blasting would increase the availability and abundance of plant foods and invertebrates for waterfowl and wading birds. Our treatment consisted of creating potholes in the marsh by placement and detonation of explosive charges. We obtained U.S. Department of the Army and South Carolina Department of Health and Environmental Control permits for experimental blasting in accordance with Sections 401 and 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Restrictions of the permits did not allow replications of the blasting arrays in more than one ricefield or marsh system. Two ricefields, therefore, were assigned to the control group and one to the treatment group.

In April 1997, five potholes, each 46 m apart, were created in a cluster within the treatment ricefield. For each pothole, 25 to 30 PVC pipes, 0.9 m long and 7.6 cm diameter each, were placed in a circular array and inserted vertically into the marsh substrate and 1.5 to 2 ammonium nitrate-diesel fuel gel packs were inserted in each pipe (approximately 22.6 kg of explosives/pothole). Non-electric delay detonators were used to ignite the gel packs. Areas of resulting potholes ranged from about 100 to 150 m^2 and average depth was about 0.5 m in each pothole at low tide. Total cost per pothole ranged from $700 to $1,000.

In September 1997 and 1998, we measured vegetation within treatment and control sites. In each control site, a 0.25-m^2 square frame was placed at 100 random points. Coverage (%) of all plants in each frame was estimated. In the treatment site, plant coverage estimates in a 0.25-m^2 square frame were recorded at 10 random points from three regions of each pothole: 25 cm from the pothole edge into the marsh, 25 cm from the pothole edge into the shallow water, and >25 cm from the pothole edge into the water. In total, 30 observations were recorded from each of the five potholes, yielding 150 estimates of plant coverage from the treatment site.

We placed Hester-Dendy type multiplate samplers (Murkin et al. 1994) in both control and blasted sites for approximately four weeks to allow invertebrates to colonize. In each pothole, one sampler was placed 1 m from the edge and one was placed directly in the center. Ten multiplate samplers were placed at randomly selected points within each control site. Each multiplate sampler consisted of 14 round plates, 7.5 cm in diameter (Mason et al. 1973). Different spacing between plates allowed different species of invertebrates to colonize. Samplers were set in late October 1997 and 1998, and retrieved in late November to determine invertebrates present during late fall. Samplers were again set in late January 1998 and 1999 and retrieved in March to measure invertebrates in early spring. Invertebrates from the samplers were preserved in the field in a 70% ethanol solution. Invertebrates were sorted and identified to the lowest possible taxon, counted, placed in an oven at 60C, and dried to a constant weight. The mass of each taxon was recorded to the nearest 0.001 g.

Because the blasting treatment was not replicated in additional experimental units (ricefields), this investigation operated under the restrictions of a pseudoreplicated study (Hurlbert 1984). However, our pseudoreplication of random samples within ricefields simulated true replications, because ricefields had similar patterns of variability within the overall marsh system and the variability among sample plots within each ricefield reflected variability among ricefields. We used two-factor analysis of variance (ANOVA) to detect differences among estimates of plant coverage (%) and invertebrate abundance (mass in grams) in which ricefield and year were effect factors. We used Tukey's test to compare means following a significant *F*–test at α=0.05.

Results

In September 1997, giant cutgrass was most prevalent in control sites and pothole edges (Table 1), and it remained prevalent at these sites in September 1998. In shallow water areas of potholes, percent coverage of giant cutgrass increased from 1997 to 1998 (Table 1).

In 1997, water primrose *(Ludwigia hexapetala)* occurred in small amounts ($\bar{x} <$ 5%) in the pothole sites and was absent in control sites. By 1998, coverage of water primrose increased in shallow water areas of the potholes, and in the middle of potholes water primrose was the most abundant plant species. The high coverage values for water primrose in shallow and middle areas of potholes (23% and 40%, respectively) in September 1998 resulted from its 100% colonization of two of the five potholes. The three other potholes remained free of water primrose or only had trace amounts. Smartweed *(Polygonum punctatum),* softstem bulrush *(Scirpus validus),* and pickerelweed *(Pontederia cordata)* colonized the potholes and increased from 1997 to 1998, although coverage remained $\leq$5% (Table 1).

Biomass of isopods (O. *Isopoda*), amphipods (O. *Amphipoda*), and leeches (Cl. *Hirudinea*) increased from fall (November) to spring (March; Table 2). Amphipod biomass was greater in pothole than control sites each spring ($P < 0.005$). Little biomass of chitons (O. *Chitonida*), bivalves (Cl. *Bivalvia*), oligochaetes (Cl. *Oligochaeta*), and diptera (O. *Diptera*) was detected in our study site.

Table 1. Estimated plant coverage (%) in control and blasted pothole sites in tidal marshes of Georgetown County, South Carolina, September 1997 and 1998.

Species	1997								1998							
			Pothole								Pothole					
	Control		Edge[a]		Shallow		Middle		Control		Edge		Shallow		Middle	
	$\bar{x}^b$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Zizaniopsis miliacea	36.6c	2.2	38.7c	4.6	3.5b	1.5	0.1a	0.1	42.8c	2.7	55.2d	3.5	17.8b	3.0	1.6a	0.8
Bidens laevis	10.9b	0.8	0.1a	0.1	0.0a	0.0	0.0a	0.0	13.0b	1.6	0.2a	0.2	0.0a	0.0	0.0a	0.0
Polygonum punctatum	4.0a	0.4	1.6b	0.4	0.2b	0.1	0.4b	0.2	3.0b	0.6	3.6b	0.8	3.6b	1.3	0.0a	0.0
Pontedaria cordata	3.0b	0.8	1.1b	0.7	2.0b	1.4	0.0a	0.0	1.8bc	0.6	3.5c	1.5	0.9b	0.4	0.0a	0.0
Scirpus validus	2.2	0.3	4.7	1.4	0.5	0.2	0.1	0.1	2.5	0.6	1.1	0.4	0.9	0.4	1.1	1.0
Ludwigia hexapetala	0.0a	0.0	1.1b	0.6	4.4b	2.4	1.5b	0.7	0.0a	0.0	0.8a	0.4	23.0b	5.3	40.0c	6.9
Ludwigia palustris	0.6a	0.2	4.2b	2.3	0.8a	0.7	0.0a	0.0	0.0a	0.0	1.8b	1.0	2.2b	1.2	0.0a	0.0
Nymphea odorata	0.0a	0.0	0.0a	0.0	0.0a	0.0	1.4b	0.8	0.0a	0.0	0.0a	0.0	0.0a	0.0	1.5b	0.5
other	6.3b	1.3	1.3a	0.4	0.2a	0.2	0.3a	0.0	6.8b	1.1	1.1a	0.5	1.8a	1.6	0.0a	0.0

a. edge = edge of pothole, shallow = shallow water region, middle = middle of pothole; $N = 50$ in each pothole location; $N = 200$ in two control sites.

b. Species means within each year followed by the same or no alphabetical letter were not different (Tukey's mean separation, $P > 0.05$).

Discussion

Ammonium nitrate-diesel fuel gel packs effectively blasted small (100–150 m^2) potholes out of giant cutgrass marsh, increasing habitat diversity and increasing access to plant and invertebrate foods by waterfowl and wading birds. Six months after blasting, however, emergent vegetation (giant cutgrass) coverage of pothole edges resembled that of the undisturbed (control) marsh areas and by 18 months, coverage

Table 2. Biomass (mg dry wt) of invertebrate taxa from Hester-Dendy multiplate samplers in control and blasted pothole sites of tidal, freshwater marsh in Georgetown County, South Carolina.

	Sample year one							
	November 1997				March 1998			
	Control[a]		Pothole		Control		Pothole	
Taxon	$\bar{x}$[b]	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Isopoda	6.13ab	3.8	0.0b	0.0	22.6a	9.49	11.35a	5.59
Amphipoda	15.55a	10.5	3.6a	2.61	105.0b	24.9	179.45c	29.63
Hirudinea	9.22	4.6	4.8	3.02	15.45	8.5	5.65	3.79
Chitonida	0.07	0.07	0.0	0.0	0.45	0.31	0.25	0.17
Bivalvia	0.05	0.05	0.0	0.0	1.55	0.7	6.40	6.40
Oligochaeta	0.10	0.10	0.0	0.0	0.0	0.0	0.0	0.0
Decapoda	11.4b	7.6	0.0a	0.0	47.6c	25.3	37.77b	29.39
Diptera	0.75	0.04	0.67	0.39	0.0	0.0	0.27	0.12

	Sample year two							
	November 1998				March 1999			
	Control		Pothole		Control		Pothole	
Taxon	x	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Isopoda	0.55a	0.3	0.0a	0.0	5.95b	2.9	4.30b	1.92
Amphipoda	0.4a	0.4	0.0a	0.0	41.8b	19.0	115.0c	35.3
Hirudinea	0.0a	0.0	0.0a	0.0	12.1b	5.2	7.60b	4.83
Chitonida	0.4	0.24	0.0	0.0	0.0	0.0	0.0	0.0
Bivalvia	0.0	0.0	0.0	0.0	4.45	2.0	0.0	0.0
Oligochaeta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decapoda	0.0a	0.0	41.70c	23.74	3.5ab	2.3	11.30bc	7.56
Diptera	0.0	0.0	0.30	0.14	0.0	0.0	0.0	0.0

a. Samples taken from two control sites (ricefields; $N = 20$) and five potholes blasted from one site ($N = 10$) all in the same tidal, freshwater marsh system.

b. Taxon means within each sample year followed by the same or no alphabetical letter were not different (Tukey's mean separation, $P > 0.05$).

along pothole edges exceeded that of the control areas and was well established in the shallow water areas. This increase of giant cutgrass coverage decreased the availability of open water to waterfowl and wading birds. As the potholes continue to age, this trend will likely continue until the potholes are completely revegetated with giant cutgrass and all open water is colonized by vegetation, ceasing use by waterfowl and wading birds (Hopper 1978). In an Iowa study (Provost 1948), 18 months after blasting, emergent plant species from adjacent natural marsh areas began to revegetate pothole edges by rhizomatous growth. Six years later, the edges of the potholes resembled the surrounding marsh and vegetation began to colonize open water areas (Provost 1948). In Colorado, two years after blasting, emergent vegetation was sparse and was only found in 50% of the potholes. Six years after blasting emergent vegetation was dominant in 60% of the potholes and had completely revegetated 15% of the potholes (Hopper 1978). The rate of colonization by adjacent marsh vegetation of blasted potholes appeared to be faster in our study area than in the Iowa or Colorado studies.

Three species of plants found in the potholes, smartweed, pickerelweed, and softstem bulrush, provide potential food for wintering dabbling ducks (Martin et al. 1961, Conrad 1966, Kerwin and Webb 1972, Landers et al. 1976). In our study, creation of potholes did not provide greater coverage of these plant species compared to that within control sites. However, potholes provided an open area for waterfowl and likely greater accessibility to these food plants. In a Maryland study, potholes blasted in a freshwater marsh contained no emergent vegetation two years after blasting, but desirable food plants were abundant (Warren and Bandel 1968). Potholes blasted in other areas such as Iowa and Colorado provided more desirable plant species than natural marsh areas (Provost 1948, Hopper 1978).

Amphipods, isopods, dipterans, and leeches typically are found on the bottom of freshwater marshes or on substrate including plants and debris, and feed on animals and/or plant matter (detritus) (Pennak 1989, Elderidge 1990). The greater invertebrate biomass we found in March samples may be explained by the increase in detritus from decaying plants during this season (Nelson and Kadlec 1984). Duffy and LeBar (1994) also found that invertebrate biomass increased in the spring (March–April) in Mississippi wetlands. In newly-created open water areas in Delaware, invertebrates, including dipterans and amphipods, increased the first four years after creation and was related to the increase in submergent and emergent vegetation (Whitman 1995). In our study, emergent vegetation increased during the two-year period. However, we detected only slight increases in biomass in some invertebrate species. These populations and the relation to soils modified by blasting should be investigated further.

Management Implications

Pothole blasting in abandoned ricefield systems in coastal South Carolina can be used to create open water areas in densely vegetated marshes. In situations where washed-out and deteriorated dike and water control systems were not repaired within 2–3 years of damage, it is unlikely that permits will be issued for their reconstruction (Federal Register 2002:2078); hence, creation of temporary openings by blasting may be a means of diversifying the giant cutgrass marsh habitat and increasing availability of foods to waterfowl and wading birds. Open water areas generally persist in blasted potholes for at least two years following blasting, and desirable plant species recolonize affected areas. Plant seeds and invertebrates are more accessible to foraging waterfowl in blasted potholes than in unmanaged sites. During our study, blasted potholes did not harbor increased invertebrate biomass with the exception of amphipods. Furthermore, invertebrate biomass did not increase as emergent plant coverage increased from the first to second year.

Landowners interested in pothole blasting should interpret our results with caution because our study was not replicated over a large area. If expenses are not an obstacle ($700–$1000/pothole), larger scale studies should examine this technique to create larger potholes replicated over more study sites. We detected an insignificant impact on surrounding marsh and water quality (Ayers 1999) so permitting will likely not be an obstacle. Further research is needed to determine how long significant portions of the potholes will remain free from giant cutgrass and open water areas will persist. Continued monitoring is needed to determine if invertebrate biomass will increase as emergent plant coverage continues to increase in pothole areas.

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