Research Article

Herbivory by Resident Geese: The Loss and Recovery of Wild Rice Along the Tidal Patuxent River

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ABSTRACT Well known for a fall spectacle of maturing wild rice (*Zizania aquatica*) and migrant waterbirds, the tidal freshwater marshes of the Patuxent River, Maryland, USA, experienced a major decline in wild rice during the 1990s. We conducted experiments in 1999 and 2000 with fenced exclosures and discovered herbivory by resident Canada geese (*Branta canadensis*). Grazing by geese eliminated rice outside exclosures, whereas protected plants achieved greater size, density, and produced more panicles than rice occurring in natural stands. The observed loss of rice on the Patuxent River reflects both the sensitivity of this annual plant to herbivory and the destructive nature of an overabundance of resident geese on natural marsh vegetation. Recovery of rice followed 2 management actions: hunting removal of approximately 1,700 geese during a 4-year period and reestablishment of rice through a large-scale fencing and planting program. (JOURNAL OF WILDLIFE MANAGEMENT 71(3):788–794; 2007)

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The high productivity of wild rice (*Zizania aquatica*), smartweeds (*Polygonum* spp.), and millet makes the tidal marshes of the upper Patuxent River, USA, an important fall stopover site for many migrating waterbirds (Meanley 1975, 1996). Wild rice is a preferred food of soras (*Porzana carolina*), bobolinks (*Dolichonyx oryzivorus*), red-winged blackbirds (*Agelaius phoeniceus*; Meanley 1961, 1965; Webster 1964), and numerous ducks (McAtee 1911, 1917; Martin and Uhler 1939; Moyle and Hotchkiss 1945). Along the Patuxent River, American black ducks (*Anas rubripes*), wood ducks (*Aix sponsa*), green-winged teal (*Anas crecca*), and blue-winged teal (*Anas discors*) occur most frequently. Soras were formerly so abundant in these marshes that in the early 20th century the Jug Bay portion of the upper Patuxent River became one of the most famous rail hunting areas in the region (Mitchell 1933). Soras aggregate in these marshes for an extended fall stopover to fatten before continuing migration (G. M. Haramis, United States Geological Survey, unpublished data). In this way, the migratory fitness of soras and other water birds may be intrinsically linked to wild rice.

The importance of these marshes to fall migrant birds led to a growing concern over the widespread decline of wild rice in the 1990s. This loss was confirmed by aerial photographic records, our casual observations accumulated over 15 years of field study of soras, and discussions with B. Meanley, a retired United States Fish and Wildlife Service biologist, who has been familiar with these marshes for over 50 years (Meanley 1975, 1996). Most apparent was the loss of river-bordering rice that was most visible during maturation in late summer and fall.

The loss of rice was enigmatic and might have been the result of a number of interrelated environmental factors. Germination and seedling survival is potentially sensitive to a number of physical, chemical, and biological factors, including sediment type, water depth, turbidity, temperature, salinity, ice scouring in winter, and to consumption by birds, fish, semiaquatic mammals, and other aquatic life (for general discussion of factors, see Martin and Uhler 1939:116–142; see also Lee and Stewart 1984, Stevenson and Lee 1987, Day and Lee 1989, Baldwin et al. 2001). In fall, red-winged blackbirds are so numerous that they appear to strip plants of seed before they mature and shatter (Meanley 1961, 1996). Seasonal variations in numbers of carp (*Cyprinus carpio*), or the possible effects of spawning or foraging activities of an abundance of estuarine fishes that move to the fresh tidal river each spring (e.g., white perch [*Morone americana*], striped bass [*M. saxatilis*], yellow perch [*Perca flavescens*], and shad [*Alosa* spp.]), might explain the loss of germinating rice seedlings (G. M. Haramis, personal observation). Waterfowl, especially resident mallards (*Anas platyrhynchos*) and Canada geese (*Branta canadensis*), also could potentially be damaging to rice. The objective of our study was to investigate and identify factors causing the decline of wild rice along the Patuxent River and to prescribe and implement methods for its restoration.

STUDY AREA

The tidal marshes of the upper Patuxent River at Jug Bay, near Upper Marlboro, Maryland, USA (38°47′N, 76°42′W), were classified as fresh estuarine river marshes (Stewart 1962, Cowardin et al. 1979). They were bordered downstream by slightly brackish (oligohaline) marshes, upstream by tidal freshwater swamps, and were characterized by a highly diverse assemblage of freshwater emergent plants (Anderson et al. 1968, Tiner and Burke 1995). The principal marshes, about 500 ha in extent, have long been known for nearly monotypic stands of the tall, broadleaf

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coastal form of wild rice known as southern wild rice (*Zizania aquatica* var. *aquatica*; Oelke et al. 2000). In addition to wild rice, the marshes contained such broad-leaved emergents as spatterdock (*Nuphar advena*), pickerelweed (*Pontederia cordata*), arrow arum (*Peltandra virginica*), and arrowhead (*Sagittaria latifolia*), which dominate deeper zones, and rice cutgrass (*Leersia oryzoides*), Walter millet (*Echinochloa walteri*), river bulrush (*Schoenoplectus fluviatilis*), dotted smartweed (*Polygonum punctatum*), arrowleaf tearthumb (*Polygonum sagittatum*), halberdleaf tearthumb (*Polygonum arifolium*), tidemarsh waterhemp (*Amaranthus cannabinus*), jewelweed (*Impatiens capensis*), cattail (*Typha* spp.), and marsh beggartick (*Bidens laevis*), which occur in higher marsh. Wild rice typically occurs in river-bordering pure stands or in mixed vegetation at intermediate depths. The pristine nature and high diversity of these marshes led to their inclusion as a component of the Chesapeake Bay National Estuarine Research Reserve (CBNERR).

METHODS

Experiments with Small Exclosures

In April 1999, we placed small- (1.3 × 1.3 cm), medium- (2.5 × 2.5 cm), and large- (5.1 × 10.2 cm) mesh fenced exclosures to test the possible effect of fish or other aquatic organisms on survival and growth of germinating rice. We placed replicate sets of circular 1.5-m-high, 1-m^2 exclosures and an unfenced control plot at 6 randomly selected locations on river-bordering tidal mudflats where an even distribution of naturally germinating rice occurred. Exclosure mesh size was small enough to exclude ducks, geese, muskrats (*Ondatra zibethicus*), beaver (*Castor canadensis*), large turtles, and fish. Because of the inherent link between site-specific factors and plant growth, we adopted a completely randomized block design. We assumed that all experimental units within blocks were homogeneous with respect to herbivory if we assigned them within broad areas of naturally germinating rice. To measure differences in rice growth and productivity, we made a total count of rice stalks, panicles, plants, and tillers within exclosures and controls at the end of the growing season. We also subsampled plant growth variables to test for effects of mesh size. We measured a systematic sample of 10 plants per experimental unit for height, panicle length, and stem diameter (nearest mm). We measured stem diameter at the nearest mid-node at half the height of each stalk. We used SAS/STAT Proc Mix to conduct analysis of variance and Proc Univariate Procedures to confirm model residual distributions and homogeneous variance (SAS Institute 2002). We made a comparison of rice density in natural stands from panicle counts around buckets (see below), and we measured tiller production from a systematic sample of 100 stalks taken at each of 3 random locations in natural marsh.

An exceptional growth response inside exclosures in 1999 prompted us to test the role of large fish on the survival of rice seedlings. We repeated the previous experiment to include exclosures staked 25 cm off the bottom to allow access by fish. We placed a full exclosure, a fish-accessible exclosure, and an unfenced control at 6 river-bordering mudflat sites with naturally germinating rice. All exclosures were constructed of large-mesh (5.1 × 10 cm) wire.

Experiments with Large Exclosures and Plantings

In spring 2000, we used 5 large fenced plots of various sizes, the largest being a 100-m linear exclusion fence along river-bordering rice, to study the effect of fencing on survival and growth of wild rice. We planted 2 5 × 20-m exclosures with rice seed in April to explore restoration potential. We collected seed from rice plants during the previous fall and maintained it in cold storage over winter (McAtee 1917). We worked a small amount of rice seed into a mud ball (50 balls/site) and threw it into each exclosure. We expanded the planting experiment during the 2001 growing season with one set of 6 circular, 9.7-m-diameter plots placed on each of 2 barren mud flats formerly occupied by wild rice. In addition, we expanded one 5 × 20-m plot planted in 2000 by about 33% in 2001, and we lengthened the large linear exclusion fence along the river from 100 m to 250 m.

Rice Production and Estimates of Seed Consumption by Blackbirds

We estimated avian seed loss to large flocks of red-winged blackbirds that appear in Patuxent marshes as early as mid-August, by subtracting an estimate of seed fall from an estimate of seed production. During fall 1998 and 1999, we estimated seed production per panicle by bagging a sample of maturing panicles to exclude feeding birds and capture all seed produced. In a nearby rice marsh, we also staked buckets at random locations to sample seed fall from maturing panicles. Each bucket opening was 28 cm in diameter (0.062 m^2) and we fitted them all with a 1.3 × 1.3-cm-mesh wire screen to allow passage of seed but exclude birds and rodents. We estimated panicle density around buckets by counting the number of panicles within a 1-m radius (3.14-m^2 area) of each bucket. We multiplied average panicle density per square meter by the average seed production per panicle to estimate seed production per square meter. The difference between seed production per square meter and seed fall per square meter yielded an estimate of avian seed consumption.

Techniques for Restoring Wild Rice

From 2001 to 2004, restoration efforts focused on use of extensive fencing to protect both natural stands and large planted areas from goose herbivory. We expanded many of these plots from year to year as rice filled available space. During this period, we deployed >6 km of fencing to protect rice from grazing geese. Although seed planting was our primary method of rice reestablishment, we also transplanted rice plants and used this restoration method until midsummer. To obtain adequate seed for restoration planting, we maximized seed capture by bagging panicles during late development. For this purpose, we used a tough, high-density polyethylene fabric (Tyvek; Dupont Company, Richmond, VA) to prevent blackbirds from pecking through the material and eating the seed.

Controlling Numbers of Resident Geese

Once we knew that the loss of rice was related to an overabundance of resident geese, it was clear that any imperative to restore rice to its former prominence would require action to not only plant and protect rice with fencing, but also to mediate herbivory by reducing the resident goose population. We developed a goose reduction plan through collaborative input and consensus of local jurisdictional land and state waterfowl managers to 1) addle eggs to reduce recruitment and 2) to use Maryland's September resident goose hunting season to reduce the population. The program sought cooperation from local land managers to access areas where geese were concentrated, many of which were formerly closed to hunting. The hunt would be managed by park staff to assure maximum public participation and effectiveness in harvest of geese in the short 2-week September season.

RESULTS

During 1999, the growth response of rice within 1-m^2 full exclosures was uniform and striking, whereas unprotected rice was virtually eliminated by grazing (Fig. 1A). The 18 fenced exclosures at 6 sites contained 1,907 panicled stalks ($\bar{x} = 105.4 \pm 6.3$ SE panicles/exclosure; Table 1), whereas the 6 controls at those sites contained no panicles and only 16 plants, which were stunted ($\bar{x} = 2.7 \pm 2.3$ SE stalks/exclosure). The virtual elimination of rice at unfenced controls produced an overriding treatment effect of exclosure on rice abundance as measured by the number of stalks ($F_{3,15} = 60.4$, $P < 0.001$). We tested for the effect of mesh size on rice abundance by deleting controls from the data set and found no difference with regard to the number of stalks ($F_{2,10} = 1.2$, $P > 0.3$). This lack of difference in numbers of stalks indicated that all mesh sizes were effective in deterring grazing by a large and likely numerous herbivore. Although we immediately suspected geese, any associated sign, such as droppings, tracks, feathers, or down, had been washed away by the tide. At one observation site, we fenced grazed rice plants in mid-June to protect them from further damage. These plants achieved about two-thirds the height of protected plants, and seed development was delayed from late August until mid-September.

The fish-accessible exclosure experiment that we conducted in 2000 was terminated because we observed geese reaching beneath the wire at ebb tide and grazing rice plants within exclosures. Although we took no plant measurements, we noted that full exclosures produced abundant rice whereas the controls were virtually destroyed by geese. The response of rice in large fenced and planted plots was equally successful (Fig. 1C, D): rice grew wherever it was protected by fencing, including plots where we expanded the fencing from one year to the next (Fig. 1E).

In 1998, seed counts from bagged panicles revealed an average rice production of 625 ± 76.7 SE seeds/panicle ($n = 29$). Based on a mean panicle density around buckets of 14.9 ± 1.7 SE panicles/m^2 ($n = 26$), we estimated a seed production of 9,300 seeds/m^2 (95% CI: 5,300–14,400) or 93 million seeds/ha. We determined the mean dry weight of rice seed from a sample of 100 seeds from each of 11 panicles to be 1.445 ± 0.084 SE g. This yielded a point estimate of rice seed production in natural marsh (dry wt) of 1,350 kg/ha. We estimated seed fall from bucket collections in 1998 at $2,650 \pm 476$ SE seeds/m^2. The large difference between production and seed fall yielded an estimate of avian consumption of 72% (95% CI: 31–89%). In 1999, mean seed production was similar to 1998 at 528 ± 31.4 SE seeds/panicle ($n = 35$), but panicle density was higher at 26.4 ± 3.0 SE panicles/m^2 ($n = 39$). These figures yielded a seed production estimate of 13,940 seeds/m^2 (95% CI: 9,439–19,212) or a dry-weight production of 2,014 kg/ha. Subtracting estimated seed fall from bucket collection ($3,999 \pm 642$ SE seeds/m^2, $n = 33$) resulted in an estimate of avian seed consumption of 71% (95% CI: 44–86%).

Rice productivity within natural marsh paled by comparison to that within exclosures. Panicle density within natural marsh as measured around buckets (14.9 ± 1.7 SE panicles/m^2 and 26.4 ± 3.0 SE panicles/m^2 in 1998 and 1999, respectively) was but a fraction of that within 1-m^2 exclosures (105.4 ± 6.3 SE panicles/m^2; Table 1). Mean tiller production within natural marsh also was lower than that within exclosures (1.4 ± 0.4 SE tillers/100 plants vs. 8.4 ± 1.5 SE tillers/100 plants, respectively; t-test with unequal variance: $t = 4.6$, df = 19, $P < 0.001$). Statistical tests based on the subsampling of rice within exclosures revealed mesh size to affect plant height ($F_{2,10} = 4.5$, $P < 0.05$) but not panicle length ($F_{2,10} = 0.26$, $P > 0.7$) or stem diameter ($F_{2,10} = 2.53$, $P > 0.1$). There was also no effect of mesh size on the number of tillers ($F_{2,10} = 0.51$, $P > 0.4$). Plant height varied inversely with mesh size (Fig. 2).

In September 2001, resident goose hunting was offered to the general public for the first time within the boundaries of the CBNERR, a wetland sanctuary where waterfowl hunting is normally prohibited. Five hundred geese were harvested in the first season and approximately 1,700 over a 4-year period. This marked reduction in geese, combined with efforts to reestablish rice with the use of 6 km of fencing and widespread seeding and planting, accelerated a major recovery of rice and other vegetation along the 10-km section of the upper Patuxent River.

DISCUSSION

The magnitude of goose grazing along the Patuxent River and the response of rice to exclosure were 2 striking outcomes of this study. A third striking outcome was the widespread recovery of rice and other marsh vegetation following the major reduction in the numbers of geese. Although we suspected geese as a possible cause of the loss of rice, only through direct surveillance were we able to confirm the magnitude and speed with which geese could graze emerging rice plants, leaving stubble that appeared as if mowed mechanically (Fig. 1B).

It became apparent that numbers of geese and their

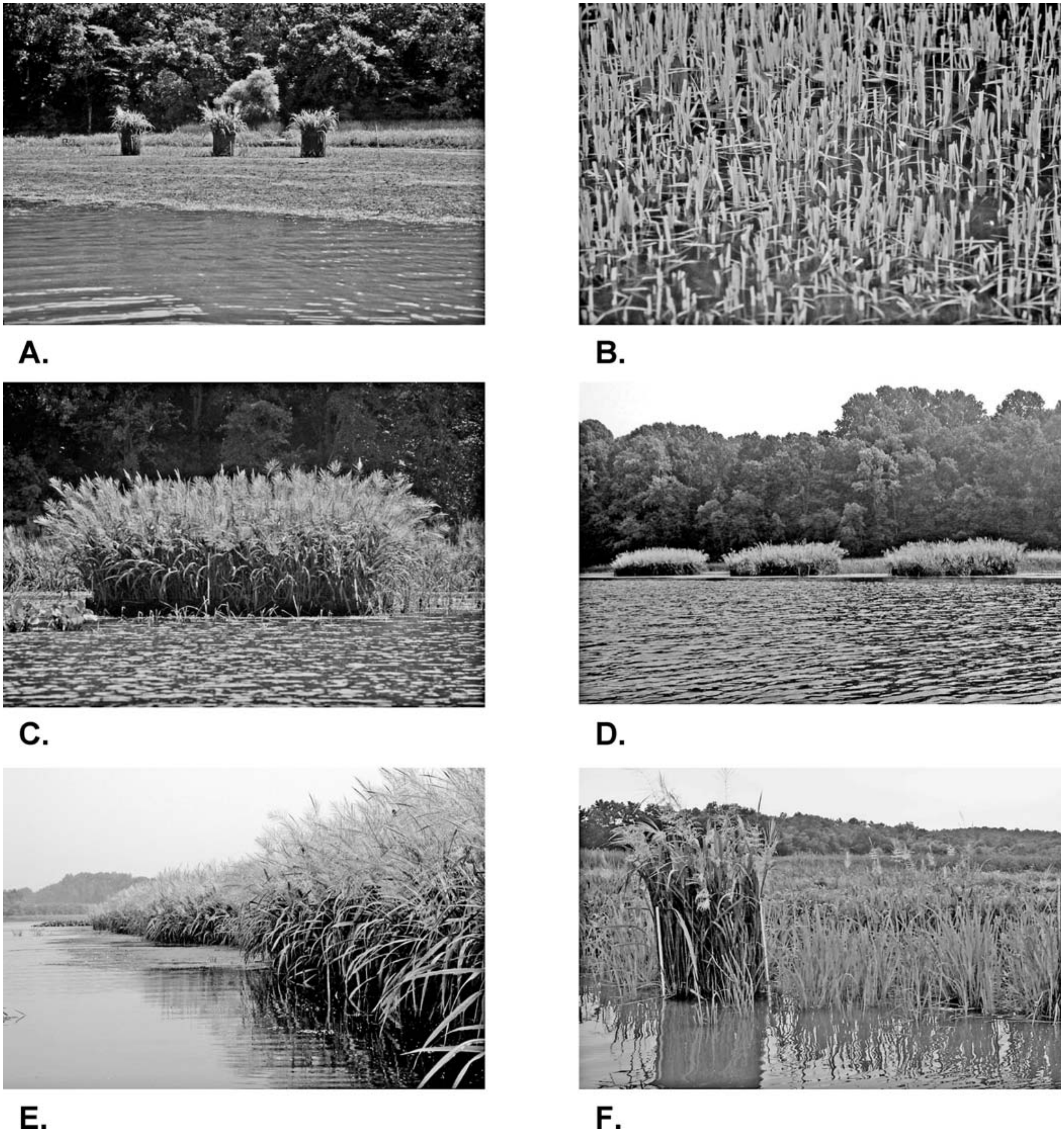

Figure 1. An August 1999 photo taken on the Patuxent River, Maryland, USA, (A) reveals the marked contrast of maturing wild rice inside exclosures and virtually no survival of rice outside (note stake marking control plot). Rice inside exclosures grew robustly and achieved heights up to 4 m. Grazed rice (B) appeared as if it had been cut mechanically. Large fenced plots of naturally germinating rice (C) and planted circular plots (D) produced the same dramatic effect. Extensive river-bordering stands of rice (E) returned quickly once protected by fencing. A single grazing would set back the growth of rice significantly as contrasted by the rice inside and outside this exclosure (F). This often produced a noticeable terracing effect between river-bordering rice and less accessible rice in the interior of the marsh.

grazing had increased unnoticed for well over a decade. This was perhaps because most grazing occurred early in the growing season when few people were in the marsh to notice it. River-bordering rice incurred the most damage and virtually was eliminated by geese. Remaining rice was patchily distributed behind protective barriers of vegetation, most commonly spatterdock and pickerelweed. In the few areas where broad stands of rice still existed on river-bordering mud flats, the plants often appeared terraced in height, with the tallest plants at the most interior locations (Fig. 1F). Because this is opposite the normal growth pattern where river-bordering rice is most robust, we believe

Table 1. September 1999 measurements of mature wild rice plants grown within sets of 1-m^2 exclosures, 1 small- (1.3 × 1.3 cm), 1 medium- (2.5 × 2.5 cm), and 1 large- (5.1 × 10.2 cm) mesh fencing, replicated ($n = 6$) on tidal flats of the Patuxent River, Maryland, USA.

		Exclosure mesh size							
		Small		Medium		Large		Overall	
Variable	n[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
No. plants/exclosure	6	100.7	7.0 A[b]	89.8	10.4 A	99.7	11.2 A	96.7	5.4
No. panicles/exclosure	6	108.0	8.0 A	98.5	12.7 A	109.7	13.1 A	105.4	6.3
No. tillers/exclosure	6	7.3	1.6 A	9.0	2.8 A	10.0	4.0 A	8.8	1.6
Stalk ht[c] (cm)	60	326.2	5.1 A	311.2	5.4 B	292.7	5.6 C	309.3	3.3
Panicle length[c] (cm)	60	63.5	1.2 A	62.6	1.4 A	61.0	1.4 A	62.4	0.8
Stem diam[c,d] (mm)	60	8.5	1.9 A	7.5	0.2 B	7.4	0.2 B	7.8	0.1

[a] Sample size for each exclosure mesh size.
[b] Means within rows sharing the same letter do not differ (Tukey's test, $P = 0.05$).
[c] Measurements of stalk ht, panicle length, and stem diam are from a systematic sample of 10 rice plants taken from each exclosure.
[d] Measured at nearest mid-node at half the ht of the stalk.

this terracing effect is a visible record of grazing activity and confirms goose access from the open river channel.

Although goose herbivory has emerged as a major factor in reducing wild rice along the Patuxent River, we recognize that numerous interrelated factors also influence establishment, growth, and survival of rice (e.g., see Martin and Uhler 1939:116–142; Lee and Stewart 1984). The striking growth response of rice within exclosures attests to a large degree on the ability of rice to stool out and thus fill exclosures by vegetative means. However, this robust growth also appeared aided by a fertilizing effect of exclosure (i.e., the wire and plants acting as a sediment trap [cf. Meeker 2000]). On removal of exclosures in September, sediment height within exclosures was several centimeters above that of adjacent tidal flats, and our finding of an inverse relationship of plant height and wire mesh cross-sectional area (Fig. 2) is consistent with the notion of increased fertility. We also note that most exclosures were located in deeper water zones that generally are more fertile for rice growth and free from competition with other emergent plants. We conclude that the greater productivity of plants inside exclosures is primarily a result of protection from herbivory, along with the aforementioned benefits of fertility and site placement.

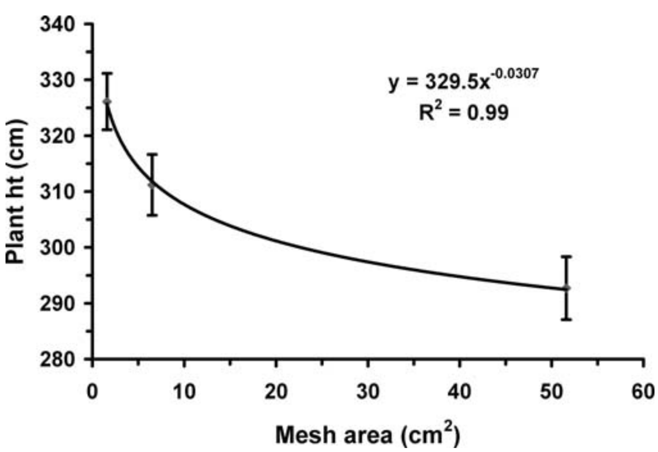

Figure 2. The relationship between height of wild rice stalks ($\bar{x} \pm$ SE) and exclosure mesh size cross-sectional area. Points are means of large- (5.1 × 10.2 cm or 52 cm^2), medium- (2.5 × 2.5 cm or 6.3 cm^2), and small- (1.3 × 1.3 cm or 1.7 cm^2) mesh exclosures taken across 6 randomly selected locations (blocks) on intertidal mud flats of the Patuxent River, Maryland, USA, with 10 measurements per block ($n = 60$/mesh size) in 1999.

Wild rice is highly vulnerable to goose grazing during a long early growth period from germination in April through emergence from the water column (floating leaf stage) in mid-May and June. This period coincides with the nesting and brood-rearing stages of geese, a time when females must acquire nutrients for eggs and goslings feed voraciously to achieve adult size in about 10 weeks. Breeding adults and growing goslings require large amounts of protein-rich foods (Buchsbaum and Valiela 1987), and early growth wild rice appears as one of few and the most nutritious of graminoids in the emergent zone of the Patuxent marshes. Adult geese uprooted germinating rice plants on exposed mud flats as soon as they appeared in spring, and by May and June flightless goslings browsed developing plants as they foraged along the river in crèches (Fig. 1B). By mid- to late June, most rice had grown beyond the reach of geese. Adult geese that entered molt on the river in July and August generally had little further grazing effect on rice.

Why the resident goose population expanded in the 1990s to overwhelm the rice resource along the Patuxent River is unknown. We speculate that several years of closed or limited hunting on migratory geese during this period was a major contributing factor (Hindman et al. 2004*a*). It was during this decade that surveys documented resident goose numbers in the Atlantic Flyway to rise sharply and exceed an unprecedented 1 million birds (Atlantic Flyway Council 1999, Hindman et al. 2004*b*). Presently, the Maryland resident goose population, as estimated from the Atlantic Flyway breeding waterfowl plot survey, is about 86,500 (Serie and Raftovich 2005).

Although imprecise, our 2 estimates of blackbird consumption of rice seed (71% and 72%) are consistent and provide some evidence of the magnitude of rice loss to these large flocks of birds. Despite this loss of seed, the rapid return of rice that accompanied restoration efforts and reduction in geese vindicates blackbirds as the cause of the rice decline. In a larger ecological context, we suggest that wild rice has evolved to accommodate high seed mortality and even be dependent on it as a process to thin and thus maintain more robust natural populations (Weiner and Whigham 1988).

MANAGEMENT IMPLICATIONS

Our experience on the Patuxent serves to alert managers to the potential threat of overgrazing by resident geese on our midlatitude marshes, and perhaps more importantly, demonstrates a course of successful remedial action. Fortunately, the loss of wild rice on the Patuxent was an obvious and striking change to which managers could justify corrective action. Goose herbivory was severe along the Patuxent and might have eventually extirpated rice and possibly other palatable species. Just as seriously, intertidal mud flats left barren of rice were vulnerable to invasion by undesirable species, such as common reed (*Phragmites australis*). The event of such colonization would have rendered rice recovery difficult, perhaps impossible, and radically altered the vegetative composition of the marshes into the future. Loss of rice to resident geese is not unique to the Patuxent River (e.g., see Nichols 2004), and the possibility of a widespread decline of rice in estuaries of the Atlantic Seaboard could affect the fall food base of many migrant marsh birds and pose deleterious effects on migration and ultimately populations. In addition, we note that many wildlife refuges and wildlife management areas have long harbored resident geese as a result of their management focus on this important game species. We recommend an evaluation of the grazing effects of these birds on local marsh vegetation and especially with regard to the status of wild rice and other palatable grasses. Finally, we could not have predicted better success in both our approaches to rice restoration and a publicly compatible goose reduction plan. Although our plan to reduce numbers of geese was successful, we note that the outcome may have been less so in the face of more stringent management constraints. We believe as numbers of resident geese continue to grow in the Atlantic Flyway, managers will need more options to meet the challenges of resolving resident goose conflicts. Our success in restoring rice along the Patuxent and affecting a solution to an overabundance of resident geese underscores the value of stewardship and collaborative commitment to maintaining our natural wetlands.

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