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THE EFFECTS OF LIVESTOCK GRAZING ON THE BOG TURTLE [*GLYPTEMYS* (= *CLEMMYS*) *MUHLENBERGII*]

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Abstract: The bog turtle *Glyptemys* (= *Clemmys*) *muhlenbergii* is an inhabitant of groundwater-fed sedge meadows in the northeastern and southeastern United States. Observations of bog turtle habitats throughout the species' range demonstrate that livestock grazing has been an important factor in staving off successional processes and abating large-scale invasions by tall-growing, competitively dominant plants—many of which are exotic in origin. The demise of small-scale dairy farming over the past three decades has led to the pastoral abandonment of the majority of bog turtle habitats in the Northeast. As a consequence, habitats are being degraded by the growth of invasive flora, changes in hydrology, and loss of turtle microhabitats created by livestock. In this study we compared the number of bog turtle captures, bog turtle demographic parameters, bog turtle densities, and vegetation at sites that are currently grazed ($n = 12$) and at sites in which grazing had recently ceased ($n = 12$). This analysis demonstrated that grazed sites contained greater numbers of turtles, greater turtle density, and greater frequency of occurrence for juvenile turtles. Grazed sites also contained greater cover of low-growing herbaceous vegetation and lower heights of tall-growing exotic and/or invasive vegetation than the formerly grazed sites. We hypothesize that nutrient enrichment from manure and agricultural run-off has promoted the establishment and growth of invasive plant species at many of the sites, but livestock grazing has kept these plants in check. When livestock are removed, invasive species proliferate, and the hummocky microtopography maintained by the livestock traffic is often reduced to a mat of vegetation. This investigation showed that efforts to preserve viable populations of bog turtles may depend on the preservation of low-intensity, pasture-based dairy and beef farming.

Key words: Bog turtle; Cattle; Grazing; Invasive flora; Threatened species

Habitat loss is widely regarded as the most severe threat to life forms at local, regional, and global scales. The primary causes of habitat loss include the physical modification of land for agriculture or urbanization and the alteration of ecological dynamics or components of ecosystems (e.g., the suppression of natural disturbance regimes or loss of keystone species) which result in unsuitable environmental conditions for certain species. The federally threatened bog turtle *Glyptemys* (= *Clemmys*) *muhlenbergii* is an elusive inhabitant of fens and boggy meadows of rural landscapes in the eastern United States (Burke et al., 2000; Herman and Tryon, 1997; Lee and Norden, 1996; Somers et al., 2000; Tryon and Herman, 1990). The northern population of the bog turtle—from Maryland northward through New York—was listed as threatened in 1997 by the U.S. Fish and Wildlife Service, citing loss of habitat and the inadequacy of federal and state regulatory mechanisms as the two major factors behind the species' decline. While outright habitat destruction has largely been stemmed, and the federal and state regulatory review process has improved since listing, bog turtle habitats continue to be lost due to ecological succession and encroachment by invasive plants. These changes in vegetation parallel the widespread loss of dairy farming in the region (Lee and Norden, 1996). As a result, for the first time in centuries many bog turtle habitats are not being grazed.

Light grazing, primarily by cattle, has been reported to benefit the bog turtle through maintaining open, sunny conditions required by the species, inhibiting the choking of rivulets and flowages by roots and vegetative litter, creating microhabitats in the form of water-filled hoof prints, and possibly subsidizing bog turtles with invertebrates that are attracted to manure (Herman and Tryon, 1997; Lee and Norden, 1996; Somers et al., 2000; Tryon, 1990; Tryon and Herman, 1990). During a study in the southern Appalachian Mountains, Herman (2004) found that sites supporting the most viable bog turtle popula-

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tions were actively grazed. In Maryland, Virginia, North Carolina, and Georgia, over 50% of extant bog turtle sites were grazed (Lee and Norden, 1996; Tryon and Herman, 1990). In New Jersey, which was once one of the largest dairy producers in the region, 202 of 225 documented bog turtle sites have a grazing history; however, only 12 sites currently are grazed (Tesauro, 2002).

Changes in vegetation and consequent declines in bog turtles following the removal of livestock from particular sites have been documented anecdotally (Lee and Norden, 1996; Somers et al., 2000), but no one has attempted to quantify these changes. Because prescribed grazing is already being used to manage for bog turtles in early successional meadows and fens (Tesauro, 2001; Thorne and Eisman, 2001), it is important to have an understanding of how livestock grazing can affect wetlands. In this study, we investigated differences in habitat attributes and bog turtle numbers within both grazed and formerly grazed sites. Specifically, we addressed two questions. First, does vegetation height and cover differ between grazed and formerly grazed sites? Second, are there differences in the total numbers of turtles, juvenile turtles, or adult turtles between the two treatments?

Materials and Methods

Study Sites

Twelve grazed and 12 formerly grazed bog turtle sites were the focus of this study. Grazed sites occurred on active farms that had pastured the wetland for at least 50 yr and possibly much longer. Formerly grazed sites occurred on both abandoned farms and active farms in which livestock operations had ceased. At these sites, the wetlands had not been pastured for at least 10 yr. No information on the bog turtle populations (i.e., size, demographics, ethology) of each site was known prior to this investigation.

Bog Turtle Surveys

For each hectare of habitat, a total of 14.8 h was spent visually searching for bog turtles over the course of at least three separate visits. The level of bog turtle search effort was consistent with the detection of bog turtle presence in previous fieldwork in New Jersey (J. Tesauro, personal observation). Bog turtle habitat, which was defined as wet meadow or fen containing saturated soils and visible springs and seeps, was delineated in the field at each site. Habitat area was calculated based on these delineations using ArcView 3.2 software (Environmental Systems Research Institute, ESRI Inc, Redlands, CA. 1992–1999). Turtles were captured through scanning potential basking areas, lifting vegetative litter, and gently probing mucky refugia with a walking stick. All searches were performed in April–June and September of 2000 and 2001. Searches were conducted on noninclement, warm days (15–27 C), which offer optimal conditions for bog turtle surface activity (USFWS, 2001). All captured bog turtles were sexed, measured, and marked at the point of capture by notching marginal scutes. We also indicated when turtles were found in cattle hoof prints. Adults were distinguished from juveniles by plastron length measurements ≥50 mm (Ernst et al., 1994).

Vegetation Surveys

The composition of the plant community of each site was characterized by sampling 5 × 5 m plots situated randomly along linear transects through the core bog turtle habitat. Twenty sampling plots were established for each hectare of bog turtle habitat. Surveys were completed in August of 2001. The floristic composition for each plot was assessed using visual percentage-cover estimates based on the following 13 categories (Table 1).

Species categories (Table 1) were derived *a priori* based upon typical vegetative community associations of bog turtles in the Northeast (Arndt, 1977; Barton and Price, 1955; Chase et al., 1989; Gemmell, 1994; Kiviat, 1978; Klemens, 1993; Lee and Norden, 1996; Nemuras, 1967; USFWS, 2001; Zappalorti, 1976). We measured the height of tall-growing vegetation (categories 6, 8, 9, 10, 11, 12, and 13) in each sample plot.

Statistics

Nonparametric statistical methods were used to compare differences in turtle populations and vegetation between grazed and

TABLE 1.—Mann-Whitney *U* Test results of vegetation cover between grazed and formerly grazed wetlands. Results significant at $P < 0.05$ are bolded and those significant after Bonferroni adjustment are indicated with an asterisk.

	FORMERLY GRAZED median % cover	GRAZED median % cover	Initial *P* level
Category 1: graminoid (sedges, grasses, and rushes <1 m at max. height)	53.8	78.3	* **<.0001**
Category 2: fern and forb	37.7	48.1	* **0.0021**
Category 3: sphagnum moss	1.3	8.7	**0.0068**
Category 4: woody saplings	0.8	2.7	0.1308
Category 5: low shrub (<1 m at max. height)	7.5	8.1	0.2301
Category 6: tall shrub (>1 m at max. height)	7	2.3	**0.0126**
Category 7: tree	2.7	2	0.6995
Category 8: *Phragmites australis* (common reed)[1]	—	—	—
Category 9: *Phalaris arundinacea* (reed canary grass)[1]	12.6	0.3	0.1531
Category 10: *Typha* spp. (cattail)[1]	15.9	7	0.0486
Category 11: *Lythrum salicaria* (purple loosestrife)[1]	14.9	11	0.1108
Category 12: *Acorus calamus* (sweetflag)[1]	1.6	4.3	0.415
Category 13: *Microstegium vimineum* (Japanese stiltgrass)[1]	3.9	2	0.0618

[1] Invasive species.

formerly grazed sites. The tendency for the samples to deviate from a normal distribution and the small size of several of the samples necessitated the use of such methods. We used the Mann-Whitney *U*-test to compare turtle density and the number of juvenile turtles, adult turtles, and all turtles between grazed and formerly grazed sites. We also used the Mann-Whitney *U*-test to assess differences in habitat area and the thirteen dominant vegetation categories between treatments. For all sites, Spearman rank correlations were used to assess the relationship between site area and the number of juveniles, adults, and all turtles. An alpha level of 0.05 was used for all analyses. For each set of related correlation analyses and Mann-Whitney tests, initial *P*-values were adjusted using the sequential Bonferroni significance-level adjustment (Rice, 1989). Analyses were completed using Statistica 5.5 (Statsoft, Inc., Tulsa, OK, 2000).

RESULTS

Grazing

In all sample sites, bog turtle habitats made up a small portion of larger, mostly upland, pastures. Of the 12 currently grazed sites, five were grazed by Holstein dairy cows, six sites occurred in beef cattle and/or dairy heifer pasture, and one site was grazed exclusively by horses. Livestock had access to bog turtle habitats year-round at 10 sites; however, wetland grazing was concentrated in July and August, presumably in response to the dry conditions of adjacent upland pastures. In addition to pasture, all dairy cows and most beef cattle were subsidized with hay and grain throughout the year. All 12 formerly grazed sites had been grazed by dairy cows and had generally been grazed in the summer.

Vegetation Surveys

Vegetation was sampled in a total of 191 plots among the 24 sites. Graminoids, forbs/ferns, *Typha*, and *Lythrum salicaria* were the most frequently occurring categories, being present in >62% of the plots. *Sphagnum*, tall and low shrub categories, trees, woody saplings, and *Phalaris arundinacea* were present in <50% of the plots. *Acorus calamus*, *Microstegium vimineum*, and *Phragmites australis* were present in <10% of the plots. *Phragmites* was present only at two sites and was omitted from the statistical analysis. The results of the Mann-Whitney tests for vegetative cover indicated a significant difference between grazed and formerly grazed sites for graminoids, fern/forb, tall shrub, *Typha*, and *Sphagnum* categories (Table 1). Cover values for graminoids, fern/forb, tall shrub, and

TABLE 2.—Mann-Whitney *U* Test results of vegetation height between grazed and formerly grazed wetlands. Results significant at $P < 0.05$ are bolded and those significant after Bonferroni adjustment are indicated with an asterisk.

	FORMERLY GRAZED median height	GRAZED median height	Initial *P* level
Category 6: tall shrub	1.2	1	* **0.0019**
Category 9: *Phalaris arundinacea*	1.1	0.5	* **0.0015**
Category 10: *Typha* spp.	1.6	1.3	* **<.0001**
Category 11: *Lythrum salicaria*	1.3	0.6	* **<.0001**
Category 12: *Acorus calamus*	1.2	0.9	* **0.0284**
Category 13: *Microstegium vimineum*	0.9	0.3	* **0.0109**

Sphagnum were greater for grazed sites, whereas formerly grazed sites supported more *Typha* cover (Table 1). However, only the results for graminoids and fern/forb were significant after Bonferroni correction. The Mann-Whitney results for vegetation height indicated that *Typha*, *L. salicaria*, *P. arundinacea*, *A. calamus*, *M. vimineum*, and tall shrubs were significantly lower at grazed sites (Table 2).

Bog Turtle Surveys

Bog turtles ($n = 126$) including 19 juveniles and 107 adults, were captured among the 24 sites. At each site, the median number for juvenile turtles, adult turtles, and all turtles was 1.0, 3.5, and 5.0, respectively. Median density for juvenile turtles, adult turtles, and all turtles was 1.9, 9.9, and 11.0 turtles per hectare, respectively.

All grazed sites combined yielded a total of 86 bog turtle captures, and formerly grazed sites yielded 40 captures. Forty-five percent of all bog turtle captures in the grazed sites occurred in hoof prints. Based on Mann-Whitney *U*-tests, there was a significant difference in the number of turtles and turtle density between grazed and formerly grazed sites (Table 3). Both of these attributes were greater at grazed sites (Fig. 1). There was also a significant difference in the number of adult turtles and juvenile turtles between treatments, with both attributes being greater at grazed sites (Fig. 1, Table 2). The frequency of occurrence of juvenile turtles was also higher for grazed sites (75%) compared to formerly grazed sites (33%) (Fig. 1).

We surveyed a total of 9.7 ha of habitat at the 24 sites. For each site, the median site area was 0.33 ha. The total time spent searching for turtles and total area of habitat surveyed was 59 hr for the 4.0 ha of grazed sites and 84 hr for the 5.7 ha of formerly grazed sites, or 14.8 h ha^{-1}. Based on Mann-Whitney *U*-test results, there was no significant difference in site area between grazed and formerly grazed sites ($U = 57$, $Z = 0.866$, $P = 0.381$) (Fig. 1). For all 24 sites combined, Spearman rank correlation results indicated no significant relationship between site area and the number juvenile turtle captures ($r = -0.24$, $P = 0.252$), number of adult turtle captures ($r = 0.12$, $P = 0.584$), or total number of turtle captures ($r = 0.05$, $P = 0.821$). Within the grazed sites, there was a significant positive correlation between habitat area and the total number of turtles collected per site ($r = 0.59$, $P = 0.042$) and the number of adult turtles collected per site ($r = 0.69$, $P = 0.013$). The relationship with the total number of turtles did not remain significant after Bonferroni correction. There

TABLE 3.—Mann-Whitney *U*-test results for the comparison of bog turtle population variables in grazed and formerly grazed sites. All four are signifcant after Bonferroni significance-level adjustment.

	FORMERLY GRAZED median captures	GRAZED median captures	Initial *P*-values
Turtle captures	3	6	0.00185
Adult turtle captures	3	5.5	0.00211
Turtle density	7.8	25	0.00553
Juvenile captures	0	1	0.04514

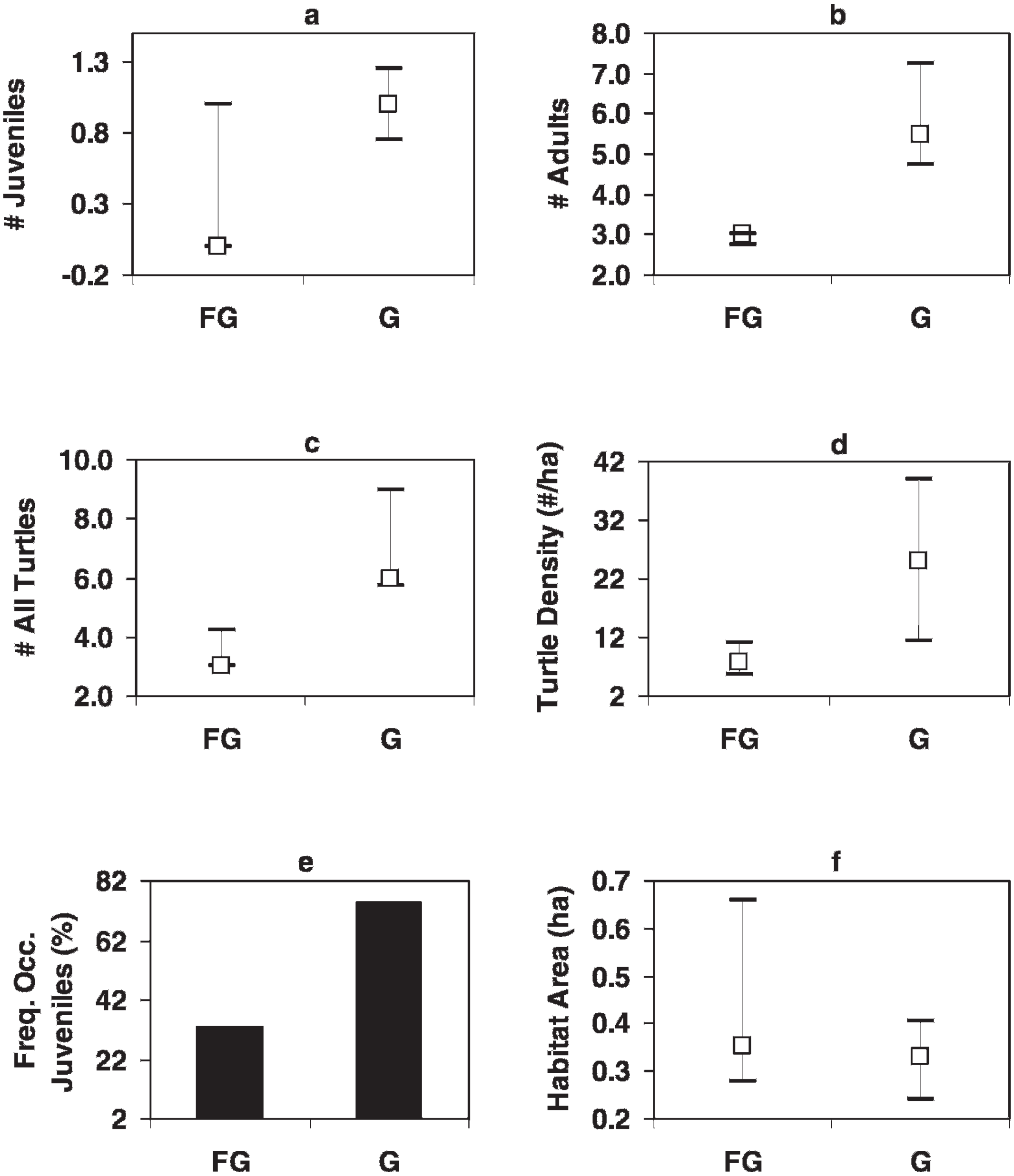

Fig. 1.—Boxplot comparisons of juvenile bog turtle captures (a), adult bog turtle captures (b), all bog turtle captures (c), bog turtle density (d), the frequency of occurrence of juveniles (e), and habitat area (f) at grazed (G) and formerly grazed (FG) sites. Medians and first and third quartiles are illustrated. Differences in the number of juveniles, adults, all turtles, and turtle density were significant after Bonferroni correction.

was no relationship between habitat area and the number of juvenile turtles for grazed sites nor were any of the turtle demographics related to habitat area in formerly grazed sites ($P > 0.05$ in all cases).

Discussion

The most obvious effect of large herbivores on bog turtle habitat and wetlands in general is the suppression of tall-growing woody or herbaceous vegetation through grazing and trampling (Ausden et al., 2005; Van Deursen and Drost, 1990). Our data demonstrated that grazed sites contained a greater cover of native sedges, grasses, forbs, sphagnum mosses, and fewer tall-growing shrubs than the formerly grazed sites. While no differences occurred in cover comparisons of any of the invasive herbaceous species (i.e., *L. salicaria*, *Typha*, *P. arundinacea*, *M. vimineum*), the height of each species was significantly lower in the grazed sites. From a plant community perspective, this difference is particularly important. Tall growth is one trait that makes these invasive species so ecologically deleterious to bog turtles. We observed that at maximum growth, plants such as *L. salicaria* dwarf native species and may deprive them of light. However, when grazed to half of their maximum height, their shading effect appeared to be minimized. The long-term effect of grazing, which occurred at the grazed sites for more than a decade, may have contributed to the difference in bog turtle numbers, as the grazing ensures ample solar radiation, which is critical for the gestation and incubation of eggs and growth of the turtles (Kiviat, 1978).

Because 45% of bog turtle captures in the grazed sites occurred in hoof prints, this microhabitat appeared to be important for turtles at these sites. In the absence of grazing, soft mucky soils were smothered by mats of litter, and several sites were choked by dense rhizomes. Research in sedge meadows in Canada (Raillard and Svoboda, 2000) demonstrated that the cessation of grazing by musk ox (*Ovibos moschatus*) led to a five-fold increase in litter accumulation. Wet hollows may play a vital role for bog turtles. They may serve as refuge from potential predators, as evidenced by our frequent observations of bog turtles rapidly retreating into the hollows when encountered. Kiviat (1978) reported that saturated substrates that facilitate burrowing are required to avoid thermal stress and dehydration. In many of the grazed sites, the hoof prints were the primary aquatic microhabitat that allowed this burrowing. The formerly grazed sites contained very few natural hollows; soft, saturated substrates that provided quick retreats were limited to seepage areas and rivulets.

It is possible that the cropped vegetation and the absence of litter at the grazed sites made the largely visual task of capturing bog turtles easier than in sites without grazers. However, the majority of bog turtle searches were performed in the spring months when the livestock grazed in the surrounding upland pasture and entered the wetlands infrequently. The vegetation in both grazed and formerly grazed wetlands during this period was equally low in height, as it was just emerging, and we feel that it did not have an effect on our visual searching. The vegetation surveys were carried out later in the season. It was during a four-week period in late summer after the bog turtle surveys were completed that the livestock concentrated their grazing in the wetlands. This late-season grazing appeared to be enough to maintain better habitat conditions for the bog turtle.

While one can only postulate the historical function that grazing by wild herbivores once performed in bog turtle habitat ecology (Lee and Norden, 1996), our study of pastured wetlands clearly shows that bog turtles are clearly more abundant when livestock are present. Modern livestock farming, primarily through its use of fertilizers and manure management practices, has dramatically altered the ecology of wetland pastures and created an environment that favors the growth of competitively dominant, invasive wetland flora (Haslam, 1965; Kiviat, 1978; Wheeler, 1983). Grazing mitigates the effects of these impacts, which may allow bog turtle populations to thrive; however, when farms are abandoned and converted to other land uses and grazing pressure is relieved, sedge meadows rapidly give way to reedy marshes and swamps, which may cause bog turtles to decline.

The biggest challenge that the conservation community faces in implementing the prescribed grazing of bog turtle habitat is securing livestock, and finding farmers willing to graze their animals. As our rural landscapes rapidly give way to subdivisions, habitats are degraded and fewer hoofed stock are available for use in habitat restoration. Moreover, the incentives available to encourage beef or dairy farmers to truck their animals to wetlands, which are regarded as mediocre pasture, often do not outweigh the costs of trucking and caring for the animals at remote locations. Even interested farmers cannot commit to long-term grazing agreements, as the future of their farming livelihood is often tenuous. Efforts to restore and maintain bog turtle habitats with prescribed grazing will only work if agricultural economics improve, livestock farmers are available to provide grazers, and the pasturing of wetlands yields a profitable return at the market. Prescribed burning and mowing are possible alternatives to grazing, and each is widely practiced in North American and European fens, respectively (Middleton et al., 2005). However, the effects of these vegetation management practices on bog turtles are poorly understood and warrant research before they can be recommended.

The use of goats or sheep may hold promise for bog turtle management because they are excellent at controlling woody plants and tall weeds, require relatively small enclosures, and are easy to transport (Tesauro, 2001). Sheep and goats, however, tend to avoid wet ground (Crawley, 1983; J. Tesauro, personal observation) and generally must be forced into wetlands through limitations of forage and/or area. Most cattle breeds do not avoid water (Menard et al., 2002), are physically the best-suited stock for wetland grazing, and create microtopographic conditions that are ideal for bog turtles (Somers et al., 2000). Perhaps the growing pasture-based market for grass-fed meat may revive grazing of wet meadows and thus aid the bog turtle. The U.S. Department of Agriculture funds bog turtle restoration through Natural Resource Conservation Service programs, in which farmers are paid to seasonally graze livestock in overgrown bog turtle habitats. Thus, if the grazing of cattle in wet meadows can resume its role in the economy of small-scale dairy or beef farming in the eastern U.S., it will have the additional benefit of helping the threatened bog turtle by maintaining the habitat type it requires.

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