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Relative Abundance and Diet of Spiny Softshells (*Apalone spinifera*) in a Lake Erie Population

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Populations of the Spiny Softshell (*Apalone spinifera*) in the Great Lakes are of conservation concern despite being secure elsewhere in their North American range. We examined the relative abundance of Spiny Softshells among the turtle fauna at Presque Isle, a peninsula on the Pennsylvania shoreline of Lake Erie. We also compared male and female diets to determine the presence of invasive Zebra and Quagga Mussels (*Dreissena* spp.). The Spiny Softshell was the fifth most common of six turtle species captured (2% of captures). In the peninsula's largest bay there was a significant increase in capture rate and proportion of Spiny Softshell captures in late summer (5% of five species of turtles) compared to early summer (3% of all turtles). Recapture was considerably lower for Spiny Softshells (5%) than for four other turtle species suggesting that either its relative abundance is higher than trapping data indicate or that they are a mobile species with less habitat fidelity than other residents. Prey from fecal samples were quantified using an Index of Relative Importance (IRI). Males (n = 26) ate primarily unidentified insects (IRI = 59), followed by algal stalks (IRI = 35) and caddisfly larvae (IRI = 4). Females (n = 5) ate primarily algal stalks (IRI = 54), followed by crayfish (IRI = 22) and fish (IRI = 19). Only two turtles, one male and one female, passed Zebra and Quagga Mussels in fecal samples, thus Spiny Softshells do not appear to make significant use of these invasive molluscs.

Key Words: Turtle; Testudines; Trionychidae; *Dreissena*; recapture rate; Presque Isle State Park

Introduction

The Spiny Softshell, *Apalone spinifera* (LeSueur, 1827), is a widely distributed freshwater turtle in the Mississippi-Ohio-Missouri drainage, several smaller Gulf Coastal rivers to the east and west of the lower Mississippi, and the St. Lawrence/Great Lakes drainage and its tributaries (Iverson 1992). In the St. Lawrence/Great Lakes watershed, Spiny Softshells have declined in number and disappeared from some areas, such that their range in the watershed has become fragmented (Fletcher 2002; Vermont Fish and Wildlife Department 2009).

The Spiny Softshell was assessed as a Threatened species in 1991 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and again 11 years later (Fletcher 2002). COSEWIC has reassessed it as Endangered in April 2016 but this change in status has yet to be recognized under the Canadian *Species at Risk Act* (SARA Registry 2016). The species has also been listed as Threatened in Vermont since 1987 (Vermont Fish and Wildlife Department 2009). They are not listed by other Great Lakes states, reflecting their wider distribution outside the St. Lawrence/Great Lakes drainage, in particular in New York, Pennsylvania, and Ohio (Hulse *et al.* 2001; Wynn and Moody 2006; Gibbs *et al.* 2007).

Canadian populations of Spiny Softshells are restricted to the lower St. Lawrence/Great Lakes drainage and are considered to have declined in recent decades. The two major Canadian subpopulations are believed to number between 600 and 1500 adults, with most of them in Ontario and fewer than 100 adults in Quebec (Environment Canada 2016). Spiny Softshell populations in Vermont were estimated to number 100–200 in the area of Missiquoi Bay of Lake Champlain and ~60 near the mouth of the Lamoille River (Graham and Graham 1997; Vermont Fish and Wildlife Department 2009).

The Eurasian invasives, the Zebra Mussel, *Dreissena polymorpha* (Pallas, 1771), and the Quagga Mussel, *D. bugensis* (Andrusov, 1897), were first introduced to the Great Lakes in the 1980s (Herbert *et al.* 1989; May and Marsden 1992). Whether or not they have become a new component of the Spiny Softshells' diet has not been investigated. The Common Map Turtle, *Graptemys geographica,* and Stinkpot, *Sternotherus odoratus*, feed on dreissenid mussels in Lake Erie at Presque Isle, Pennsylvania (Lindeman 2006; Patterson and Lindeman 2009). Common Map Turtles also feed on dreissenid mussels in Lake Opinicon in Ontario (Bulté and Blouin-Demers 2008) and along the Thames River and in Lake Erie in Ontario (S. Gillingwater, personal communica-

tion). Recently, the sister species of the Spiny Softshell, the Smooth Softshell, *Apalone mutica*, was also reported to feed on dreissenid mussels in the upper Mississippi River (Cochran and Peterson 2011).

Turtle trapping has been conducted at Presque Isle since 1999 (Lindeman 2006; Patterson and Lindeman 2009). We had two objectives: a) to examine the relative abundance of Spiny Softshells at Presque Isle, including seasonal changes, and b) to quantify and compare male and female diets with an emphasis on determining the extent to which Spiny Softshells are feeding on Zebra and Quagga Mussels.

Methods

Data were collected at Presque Isle State Park in Erie, Pennsylvania (42°09'40"N, 80°05'26"W). Presque Isle is a sandspit peninsula that juts out into Lake Erie. The park is approximately 1300 ha of stabilized sand with several public beaches and a variety of terrestrial and aquatic wildlife habitats. The study area was located at the eastern (distal) end of the peninsula at Misery Bay and an adjoining lagoon, Graveyard Pond (Figure 1).

We captured turtles in Misery Bay and Graveyard Pond using platform basking traps (MacCulloch and Gordon 1978) and single- and double-ended fykenets (Vogt 1980) with 5- to 15-m lead nets and 0.9-m openings. Fykenets were left overnight and checked once daily, while basking traps were checked for use by turtles throughout the day. We conducted occasional trapping in other habitats on Presque Isle, but greater than 95% of all turtle captures on the peninsula were in Misery Bay and Graveyard Pond. In Misery Bay, where most softshells were caught, the greatest trapping effort and most captures occurred in late August and early September (hereafter late summer). We also trapped in late May, June, and early July (hereafter early summer), when trapping was generally more intense in Graveyard Pond and basking traps were used more than fykenets. We compared the relative abundance of Spiny Softshells from Misery Bay fykenet captures between early and late summer using a 2×2 χ^2 contingency table. Trap types and trap nights were recorded consistently beginning in 2002, but only sporadically in prior years, so some earlier data were withheld from analysis. We made additional captures of Spiny Softshells at a nesting site in Thompson Bay and on one occasion in Horseshoe Bay, when hatchlings were captured by hand (Figure 1).

We marked turtles individually by cutting combinations of 1–3 triangular notches in the posterior half of the rim of the carapace through 2011 (Plummer 2008)

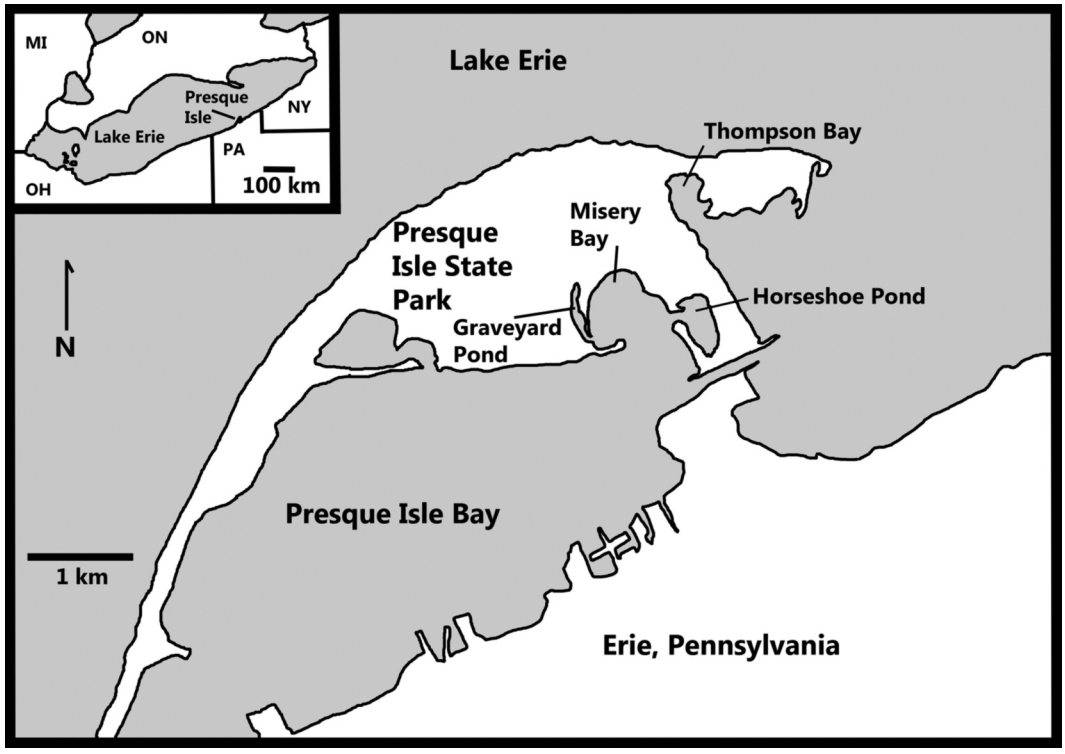

FIGURE 1. Presque Isle State Park on Lake Erie in Erie, Pennsylvania, showing the primary turtle trapping locations in Misery Bay and Graveyard Pond. The locations of Thompson Bay and Horseshoe Pond, where opportunistic captures of Spiny Softshells (*Apalone spinifera*) occurred, are also shown.

and thereafter by applying three-digit numbers with a tattoo gun (Weber *et al.* 2012). Straight-line carapace length (SCL) was measured to the nearest mm with forestry calipers and body mass (BM) was determined to the nearest 1 g, 10 g, or 100 g using 100-g, 1000-g, and 5-kg spring scales, respectively (models pes20100, pes41000, and pes80005, respectively; Pesola Scales, Kapuskasing, Ontario). We determined sex based on diameter of the base of the tail, which is larger relative to overall body size in males, and the more mottled pattern of the carapace in females.

From 2005–2013, we confined Spiny Softshells for 48 hr indoors in plastic bins containing a few centimeters of water. We collected fecal samples by passing the water through a sieve. Samples were preserved in 70% ethanol. Turtles were re-released where they had been captured.

Prey remains in the feces were sorted to the lowest taxonomic category possible under a dissecting microscope (7–30×). Most insects were not identifiable to taxonomic order due to fragmentation, except for caddisfly larvae, whose cases were passed intact, allowing them to be categorized separately from other insects. We calculated the volume of each prey type using volumetric displacement. If a prey type made no noticeable displacement, it was estimated to constitute either 0.01 or 0.05 mL based on size. Each prey category was ranked using an Index of Relative Importance (IRI) based on average volume of feces by type multiplied by the frequency at which each type occurred in feces, divided by the total of the products for all taxa. The IRI values sum to 100 (Hyslop 1980, as modified by Bjorndal *et al.* 1997). We separated IRI sample calculations by sex.

Results

Over 17 years, 73 Spiny Softshells were captured a total of 77 times at Misery Bay (n = 68; 67 fykenet captures and one hand-captured hatchling), Graveyard Pond (n = 4; two fykenet captures, one basking trap capture, and one hand-captured hatchling), Thompson Bay (n = 3; females encountered while nesting), and Horseshoe Pond (n = 2; hand-captured hatchlings). Spiny Softshells accounted for 2% of the total catch of 3749 turtles and were the fifth most common of six species captured overall in trapping on Presque Isle (Table 1).

Relative abundance in Misery Bay fykenet captures rose significantly in the late summer. There were 53 Spiny Softshells of 1027 turtles caught in late summer (5% of all turtles) compared to only 12 Spiny Softshells of 454 turtles caught in early summer (3% of all turtles; $\chi^2_1 = 4.75$, $P = 0.029$; Figure 2). From May to July, Spiny Softshells averaged 0.05 captures per trap-night (one capture per 22 trap-nights), while from August to September, Spiny Softshells averaged 0.33 captures per trap-night (one capture per 3 trap-nights). The total catch of turtles in fykenets set in Misery Bay was higher in late summer (1.70 turtles per trap-night) compared to early summer (0.33 turtles per trap-night). This was due to an increased late-summer catch of Spiny Softshells, Common Map Turtles, and Stinkpots, countering a seasonal decline in the capture rate of the Common Snapping Turtle, *Chelydra serpentina*, while the capture rate of Painted Turtles, *Chrysemys picta,* remained low in both periods (Figure 3). The Spiny Softshell recapture rate (5%) was very low compared to recapture rates for the four other most commonly captured species (range 17–36%; Table 1).

TABLE 1. Turtle catch statistics at Presque Isle State Park for all capture methods, 1999–2015.

Species	New captures	Recaptures	Total	% of total captures	% new captures
Graptemys geographica	1571	814	2385	64	66
Chrysemys picta	207	44	251	7	82
Sternotherus odoratus	385	78	463	12	83
Chelydra serpentina	364	207	571	15	64
Apalone spinifera	73	4	77	2	95
Emydoidea blandingii	2	0	2	0.0005	100
Total	2602	1147	3749		69

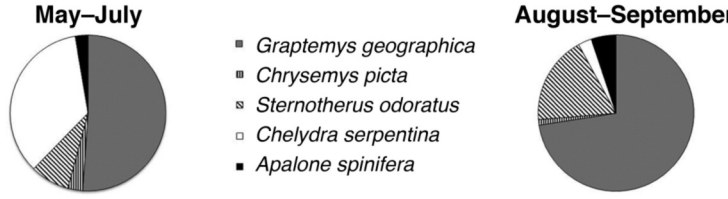

FIGURE 2. Proportions of all turtles captured by species using fykenets set in Misery Bay for early summer (May–July, n = 454) versus late summer (August–September, n = 1027) for 2003–2015 and dates from the period 1999–2002 when trap type was recorded.

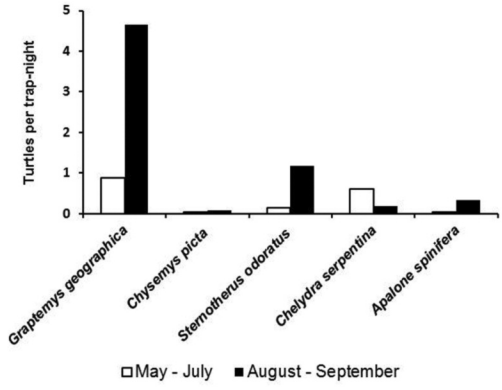

FIGURE 3. Average number of turtles captured per fykenet trap-night by species for early summer (May–July) versus late summer (August–September) for 1999–2015.

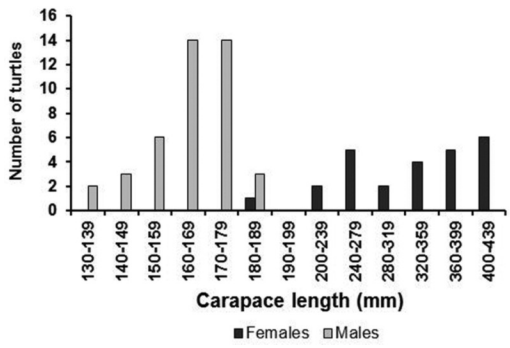

FIGURE 4. Distribution of straight-line carapace length for female and male Spiny Softshells (*Apalone spinifera*) at Presque Isle State Park.

We found almost no overlap in body size between male Spiny Softshells (n = 42; from 133 to 183 mm SCL, mean 164.9 mm SCL; from 192 to 591 g BM, mean 426.4 g BM) and female Spiny Softshells (n = 25; from 188 to 422 mm SCL, mean 327.5 mm SCL; from 522 to 6400 g BM, mean 3401.3 g BM; Figure 4).

Fecal samples were collected from 31 individuals between 2005 and 2013, with 26 samples from males and five samples from females. Eight prey categories were found: fish, caddisfly larvae, crayfish, insect fragments, *Dreissena* spp. mussels, sphaeriid clams, algal stalks, and leaf fragments (Table 2). Among males, insect fragments had the highest IRI value, followed by algal stalks and caddisfly larvae. Among females, algal stalks had the highest IRI value, followed by crayfish and fish. Samples from three females were predominantly algal stalks and fish, while samples from the other two females were predominantly crayfish. *Dreissena* shell fragments were present in two samples, from a male measuring 133 mm SCL, at 43% of sample volume, and a female measuring 393 mm SCL, at 5% of sample volume.

Discussion

Trapping data indicated a low relative abundance for Spiny Softshells in the Presque Isle turtle assemblage, although this value doubled during late summer in Misery Bay. There was however a paradox with respect to the species' relative abundance versus its recapture rate. We recorded a 5% recapture rate. This was much lower than the recapture rates of the four other, more abundant species. In the absence of the relative abundance data we collected, the low recapture rate might be interpreted as being consistent with high abundance of Spiny Softshells. However, the fact that Spiny Softshells were only 4% of turtles caught in fykenets in Misery Bay, by far the most successful trapping method and trapping site for the species, suggests they are relatively rare at Presque Isle rather than abundant.

Movement habits and trap avoidance may provide alternative explanations for the low recapture rate of Spiny Softshells at Presque Isle. The results of a telemetry study by Galois *et al.* (2002) on Spiny Softshell movement patterns in Lake Champlain may explain the seemingly contradictory catch statistics at Presque Isle. Female average home range size was 32.1 km^2 and male average home range size was 2.8 km^2. Females and males were recorded to move minimum distances

TABLE 2. Dietary data for Spiny Softshells (*Apalone spinifera*) at Presque Isle State Park, with percent frequency of occurrence (%F), mean percent volume (%V), and index of relative importance (IRI).

	Males (n = 26)			Females (n = 5)		
Prey taxon	%F	%V	IRI	%F	%V	IRI
Crayfish	4	3.0	0.20	40	36.0	22.00
Caddisfly larvae	35	9.0	4.00	40	0.3	0.10
Insect fragments	100	49.0	59.00	80	3.0	4.00
Zebra and Quagga Mussels	4	2.0	0.08	20	0.9	0.30
Sphaeriid clams	0	0.0	0.00	20	0.9	0.30
Fish	15	7.0	1.30	60	22.0	19.00
Algal stalks	100	29.0	35.00	100	36.0	54.00
Leaf fragments	8	2.0	0.20	20	0.1	0.03

of up to 25.0 and 6.3 km, respectively. It may be that the recapture rate of Spiny Softshells at Presque Isle was low because they are such capable swimmers and are more transient in Misery Bay and Graveyard Pond than the other resident turtle species. It is also possible that marked Spiny Softshells exhibit a greater ability than the other turtle species in Presque Isle to learn to avoid fykenets following capture and release. Trap shyness comparisons among co-occurring turtle species have not been investigated. A low recapture rate of marked Spiny Softshells has also been recorded in the Thames River in Ontario (S. Gillingwater, personal communication). A study of this phenomenon, if indeed it is a general attribute of the species, should be the focus of future research.

The reasons for the seasonal increase in Spiny Softshell captures in Misery Bay in late summer are unknown. Similar increases occurred for two other species, Common Map Turtles and Stinkpots, while Common Snapping Turtle captures declined in the same months. These changes probably relate to seasonal shifts in habitat use, as they were predictably encountered throughout the 17 years of study (P. Lindeman, unpublished data).

The most important prey of Spiny Softshells at Presque Isle were insects, crayfish, fish, and algae. Previous dietary studies of Spiny Softshells have found insects and crayfish to be important prey (Lagler 1943; Williams and Christiansen 1981; Cochran and McConville 1983). Fish and algae (the latter as part of poorly defined vegetative categories) have variously been reported as relatively important (Williams and Christiansen 1981; Cochran and McConville 1983) or nearly absent from the diet (Lagler 1943).

Notwithstanding the fact that female fecal sample size was low (many females held over one to two nights did not defecate), dietary differences between the sexes were relatively pronounced. While both sexes fed moderately heavily on stalked algae (the only taxon present in every sample), males fed most heavily on insects, while females ate less insects and all five passed relatively large amounts of either crayfish or fish. Both fish and crayfish were of low importance (IRI less than two) in male diets. Surprisingly, this widespread, frequently abundant, and strongly size-dimorphic species has not been studied for dietary differences between the sexes. The three most detailed dietary studies of Spiny Softshells have reported pooled samples from males and females (Lagler 1943; Williams and Christiansen 1981; Cochran and McConville 1983), although in the last of these studies, males were reported to eat more dragonfly naiads and females more fish, with similar amounts of crayfish eaten by both sexes. In a similarly size-dimorphic congener, the Smooth Softshell, dietary differences between the sexes were reported by Plummer and Farrar (1981): males fed more on terrestrial food sources, including various insect taxa, fruits, and seeds. Females fed more on aquatic food sources, in particular caddisfly larvae, fish, and crayfish, partly mirroring the results presented here. In many Map Turtle and Sawback species of the diverse emydid turtle genus *Graptemys*, strongly divergent diets typify the small males and much larger females (Lindeman 2013). Further studies of dietary differences between the sexes in the two widespread North American Softshell species are clearly warranted.

While dreissenid mussels were found in only two samples and in low mean percent volume, at least two other species of turtles feed heavily on these invasive molluscs in Misery Bay and Graveyard Pond. Adult female Common Map Turtles consumed primarily dreissenid mussels, with an IRI score of 98; IRI scores declined sharply in smaller juvenile females and both small-bodied adult males and unsexed juveniles had IRI scores less than two (Lindeman 2006). Stinkpots of both sexes also fed heavily on dreissenid mussels, with IRI values of 62 for males and 60 for females (Patterson and Lindeman 2009). Mussels increased in importance in the diets of larger turtles in both species.

Mussels and other hard-shelled molluscs have not been reported to be important prey of Spiny Softshells (Lagler 1943; Williams and Christiansen 1981; Cochran and McConville 1983). Nevertheless, it is possible that the low number of dietary samples from large females (n = 5) obscured the dietary importance of invasive dreissenid mussels in our study. In the only previous report of a species of *Apalone* in North America eating dreissenids, Cochran and Peterson (2011) found that five of 17 female Smooth Softshells caught in a Mississippi River side channel in Wisconsin contained dreissenids (volumetric percentages were not reported). Spiny and Smooth Softshells, along with the Map Turtles and Sawbacks, are among the world's most size-dimorphic turtle species, with adult females in all of these species being greater than 50% longer than adult males in shell length (Gibbons and Lovich 1990). Given the much greater proclivity for mollusc consumption among large adult females than in the smaller conspecific males in many species of Map Turtles and Sawbacks (Lindeman 2013), further study of the possible use of dreissenid mussels by Spiny Softshells should concentrate on the diets of large adult females. Gulf Coast populations of Spiny Softshells have enlarged heads and jaws and may be significant mollusc predators (Lindeman 2000), but the degree to which females in northern populations have the jaw strength and alveolar structure necessary to crush and consume molluscs, particularly the relatively thin shells of dreissenid mussels, is not yet clear.

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