Anti-predator Defenses of Brown Bullheads (*Ameiurus nebulosus*) and Interactions with Snapping Turtles (*Chelydra serpentina*)

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Ictalurid catfishes have sharp spines on their dorsal and pectoral fins that can be hazardous to predators. The pectoral spines may lock in an abducted position, effectively increasing body size and preventing ingestion by gape-limited predators. Further, sharp spines may injure predators or increase prey handling time, affording catfish opportunities for escape. As part of a long-term mark–recapture study of turtle ecology in Algonquin Provincial Park, Ontario, Canada, we documented the presence of Brown Bullheads, *Ameiurus nebulosus*, in the diet of Snapping Turtles, *Chelydra serpentina.* Here, we report on injuries inflicted by the pectoral spines of bullheads on Snapping Turtles during predator–prey interactions and provide a brief literature review of the functional significance and potential dangers of catfish pectoral spines to predators.

Key Words: Brown Bullhead; *Ameiurus nebulosus*; Snapping Turtle; *Chelydra serpentina*; pectoral spine; prey defense; prey handling; diet; Algonquin Provincial Park

Introduction

North American catfishes (Ictaluridae) are equipped with short, stout, flattened pectoral fin rays (Reed 1924; Fine *et al.* 1997; Fine and Ladich 2003). Ictalurid genera (bullheads, *Ameiurus*; channel and blue catfishes, *Ictalurus*; flathead catfish*, Pylodictis*; madtoms, *Noturus*) have pectoral spines adorned with sharp serrations akin to saw-like teeth and a sharp distal tip, creating a formidable defensive spine (Reed 1924; Alexander 1965; Bosher *et al*. 2006; Holm *et al.* 2009; Fine *et al.* 2011). Specialized modification of the bone and muscle tissue allows these spines to be locked in an erect position at a right angle to the fish's body (Alexander 1965; Fine *et al.* 1997; Miano *et al.* 2013). Flaring and locking of the pectoral spines increases the effective size of the catfish and, thus, deters gape-limited predators (Forbes 1989; Fine *et al.* 2011; Sismour *et al.* 2013). Predators may be discouraged from consuming these catfish as a result of injury inflicted by the spines or reduced profitability due to lengthy handling time (Moser 1986; Werner *et al.* 2001; Bosher *et al.* 2006; Nellis 2010; Sismour *et al.* 2013).

The Snapping Turtle (*Chelydra serpentina*) is omnivorous, consuming a variety of aquatic vegetation and prey ranging from aquatic insects and molluscs to fish, anurans, and, occasionally, waterfowl (Alexander 1943; Carr 1952; Hammer 1969; Punzo 1975; Ernst and Lovich 2009). The Brown Bullhead (*Ameiurus nebulosus*) has been recorded in the diet of the Snapping Turtle (Alexander 1943; Ernst and Lovich 2009). The Snapping Turtle and the Brown Bullhead have a largely sympatric geographic range in eastern and midwestern North America, both species occupying similar habitat (Scott and Crossman 1973; Ernst and Lovich 2009). As both may occur in high densities (Iverson 1982; Congdon *et al.* 1986; Galbraith *et al.* 1988; Coad *et al.* 1995; Iverson *et al.* 2000; Kaemingk *et al.* 2012), it is likely that the two species interact regularly.

A long-term study of the life history and ecology of Snapping Turtles based at the Wildlife Research Station (WRS), Algonquin Provincial Park, Ontario, began in 1972. Data are collected annually through standard field methods, including mark–recapture, nest site surveys, and radio telemetry. Turtles are captured from a canoe using a landing net or by hand, or by baited hoop trap, and transported to a laboratory at the WRS where they are measured and weighed. Turtles are marked with notches in the marginal scutes (Cagle 1939), and an aluminum tag bearing an alphanumeric identification code is affixed to the posterior marginal scutes of adults (Loncke and Obbard 1977). The Brown Bullhead is the only catfish species present at the site.

Observations

On 2 July 2010, an adult female Snapping Turtle (ID 076) was captured in Lake Sasajewun (45°35'38"N, 78°31'26"W) with a Brown Bullhead pectoral spine embedded in the tissue of her anterior left forelimb (Figure 1). The spine was removed and no complications were observed on later recaptures in 2010 and 2011–2014.

On 2 July 2014, an adult female Snapping Turtle (ID 587) was captured in Peewee Lake (45°34'18"N, 78°31'29"W). It was immediately noted that her throat was distended and, when she gaped defensively, a large black object was observed obstructing her esophagus (Figure 2A). The turtle was transported to the WRS where she was restrained, and the esophageal obstruc-

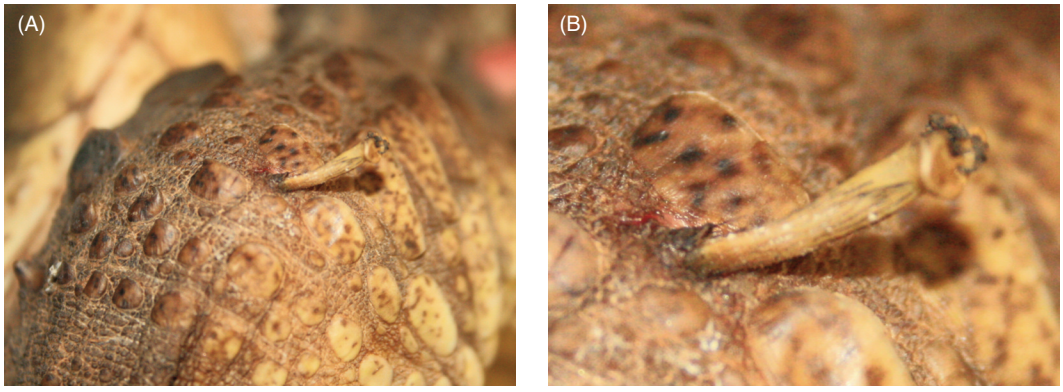

FIGURE 1. A. Pectoral spine of a Brown Bullhead (*Ameiurus nebulosus*) embedded in the anterior surface of the left forelimb of a female Snapping Turtle (*Chelydra serpentina*), ID 076, captured in Lake Sasajewun, Ontario. B. Enlarged view. Photos: P. Moldowan.

tion, a Brown Bullhead that had been swallowed tail-first, was extracted with forceps. The fish's abducted pectoral spines had punctured the turtle's esophageal tissue and caused secondary inflammation and irritation (Figure 2B). Fresh blood was visible on the throat in and around the puncture sites (Figure 2C). This turtle had been previously captured on 6 June 2014 and was observed nesting on 18 June 2014. The lodged Brown Bullhead was not observed on these dates and, therefore, must have been ingested in the 14-day period between 18 June and 2 July 2014. Also, the bullhead was in a mid-stage of decay, suggesting that it had been lodged in the throat for several days.

On 14 August 2014, an adult female Snapping Turtle (ID 721) was captured in Mew Lake (45°34'35"N, 78°31'06"W). A Brown Bullhead pectoral spine was observed projecting through the gular portion of her throat, immediately posterior to the chin barbels and mandibular symphysis (Figure 3). The spine punctured the throat from the inside. The tissue surrounding the embedded spine was well healed, but demonstrated localized swelling and irritation. The portion of pectoral spine extending outside the turtle's body was clipped with pliers, but the base of the spine inside the turtle's mouth was not removed. This turtle was not recaptured again in 2014; thus, we were unable to re-evaluate her condition. The pectoral spine injury was not present when the same turtle was previously captured on 25 June 2013.

Fin spine injuries from Brown Bullhead are seemingly rare in our Algonquin Park Snapping Turtle population. Of the 725 turtles captured in 2009–2014, the three records presented here represent a 0.4% frequency of occurrence of pectoral spine injuries. From over 2500 captures from 1972 to 2008, no catfish-spine injuries were recorded. This lack of records may reflect a lower number of injuries or a similar number of injuries that were not recognized or recorded. Two of us (PDM and MGK) were closely involved in data collection from 2009 to 2014, and observer effort in characterizing injuries was close to uniform over this period. It is notable that all three instances of injuries from Brown Bullhead pectoral spines involved adult female Snapping Turtles, although there is an overall bias toward female captures resulting from nesting site surveys; the average male:female capture ratio from 1972 to 2014 was 0.26:1. In all cases, it is not known whether the fish were taken alive or scavenged.

FIGURE 2. A. Brown Bullhead (*Ameiurus nebulosus*) lodged in the esophagus of a female Snapping Turtle (*Chelydra serpentina*), ID 587, captured in Peewee Lake, Ontario. B. Paired puncture wounds revealed after removal of the catfish. C. Enlarged view (only one puncture visible) showing localized inflammation and fresh blood. Photos: P. Moldowan.

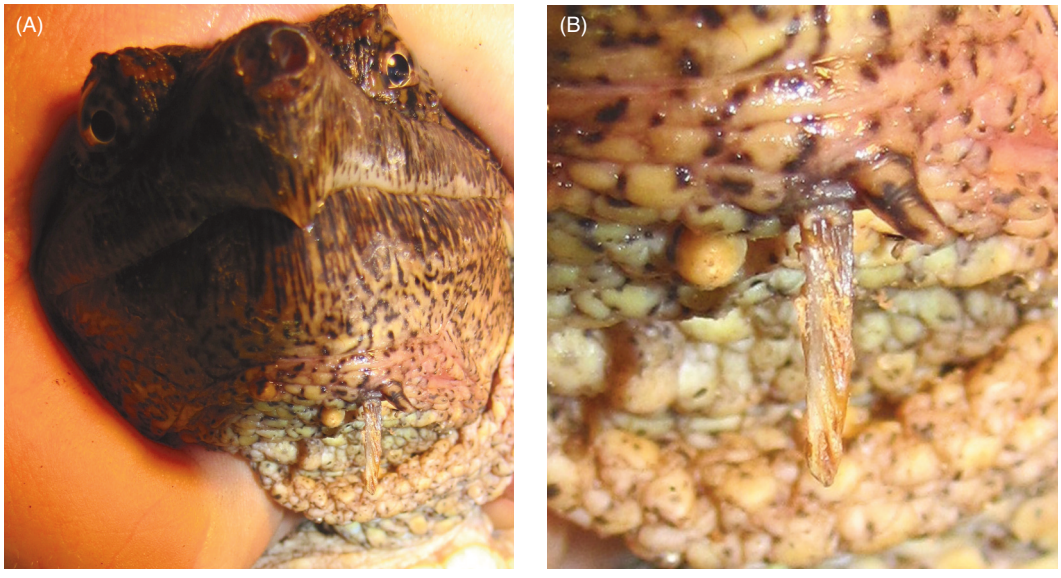

FIGURE 3. A. Pectoral spine of a Brown Bullhead (*Ameiurus nebulosus*) projecting through the throat immediately posterior to the chin barbels of a female Snapping Turtle (*Chelydra serpentina*), ID 721, captured in Mew Lake, Ontario. B. Enlarged view. Photos: M. Keevil.

Discussion

Our observations of injuries incurred during consumption of Brown Bullheads by Snapping Turtles provide information related to the anti-predator, functional significance of ictalurid catfish pectoral spines and the feeding behaviour and ecology of Snapping Turtles. Injuries and fatalities from catfish spines have been recorded in a number of predator taxa: fish (Scott and Crossman 1973; McAda 1983; Pimental *et al.* 1985; Ryden and Smith 2002; Bosher *et al.* 2006; Fine *et al.* 2011; Sismour *et al.* 2013), birds (Bunkley-Williams *et al.* 1994), snakes (Smith 1956; Kofron 1978; Burr and Stoeckel 2000; Gibbons and Andrews 2004; Gibbons and Dorcas 2004; Šukalo *et al.* 2012, 2014), and humans (Murphey *et al.* 1992; Baker 1997; Blomkalns and Otten 1999). The introduction of the Brown Bullhead to Bosnia and Herzegovina has proved dangerous for grass snakes, *Natrix* spp.; preying on this alien fish species has resulted in snakes becoming impaled by the pectoral spines during ingestion (Šukalo *et al.* 2012, 2014). Spines of a marine catfish species have been found embedded in the neck, flippers, and carapace of the Leatherback Sea Turtle, *Dermochelys coriacea* (Pete and Winn 1998). Recently, the spine of an unidentified catfish species was recovered from the roof of the mouth of a Snapping Turtle in Nebraska (Schmidt 2014). The spine was deeply embedded in the tissue of the palate and appeared to have been there for an extended period (C. J. Schmidt, personal communication, 2014). The lodging of an intact catfish in the throat of predatory fish (McAda 1983; Ryden and Smith 2002), birds (Bunkley-Williams *et al.* 1994), and snakes (Šukalo *et al.* 2012, 2014) is similar to that described here for the Snapping Turtle.

Considering the breadth of research on the Snapping Turtle (Lovich and Ennen 2013) and the near absence of other reported pectoral spine injuries, such injuries are probably rare. The Snapping Turtle may be particularly adept at handling catfish prey and avoiding injury from the sharp spines. Alternatively, the inconspicuous injuries caused by pectoral spines may be easily overlooked or misclassified. Soft tissue wounding is common in Algonquin Park Snapping Turtles, especially among combative males (Keevil *et al*., unpublished data). In the absence of an identifiable spine, the cause of soft tissue injuries is often difficult to classify.

The pectoral spine of catfishes has long been described as an anti-predator adaptation (Sörensen 1895; Reed 1924; Alexander 1965), although experimental evidence in support of this idea is relatively recent (Fine *et al.* 1997; Bosher *et al.* 2006; Sismour *et al.* 2013). Rather than using the spines preemptively to ward off would-be predators, Channel Catfish, *Ictalurus punctatus*, erect their pectoral spines to discourage ingestion only when restrained by a predator (Bosher *et al.* 2006; Sismour *et al.* 2013). Abduction of the pectoral spines can more than double the width of Channel Catfish, inhibiting prey handling and ingestion by gape-limited predators, such as the Largemouth Bass, *Micropterus salmoides* (Sismour *et al.* 2013). Pectoral spines do not deter Largemouth Bass from capturing Channel Catfish, but the spines do, ultimately, decrease risk of mortality and discourage repeated predation attempts (Bosher *et al.* 2006; Sismour *et al.* 2013). Compared

with fish predators, adult Snapping Turtles are only marginally gape-limited. Small prey are captured through a high-speed ram feeding mechanism (Lauder and Prendergast 1992) and may be swallowed intact (Punzo 1975; Ernst and Lovich 2009; P. Moldowan, personal observation); however, oversized prey items are held securely in the jaws and shredded with the foreclaws (Punzo 1975; Igl and Peterson 2010; Bobbie *et al.* 2015; P. Moldowan, personal observation). This tearing and dismemberment may help Snapping Turtles avoid the potentially injurious consumption of pectoral spines. It is probably this prey-handling behaviour that is responsible for the embedded pectoral spine in the forearm of Snapping Turtle ID 076.

Catfish pectoral spines can hinder ingestion, especially when the fish is swallowed tail-first, as illustrated by Snapping Turtle ID 587. Similarly, Largemouth Bass that ingested Channel Catfish tail-first experienced prey-handling difficulties (Bosher *et al*. 2006). The low incidence of pectoral spine injury in Algonquin Park Snapping Turtles may indicate that Brown Bullheads constitute a small portion of the diet, consistent with findings by Alexander (1943). Based on our direct and indirect predation observations, it seems that Snapping Turtles do not necessarily discriminate against Brown Bullheads as prey items despite the risk posed by the defensive pectoral spines (i.e., the spines do not serve as a preemptive warning). Also, given the rapid predatory strike (Lauder and Prendergast 1992) and substantial bite force (Herrel *et al.* 2002) of Snapping Turtles, the pectoral spines probably do not adequately protect Brown Bullheads (i.e., a landed strike would likely be fatal to the catfish, thereby negating the anti-predator significance of pectoral spines). As noted by Sismour *et al.* (2013), the effectiveness of catfish pectoral spines as anti-predator defense depends on relative predator–prey size and predator aggressiveness.

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