

Freshwater turtle by-catch from angling in New Brunswick, Canada

CONSTANCE L. BROWNE^{1,*}, S. ANDREW SULLIVAN¹, and DONALD F. MCALPINE¹

¹New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada

*Corresponding author: cbrowne@unb.ca

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Abstract

Turtles are among the most threatened vertebrate taxa, with populations especially vulnerable to any increase in adult mortality. By-catch from freshwater angling, as a potential cause of turtle mortality is poorly documented and little understood. Here we document cases of turtle by-catch by recreational anglers in an urban park in New Brunswick and among the wider angling communities in the province. We also consider factors that may influence rates of hooking. Although we are unable to estimate turtle hooking frequency for the provincial recreational angling community as a whole, five of 75 (~7%) anglers interviewed in the urban park reported interactions with a turtle, with most reported incidents (75%) involving hooking. Snapping Turtles (*Chelydra serpentina*) seem to be more prone to hooking than Eastern Painted Turtles (*Chrysemys picta picta*). Although we conclude that turtle hooking by recreational anglers appears to be generally uncommon in New Brunswick, even apparently low by-catch rates may be sufficient to lead to population declines at heavily fished sites. The collection of additional data on turtle by-catch in the recreational fishery in Canada is warranted.

Key words: Angling by-catch; *Chelydra serpentina*; *Chrysemys picta picta*; *Glyptemys insculpta*; fishing; New Brunswick; Eastern Painted Turtle; Snapping Turtle; Wood Turtle; Red-eared Slider; threats; *Trachemys scripta*

Introduction

Turtle populations have declined worldwide. Globally, 62% of turtle species are at risk of extinction (IUCN 2020). Numerous investigations have focussed on mitigating threats to turtles, which include roads (e.g., Gibbs and Shriver 2002; OMNRF 2016), agriculture (e.g., Saumure and Bider 1998; Tingley *et al.* 2009; Erb and Jones 2011), and subsidized predators (Ratnaswamy *et al.* 1997; Browne 2003; Browne and Hecnar 2007; Wirsing *et al.* 2012). Although it is known that freshwater turtles are accidentally caught by recreational anglers (Nemoz *et al.* 2004; Enge *et al.* 2013; Steen *et al.* 2014), little information is available about rates of turtle by-catch in recreational fisheries; survival rates for hooked, injured, and released turtles; or impacts on populations. Where oral structures are affected (Figure 1), a hooked turtle may die following release, even if the hook has been removed.

The extirpation of Eastern Musk Turtle (*Sternotherus odoratus*) around the city of Hamilton, Ontario, is believed to have been the result of angling combined with habitat modification (Lamond 1994 cited in COSEWIC 2012). Steen and Robinson (2017) demonstrate that in settings where recreational fishing pressure is intense, hooking by anglers could have

a great enough impact to affect populations. Steen *et al.* (2014) x-rayed over 600 turtles from five rivers in the southeastern United States and found that the prevalence of ingested fish hooks ranged from 0% to 33% depending on species, sex, age class, and site; the highest rate, 33%, was for adult female Snapping

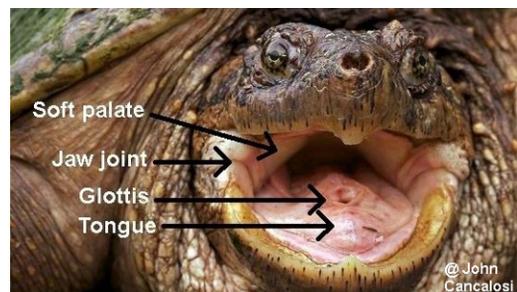


FIGURE 1. Structures of Snapping Turtle (*Chelydra serpentina*) mouth that are sensitive to hooking. Although hooks in the mouth are generally considered a lower risk than swallowed hooks, when penetrated by a hook, the glottis, jaw joint, soft palate, and tongue are prone to infection. If the glottis is damaged, water may drip into the lungs of a released turtle and may cause pneumonia and eventual death (Parga 2012). Photo: John Cancalosi.

Turtle (*Chelydra serpentina*). Steen and Robinson (2017) estimated that the probability of an individual turtle ingesting a hook and dying was 1–11%, depending on the species and the population, and was sufficient to cause declines in simulation models.

Here we suggest that hooking by recreational anglers may be a greater cause of turtle mortality at some sites than is recognized. We document turtle by-catch by recreational anglers in New Brunswick, assess frequency, and consider factors that may influence rates of hooking. We then present an approach to mitigating hooking mortality in the recreational fishery applied in New Brunswick. Most of our data were collected in a heavily fished urban park, but we also collected data more broadly in the province using a social media survey. All native freshwater turtles in New Brunswick are near the northeastern limit of their range, and populations often appear to be small and isolated (McAlpine 2010), leaving them particularly susceptible to even apparently minor incidents of anthropogenic mortality.

Methods

Study area and Rockwood Park turtle communities

Rockwood Park (RWP), Saint John, New Brunswick, (45°17'29.0"N, 66°03'14.1"W) is one of the oldest (established in 1896) and largest (~695 ha) urban parks in Canada. Ten lakes (1.4–10.3 ha) and several ponds (≤ 1.0 ha) lie within RWP boundaries. Several RWP lakes, including Lily Lake and Fisher Lakes are located in a designated recreation zone that is heavily used by the public, including recreational anglers (Figure 2). Although we do not have data on the number of anglers in RWP, angling was rare at remote sites but common at easily accessible sites. Crescent Lake is adjacent to the Rockwood Park golf



FIGURE 2. Annual fishing derby in Rockwood Park, Saint John, New Brunswick. Fishing derbies in urban parks can concentrate recreational anglers in turtle habitat and threaten freshwater turtles. Photo: Acadia Broadcasting.

course and supported an aquatic driving range from 1973 to 2013; the driving range was closed from 2014 to 2017, but reopened in 2018. Angling was not permitted at Crescent Lake when the aquatic driving range was in operation (S. Koval pers. comm. 2014), but did occur during the years it was closed. The remaining lakes are in a designated wilderness area and are less used by the public. We conducted visual and trap surveys for turtles at all 10 lakes in RWP, five ponds located in the RWP recreational zone, and one wetland in the wilderness zone (Table 1).

Four species of turtles have been reported in RWP, although only one appears to form a self-sustaining population. Eastern Painted Turtle (*Chrysemys picta picta*) is resident at Crescent Lake with some use of an adjacent small pond in the golf course during summer (Golf Course Pond 1). A single Eastern Painted Turtle, originally marked at Crescent Lake and recaptured at Harrigan Lake, appears to have been dispersing. In 2015, using mark–recapture and the Jolly-Seber method (Krebs 1999), the population of Eastern Painted Turtles at RWP was estimated at 55 individuals (95% CI 48–74), including 17 females (95% CI 17–17), nine males (95% CI 9–9), and 29 juveniles (95% CI 22–48; C.L.B. and S.A.S. unpubl. data). Snapping Turtles appear to be widely distributed in RWP. From 2005 to 2016, members of the public submitted eight Snapping Turtle observations that were confirmed by photo evidence or expert identification and 12 unconfirmed observations (descriptions matched Snapping Turtle). Nonetheless, trapping only produced three Snapping Turtles, indicating that few individuals are present (Tables 1 and 2). It is not known whether the Snapping Turtles in RWP are the remnants of a previously larger population, are dispersers from populations in the Saint John River system, or are human releases. In 2016, we caught one Wood Turtle (*Glyptemys insculpta*) at A-frame Pond; we believe this was a human release, as suitable habitat to support a resident Wood Turtle population does not appear to be present in RWP. Red-eared Slider (*Trachemys scripta elegans*) is present in RWP, but this species is non-native and of pet trade origin. In 2014–2016, we caught and removed two Red-eared Sliders from Lily Lake and four from First Arch Pond and found one dead individual in Fisher Lakes.

During our trapping efforts and surveys, we noted any injuries to turtles potentially attributable to hooking events. Eastern Painted Turtle and Snapping Turtle are both assessed as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2018a and 2008, respectively) with Snapping Turtle listed in the *Species at Risk Act* as Special Concern (SARA Registry 2019a); Wood Turtle is assessed (COSEWIC 2018b) and listed as

TABLE 1. Turtle species* documented and angler presence recorded at lakes in Rockwood Park, Saint John, New Brunswick.

Site	Size of lake, ha	Sampling dates†	No. trap-days	Turtle species captured	No. days visited in 2016	Angler recorded in 2016
Lily Lake‡	10.32	21 July–9 Sept. 2016 (basking)	50	RES	51	Y
Harrigan Lake	7.78	27 July–10 Aug. 2015	84	0	—	—
Harrigan Lake	7.78	27 July–3 Aug. 2016	125	EPT	8	N
Crescent Lake‡	7.60	25–29 Aug., 31 Aug.–12 Sept. 2014	96	EPT	—	—
Crescent Lake‡	7.60	13 May–17 June 2015	210	EPT/ST	—	—
Crescent Lake‡	7.60	25 Aug.–12 Sept., 15–27 Sept. 2015	180	EPT	—	—
Crescent Lake‡	7.60	17 May–15 June 2016	174	EPT	30	Y
Fisher Lakes‡	6.31	18–25 Aug. 2015	42	RES§	—	—
Fisher Lakes‡	6.31	22–29 June 2016	126	0	8	Y
Long Lake	5.37	13–27 July 2016	180	0	15	Y
Mayflower Lake	2.78	15–22 June 2016	42	0	8	Y
Owen Lake	2.10	14–20 July 2016	63	0	7	N
TCT Wetland	1.90	24–30 June 2015	36	0	—	—
Frying Pan Lake	1.63	6–13 July 2016	126	0	8	N
Crystal Lake	1.52	18–22 Aug. 2014	24	ST	—	—
Crystal Lake	1.52	29 June–6 July 2016	126	ST	8	N
Little Harrigan Lake	1.44	10–18 Aug. 2015	48	0	—	—
Little Harrigan Lake	1.44	3–10 Aug. 2016	84	0	8	N
First Arch Pond‡	0.93	16–18 July, 20–25 July, 5–8 Aug. 2014	51	RES	—	—
First Arch Pond‡	0.93	24 June–21 July 2016 (basking)	27	RES	28	Y
A-Frame Pond‡	0.43	11–15 Aug. 2014	24	WT¶	—	—
Golf Course Pond 1‡,**	0.27	17–24 June 2015	25	EPT	—	—
Golf Course Pond 1‡,**	0.27	3–10 Aug. 2016	35	EPT	8	—
A-Frame Picnic Pond‡	0.12	27 July–1 Aug. 2014	30	0	—	—
Golf Course Pond 2‡,**	0.09	17–24 June 2015	5	0	—	—
Golf Course Pond 2‡,**	0.09	3–10 Aug. 2016	7	0	8	—

*EPT = Eastern Painted Turtle, RES = Red-eared Slider, ST = Snapping Turtle, WT = Wood Turtle.

†Note: Hoop traps used, unless “basking” traps noted (see Browne and Hecnar 2005).

‡Located in designated Rockwood Park recreational zone.

§Found dead on 21 May 2015.

¶Captured opportunistically on 21 May 2016.

**Not open to angling during the time of this study.

TABLE 2. Number of Eastern Painted Turtles (*Chrysemys picta picta*; EPT) and Snapping Turtles (*Chelydra serpentina*; ST) marked in 2014–2016, Red-eared Sliders (*Trachemys scripta elegans*; RES) captured and removed in 2014–2016, and number of angling incidents/potential interactions reported in 2016* in Rockwood Park, Saint John, New Brunswick.

Site	No. EPT marked	No. EPT with mouth injuries	No. ST marked	No. ST hooked or nibbled	No. RES caught and removed	No. RES hooked or nibbled
Crescent Lake	53	3	1	0	0	0
Fisher Lakes	0	0	0	1 (1)	0	0
First Arch Pond	0	0	0	0	4	5
Crystal Lake†	0	0	2	0	0	0
Lily Lake	0	0	0	0	2	(1)

*Incidents occurred in 2013–2016.

†Crystal Lake flows into Fisher Lakes; the main waterbodies are ~130 m apart; thus, ST observed at these two sites could be the same individual.

Threatened (SARA Registry 2019b). Red-eared Slider is now considered invasive in many parts of its introduced range (Kikillus *et al.* 2010) and a potential vector for disease in native turtle populations, including those in parts of southern Canada (Galois and Ouellet 2007). Red-eared Sliders captured in RWP in early spring suggest successful overwintering, although that has yet to be demonstrated for this species in New Brunswick.

Turtle hooking survey

We documented interactions between anglers and freshwater turtles by conducting interviews with 75 adult anglers encountered fishing in RWP from 20 May to 13 July 2016. Anglers were encountered when we visited lakes and ponds in RWP for turtle surveys and during other incidental travel. If a turtle was reported to have attempted to take bait from a hook or was reported hooked, we requested the following information: species involved or a description; date; location; hook type; bait type; nature of hooking event (e.g., hook swallowed, caught on leg); and outcome (e.g., hook removed and turtle released, released with hook embedded).

Social media survey

On 14 May 2017, we also assessed turtle hooking rates elsewhere in New Brunswick by soliciting information on turtles accidentally caught during angling from the New Brunswick fishing forum (<http://www.NewBrunswickFishing.com/forums/>).

To reduce turtle by-catch mortality among recreational anglers in New Brunswick, we developed a list of actions for anglers to follow once a turtle is hooked and delivered this information via social media (New Brunswick Museum Facebook post on 26 May 2017) and in the annual fishing regulations booklet for the province.

Results

Turtle hooking survey

Five of the 75 adult recreational anglers we encountered (6.7%) reported interactions with turtles in RWP in 2013–2016. Eight interactions, of which six (75%) involved hooking, were reported by five anglers (Table 3). Two of the interactions were with Snapping Turtles, both in Fisher Lakes, and both involving hooks baited with fish. In 2014, one Snapping Turtle attempted to consume fish on a line, but it was not hooked, and so was unharmed. In the second case, the fish was consumed and the line with hook was cut at a distance from the turtle. Six additional interactions, which we believe involved Red-eared Sliders, were reported in RWP. These occurred in Lily Lake and First Arch Pond, where only Red-eared Sliders were observed during our study. One turtle interaction occurred in Lily Lake in 2013 or 2014, in which a turtle consumed Pumpkinseed Sunfish (*Lepomis gibbosus*) bait without being hooked. The remaining five turtles were hooked by two anglers in one evening in

TABLE 3. Summary of interactions between turtles and anglers in New Brunswick, 2013–2016.

Turtle species	No. turtles	Year	Location	Gear	Interaction	Outcome
Snapping Turtle (<i>Chelydra serpentina</i>)	1	Unknown ("recent" in 2016)	Fisher Lakes, RWP	Hook baited with fish	Swallowed hook	Line cut, turtle released with ingested hook
Snapping Turtle (<i>Chelydra serpentina</i>)	1	2014	Fisher Lakes, RWP	Hook baited with fish	Bait taken	Unharmed
Red-eared Slider (<i>Trachemys scripta elegans</i>)	5	2014	First Arch, RWP	Small barbless J hooks and earthworm bait	Swallowed hook	Line cut, turtle released with ingested hook
Red-eared Slider (<i>Trachemys scripta elegans</i>)	1	2013–2014	Lily Lake, RWP	Hook baited with <i>Lepomis gibbosus</i> (Pumpkinseed Sunfish)	Bait taken	Unharmed
Eastern Painted Turtle (<i>Chrysemys picta picta</i>)	1	2014	Grand Lake	Unknown	Hooked at edge of shell/leg	Hook easily removed, turtle released
Wood Turtle (<i>Glyptemys insculpta</i>)	1	2016	New Brunswick*	Hook baited with a worm	Hooked in mouth by beak	Hook easily removed, turtle released
Wood Turtle (<i>Glyptemys insculpta</i>)	1	Unknown	New Brunswick*	Fly fishing	Hooked in tail	Hook easily removed, turtle released

RWP = Rockwood Park.

*Precise location on file at the New Brunswick Museum, but not disclosed here to protect a species at risk.

2014 at First Arch Pond. The anglers reported the five turtles as different individuals of the same species, which we were able to confirm as Red-eared Slider based on a photo. Small barbless J hooks and earthworm bait were in use. Each of these turtles swallowed the hook, and anglers cut the line and released the turtles. We do not know the fate of these individuals. Swallowed hooks are believed to lead to high risk of mortality in marine turtles (Parga 2012). In an attempt to gain more information, in 2019, we radiographed two Red-eared Sliders that were caught and removed from First Arch Pond in 2014 and had since been held in captivity at the RWP interpretation centre; no hooks were present.

Although our angler survey did not reveal any reports of interactions with Eastern Painted Turtles, during our population estimate we did observe injuries to this species consistent with hook-inflicted angling. For example, one adult male Eastern Painted Turtle had a penetrating wound between the lower mandibles (possible site of a hook removal; Figure 3) and two juvenile painted turtles (estimated to be two years old based on size and growth lines) had severe infections of the internal tissue of the throat/mouth (characteristic of hook injuries, S. Gillingwater pers. comm. 9 September 2015). Viewed in subsequent captures, the wound of the adult male appeared to be healing well. One of the juvenile turtles was taken to a local wildlife rehabilitation centre with a turtle program (Atlantic Wildlife Institute, Cookville, New Brunswick), but it did not survive. Necropsy results could not determine whether the infection was from a hook injury. The other juvenile was not recaptured during subsequent sampling.

The distribution of Eastern Painted Turtles, Red-eared Sliders, and Snapping Turtles and angling effort differed among sites. We encountered anglers most frequently at lakes and ponds that were easily accessible. Therefore, we cannot easily assess whether risk differed among species by comparing turtle capture numbers to number of angling interactions (Table 2). However, our data suggest that Snapping Turtles and Red-eared Sliders are more likely to swallow hooks than Eastern Painted Turtles.

Social media survey

Our post to the New Brunswick fishing forum received 1331 views and nine responses: five anglers reported never having hooked a turtle, two had hooked turtles outside New Brunswick, and two had hooked turtles in New Brunswick. An Eastern Painted Turtle was hooked under the edge of the shell by a leg. One Wood Turtle was hooked in the beak on 26 July 2016 when attracted to an earthworm on a hook. A third case, submitted independently to C.L.B., involved a Wood Turtle accidentally hooked in the tail dur-



FIGURE 3. Probable hooking injury in an adult male Eastern Painted Turtle (*Chrysemys picta picta*) captured in Crescent Lake, Rockwood Park, Saint John, New Brunswick, on 11 September 2015. The injury penetrated the lower mandible and oral cavity. Photo: Sean Andrew Sullivan.

ing casting by a fly fisherman. In each of these cases, hooks were successfully removed and the turtles released without significant injuries. Nonetheless, we found that anglers, both those responding to our social media survey and those interviewed at RWP, were generally uncertain how to deal with a hooked turtle.

Our social-media-delivered guidelines for anglers who hook turtles reached 24 185 people and was shared 237 times, while a 14 May 2017 post in New Brunswick fishing forum's conservation section (<http://www.NewBrunswickFishing.com/forums/index.php/forum/23-conservation/>) received 1714 views by 9 October 2020. We were also able to place our guidelines (Figure 4) in the fishing regulations booklet for the province of New Brunswick (Browne 2018, 2019, 2020), which is distributed online and in hard copy at no cost through local Fish and Wildlife Branch offices and retail outlets that sell angling licenses.

Discussion

We documented instances of freshwater turtle bycatch by recreational anglers in New Brunswick for all three native species and one non-native turtle. Although we did not receive any reports of Eastern Painted Turtles being hooked in RWP, we did document one instance in New Brunswick outside RWP, and we observed Eastern Painted Turtles in RWP with injuries consistent with hooking. Hooking incidents, including swallowed hooks, have been documented for painted turtles elsewhere in Canada (S. Carstairs pers. comm. 4 March 2019). Mortality from hooking

Our turtle populations are in decline

IF YOU REALIZE YOU HAVE HOOKED A TURTLE WHILE ANGLING:

1. Reel it in slowly and gently to prevent the hook from digging in deeper.
2. Never cut your line. A hook left embedded in a turtle could lead to its death.
3. Use a net or hold the back end of the turtle's shell to lift it out of the water. (Don't lift by the line.)
4. Be cautious. Turtles may bite to protect themselves, especially when feeling pain from being hooked. Be extra careful with snapping turtles, they can swing their heads back and have a powerful bite.
5. Identify how the hook is embedded. If it can be removed easily, then do so and release the turtle.
6. If the hook is difficult to remove, caught in the mouth, or swallowed, medical care is required. Call the Atlantic Wildlife Institute at (506) 364-1902 – they will provide medical care at no charge and have volunteers to assist with transport.

For more information, visit: <http://cbrowne0.wixsite.com/cbrowne/angler-survey> or email Dr. Constance Browne, NBM Research Associate: Constance.Browne@nbm-mnb.ca



NBWTF
www.nbwtf.ca



PARC ROCKWOOD PARK



FIGURE 4. Guidelines instructing anglers how to deal with hooked freshwater turtles (Browne 2020).

is difficult to quantify, and is likely underestimated for many populations, as the remains of turtles that have died as a result of hooking are rarely encountered and available for examination.

We suspect that Eastern Painted Turtles were hooked less frequently in RWP than other species because anglers seldom fish the sections of Crescent Lake most heavily used by painted turtles. An intensive mark–recapture study conducted during 2014–2016 captured all adult painted turtles from the Crescent Lake population (>95% confidence that all were captured). The population was estimated to include 27 adults (10 males, 17 females) in spring 2015 and 26 (nine males, 17 females) in late summer 2015 (C.L.B. and S.A.S. unpubl. data). Of the adult turtles, only one male was unaccounted for in 2016.

Snapping Turtle populations may suffer greater impact from angling than other turtle species, as their larger size may allow them to swallow bait and hook more easily. Snapping Turtles admitted to the Ontario Turtle Conservation Centre have higher frequencies of ingested hooks than other turtle species (S. Carstairs pers. comm. 4 March 2019), and the highest hooking rates reported in Steen *et al.* (2014) were for Snapping Turtles. Post-release mortality estimates for sea turtles injured by hooks range from 19% to 82% (Swimmer *et al.* 2014). A swallowed hook, with line left trailing, is associated with the lowest survival rate (Parga 2012).

Target fish species may play a role in turtle by-catch rates in New Brunswick and elsewhere in Canada. Brook Trout (*Salvelinus fontinalis*) is the species most frequently fished recreationally in New

Brunswick. This is a cold-water fish with a temperature preference of 10–18°C (Smith 1962). The four turtles present in RWP prefer temperatures of 20–30°C (Gatten 1974; Graham and Hutchison 1979; Schuett and Gatten 1980; Dubois *et al.* 2008). Thus, the microsites used by turtles and trout in RWP likely differ. However, Smallmouth Bass (*Micropterus dolomieu*), which is also a target species for anglers in RWP and elsewhere in New Brunswick, is a warm-water fish with a summer temperature preference of 30°C (Coutant 1977). This species is invasive in Maritime Canada and has been expanding its range, most recently in response to climate change (Sharma *et al.* 2009). Smallmouth Bass catch rates have been increasing in New Brunswick, whereas Brook Trout catch rates have declined (C. Connell unpubl. data). This difference may have implications for turtle by-catch rates in the future and is an example of how invasive species, climate change, and human recreational activities can interact to impact native species in ways that are difficult to predict.

Survey results from RWP cannot be extrapolated to infer rates of by-catch outside the park. We received only nine responses from anglers in other parts of New Brunswick, which represents <0.02% of the 57 025 angling licences (salmon excepted) issued in 2016 (C. Connell unpubl. data) limiting our ability to assess angling by-catch rates outside of RWP. Angling pressure undoubtedly varies across water bodies, and the overlap of turtles and anglers may be higher or lower than in RWP. Responses to our New Brunswick fishing forum query suggest that, currently, turtle by-catch by recreational anglers is generally uncommon

in New Brunswick. Furthermore, the Atlantic Wildlife Institute has not received any New Brunswick turtles confirmed injured as a result of angling (P. Novak pers. comm. 1 May 2018). However, in each of the New Brunswick cases confirmed as by-catch that we did document, the turtle was released, including six high-risk cases where the hook was swallowed.

Where recreational fishing pressure is particularly intense, it may add a cumulative element to natural mortality and other anthropogenic deaths (i.e., road mortality) that may lead to population decline. Recreational fishing has been demonstrated to exert negative pressure on turtle populations in the United States (Steen and Robinson 2017). If similar pressures are present in Canada, impacts could be even greater because age of maturity is greater and clutch frequency reduced in northern climates (Galbraith *et al.* 1989; Iverson and Smith 1993; Iverson *et al.* 1997), increasing the importance of adult survivorship. At range margins, populations are often fragmented or isolated (Cook 1984), limiting immigration. However, even in connected habitats, long-lived species are slow to recover following impacts, and some populations may fail to recover even after survivorship rates improve (Keevil *et al.* 2018).

Freshwater turtle by-catch in the recreational fishery is still poorly documented in Canada, although we readily collected evidence of its occurrence in both urban and non-urban settings in New Brunswick. How significant recreational hooking may be overall to freshwater turtle mortality remains unclear. However, given that increased adult mortality of as little as 2–3% can, if chronic, result in marked declines in turtle populations (Congdon *et al.* 1994; Cunnington and Brooks 1996), we suggest that the issue requires greater scrutiny.

Author Contributions

Conceptualization: C.L.B.; Methodology: C.L.B.; Investigation: C.L.B. and S.A.S.; Data Curation: C.L.B. and S.A.S.; Writing – Original Draft: C.L.B.; Writing – Review & Editing: C.L.B., S.A.S., and D.F.M.; Visualization: C.L.B. and D.F.M.; Funding Acquisition: C.L.B. and D.F.M.

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in turtles. Sue Carstairs, Ontario Turtle Conservation Centre, provided information on hook injuries documented for turtles in Ontario. Pam Novak, Atlantic Wildlife Institute, documented that their institute has not received any turtles injured from angling. Chris Connell, Department of Natural Resources and Energy Development, Government of New Brunswick, provided data on catch rates for fish species recreationally fished in New Brunswick and number of angling licences sold each year from 1965 to 2019. Catherine Adams, Fairvale Animal Hospital, radiographed Red-eared Sliders to screen for fishing hooks. We thank all of the above for their contributions. Funding and in-kind support for this project were provided by the New Brunswick Environmental Trust Fund, the New Brunswick Wildlife Trust Fund, the New Brunswick Museum, and the City of Saint John. All animals were treated humanely and ethically. Work was conducted under scientific permits ES14-024, ES15-006, and ES16-016 from the New Brunswick Department of Natural Resources and Energy Development.

Literature Cited

- Browne, C.L.** 2003. The status of turtle populations in Point Pelee National Park. M.Sc. thesis, Lakehead University, Thunder Bay, Ontario, Canada.
- Browne, C.** 2018. Turtle guidelines for anglers. Page 31 *in* Fish 2018, A Part of Our Heritage. Fishing Regulations for New Brunswick. Province of New Brunswick, Fredericton, New Brunswick, Canada.
- Browne, C.** 2019. Turtle guidelines for anglers. Page 32 *in* Fish 2019, A Part of Our Heritage. Fishing regulations for New Brunswick. Province of New Brunswick, Fredericton, New Brunswick, Canada.
- Browne, C.** 2020. Turtle guidelines for anglers. Page 32 *in* Fish 2020, A Part of Our Heritage. Fishing regulations for New Brunswick. Province of New Brunswick, Fredericton, New Brunswick, Canada. Accessed 9 October 2020. <https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Fish/Fish.pdf>.
- Browne, C.L., and S.J. Hecnar.** 2005. An effective method for trapping map turtles (*Graptemys geographica*) and other basking freshwater turtles. *Herpetological Review* 36: 145–147.
- Browne, C.L., and S.J. Hecnar.** 2007. Species loss and shifting population structure of freshwater turtles despite habitat protection. *Biological Conservation* 138: 421–429. <https://doi.org/10.1016/j.biocon.2007.05.008>
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels.** 1994. Demographics of common Snapping Turtles (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. *American Zoologist* 34: 397–408. <https://doi.org/10.1093/icb/34.3.397>
- Cook, F.R.** 1984. Introduction to Canadian Amphibian and Reptiles. National Museums of Canada, Ottawa, Ontario, Canada. <https://doi.org/10.5962/bhl.title.124171>
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2008. COSEWIC assessment and status report on the Snapping Turtle *Chelydra serpentina*

- in Canada. COSEWIC, Ottawa, Ontario, Canada.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2012. COSEWIC assessment and status report on the Eastern Musk Turtle *Sternotherus odoratus* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2018a. COSEWIC assessment and status report on the Midland Painted Turtle *Chrysemys picta marginata* and the Eastern Painted Turtle *Chrysemys picta picta* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2018b. COSEWIC assessment and update status report on the Wood Turtle *Glyptemys insculpta* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- Coutant, C.C.** 1977. Compilation of temperature preference data. *Journal of the Fisheries Board of Canada* 34: 739–745. <https://doi.org/10.1139/f77-115>
- Cunnington, D.C., and R.J. Brooks.** 1996. Bet-hedging theory and eigenelasticity: a comparison of the life histories of Loggerhead Sea Turtles (*Caretta caretta*) and Snapping Turtles (*Chelydra serpentina*). *Canadian Journal of Zoology* 74: 291–296. <https://doi.org/10.1139/z96-036>
- Dubois, Y., G. Blouin-Demers, and D. Thomas.** 2008. Temperature selection in Wood Turtles (*Glyptemys insculpta*) and its implications for energetics. *Ecoscience* 15: 398–406. <https://doi.org/10.2980/15-3-3139>
- Enge, K.M., T.M. Thomas, and E. Suarez.** 2013. Population status and distribution of the alligator snapping turtle in the Suwannee River, Florida. Florida Fish and Wildlife Conservation Commission, Wildlife Research Laboratory, Gainesville, Florida, USA.
- Erb, L., and M.T. Jones.** 2011. Can turtle mortality be reduced in managed fields? *Northeastern Naturalist* 18: 489–496.
- Galbraith, D.A., R.J. Brooks, and M.E. Obbard.** 1989. The influence of growth rate on age and body size at maturity in female snapping turtles (*Chelydra serpentina*). *Copeia* 1989: 896–904. <https://doi.org/10.2307/1445975>
- Galois, P., and M. Ouellet.** 2007. Health and disease in Canadian reptile populations. Pages 131–168 in *Ecology, Conservation, and Status of Canadian Reptiles in Canada*. Edited by C.N.L. Seburn and C.A. Bishop. Herpetological Conservation 2, Society for the Study of Amphibians and Reptiles, Salt Lake City, Utah, USA.
- Gatten, R.E., Jr.** 1974. Effect of nutritional status on the preferred body temperature of the turtles *Pseudemys scripta* and *Terrapene ornata*. *Copeia* 1974: 912–917. <https://doi.org/10.2307/1442590>
- Gibbs, J.P., and W.G. Shriver.** 2002. Estimating the effects of road mortality on turtle populations. *Conservation Biology* 16: 1647–1652. <https://doi.org/10.1046/j.1523-1739.2002.01215.x>
- Graham, T.E., and V.H. Hutchison.** 1979. Effect of temperature and photoperiod acclimatization on thermal preferences of selected freshwater turtles. *Copeia* 1979: 165–169. <https://doi.org/10.2307/1443750>
- IUCN (International Union for the Conservation of Nature).** 2020. Summary statistics. In IUCN red list version 2020-2. IUCN Global Species Programme Red List Unit, Cambridge, United Kingdom. Accessed 26 October 2020. <https://www.iucnredlist.org/resources/summary-statistics>.
- Iverson, J.B., H. Higgins, A. Sirulnik, and C. Griffiths.** 1997. Local and geographic variation in the reproductive biology of the snapping turtle (*Chelydra serpentina*). *Herpetologica* 53: 96–117.
- Iverson, J.B., and G.R. Smith.** 1993. Reproductive ecology of the painted turtle (*Chrysemys picta*) in the Nebraska Sandhills and across its range. *Copeia* 1993: 1–21. <https://doi.org/10.2307/1446291>
- Keevil, M.G., R.J. Brooks, and J.D. Litzgus.** 2018. Post-catastrophe patterns of abundance and survival reveal no evidence of population recovery in a long-lived animal. *Ecosphere* 9:e02396. <https://doi.org/10.1002/ecs2.2396>
- Kikillus, K.H., K.M. Hare, and S. Hartley.** 2010. Minimizing false-negatives when predicting the potential distribution of an invasive species: a bioclimatic envelope for the Red-eared Slider at global and regional scales. *Animal Conservation* 13: 5–15. <https://doi.org/10.1111/j.1469-1795.2008.00299.x>
- Krebs, C.J.** 1999. *Ecological Methodology*. Second Edition. Addison-Wesley Educational Publishers, Inc., Don Mills, Ontario, Canada.
- Lamond, W.G.** 1994. The reptiles and amphibians of the Hamilton area: a historical summary and the results of the Hamilton Herpetofaunal Atlas. Hamilton Naturalists' Club, Hamilton, Ontario.
- McAlpine, D.F.** 2010. Amphibians and reptiles of the Atlantic Maritime eozone. Pages 613–631 in *Assessment of Species Diversity in the Atlantic Maritime Eozone*. Edited by D.F. McAlpine and I.M. Smith. NRC Research Press, Ottawa, Ontario, Canada.
- Némoz, M., A. Cadi, and S. Thienpont.** 2004. Effects of recreational fishing on survival in an *Emys orbicularis* population. *Biologia* 59(supplement) 14: 185–189.
- OMNRF (Ontario Ministry of Natural Resources and Forestry).** 2016. Best management practices for mitigating the effects of roads on amphibian and reptile species at risk in Ontario. Queen's Printer for Ontario, Toronto, Ontario, Canada. Accessed 9 October 2020. https://files.ontario.ca/bmp_herp_2016_final_final_resized.pdf.
- Parga, M.L.** 2012. Hooks and sea turtles: a veterinarian's perspective. *Bulletin of Marine Science* 88: 731–741. <https://doi.org/10.5343/bms.2011.1063>
- Ratnaswamy, M.J., R.J. Warren, M.T. Kramer, and M.D. Adam.** 1997. Comparisons of lethal and nonlethal techniques to reduce raccoon depredation of sea turtle nests. *Journal of Wildlife Management* 61: 368–376. <https://doi.org/10.2307/3802593>
- SARA (Species at Risk Act) Registry.** 2019a. Species summary: Snapping Turtle (*Chelydra serpentina*). Government of Canada, Ottawa, Ontario, Canada. Accessed 6 July 2019. <https://species-registry.canada.ca/index-en.html#/species/1033-710>.
- SARA (Species at Risk Act) Registry.** 2019b. Species summary: Wood Turtle (*Glyptemys insculpta*). Government of Canada, Ottawa, Ontario, Canada. Accessed 6 July 2019. <https://species-registry.canada.ca/index-en.html#/species/286-449>.
- Saumure, R.A., and J.R. Bider.** 1998. Impact of agricul-

- tural development on a population of Wood Turtles (*Clemmys insculpta*) in southern Québec, Canada. *Chelonian Conservation and Biology* 3: 37–45.
- Schuett, G.W., and R.E. Gatten, Jr.** 1980. Thermal preference in Snapping Turtles (*Chelydra serpentina*). *Copeia* 1980: 149–152. <https://doi.org/10.2307/1444147>
- Sharma, S., D.A. Jackson, and C.K. Minns.** 2009. Quantifying the potential effects of climate change and the invasion of Smallmouth Bass on native Lake Trout populations across Canadian lakes. *Ecography* 32: 517–525. <https://doi.org/10.1111/j.1600-0587.2008.05544.x>
- Smith, M.W.** 1962. Establishing and managing artificial trout ponds in the Maritime provinces. Manuscript report series (biological) 727. Fisheries Research Board of Canada, Biological Station, St. Andrews, New Brunswick, Canada.
- Steen, D.A., B.C. Hopkins, J.U. Van Dyke, and W.A. Hopkins.** 2014. Prevalence of ingested fish hooks in freshwater turtles from five rivers in the southeastern United States. *PLoS ONE* 9: e91368. <https://doi.org/10.1371/journal.pone.0091368>
- Steen, D.A., and O.J. Robinson, Jr.** 2017. Estimating freshwater turtle mortality rates and population declines following hook ingestion. *Conservation Biology* 31: 1333–1339. <https://doi.org/10.1111/cobi.12926>
- Swimmer, Y., C. Empey Campora, L. Mcnaughton, M. Musyl, and M. Parga.** 2014. Post-release mortality estimates of Loggerhead Sea Turtles (*Caretta caretta*) caught in pelagic longline fisheries based on satellite data and hooking location. *Aquatic Conservation* 24: 498–510. <https://doi.org/10.1002/aqc.2396>
- Tingley, R., D.G. McCurdy, M.D. Pulsifer, and T.B. Herman.** 2009. Spatio-temporal differences in the use of agricultural fields by male and female Wood Turtles (*Glyptemys insculpta*) inhabiting an agri-forest mosaic. *Herpetological Conservation and Biology* 4: 185–190.
- Wirsing, A.J., J.R. Phillips, M.E. Obbard, and D.L. Murray.** 2012. Incidental nest predation in freshwater turtles: inter- and intraspecific differences in vulnerability are explained by relative crypsis. *Oecologia* 168: 977–988. <https://doi.org/10.1007/s00442-011-2158-y>

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