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Accidental Bait: Do Deceased Fish Increase Freshwater Turtle Bycatch in Commercial Fyke Nets?

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Abstract Bycatch of turtles in passive inland fyke net fisheries has been poorly studied, yet bycatch is an important conservation issue given the decline in many freshwater turtle populations. Delayed maturity and low natural adult mortality make turtles particularly susceptible to population declines when faced with additional anthropogenic adult mortality such as bycatch. When turtles are captured in fyke nets, the prolonged submergence can lead to stress and subsequent drowning. Fish die within infrequently checked passive fishing nets and dead fish are a potential food source for many freshwater turtles. Dead fish could thus act as attractants and increase turtle captures in fishing nets. We investigated the attraction of turtles to decomposing fish within fyke nets in eastern Ontario. We set fyke nets with either 1 kg of one-day or five-day decomposed fish, or no decomposed fish in the cod-end of the net. Decomposing fish did not alter the capture rate of turtles or fish, nor did it alter the species composition of the catch. Thus, reducing fish mortality in nets using shorter soak times is unlikely to alter turtle bycatch rates since turtles were not attracted by the dead fish. Interestingly, turtle bycatch rates increased as water temperatures did. Water temperature also influences turtle mortality by affecting the duration turtles can remain submerged. We thus suggest that submerged nets to either not be set or have reduced soak times in warm water conditions (e.g., >20 °C) as turtles tend to be captured more frequently and cannot withstand prolonged submergence.

Keywords Inland commercial fisheries · Bycatch mortality · Decomposition · Olfaction · Fyke nets · At-risk species

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Introduction

Bycatch, the capture of non-target species, is one of the most pressing conservation issues for commercial fisheries worldwide (Alverson and others 1994; Pascoe 1997; Hall and others 2000; Hall and Mainprize 2005). Prolonged submergence of air-breathing animals (e.g., turtles, birds, mammals) may lead to stress while entangled or to subsequent drowning (Hall and others 2000; Lewison and others 2004; Benjamins and others 2008; Soykan and others 2008). Detriment caused to individuals can translate to population level changes (e.g., decline of albatrosses; Weimerskirch and others 1997; decline of dolphins; Dans and others 2003). As a result, the decline of many marine vertebrates, such as marine turtles, is often considered to be a consequence of bycatch (Alverson and others 1994; Roosenburg and others 1997; Lewison and others 2004; Lewison and Crowder 2007).

Like marine turtles, freshwater turtles are also susceptible to capture in nets and are at risk of similar population declines. Although the study of freshwater bycatch lags far behind that of marine bycatch (Soykan and others 2008; Raby and others 2011), freshwater turtle bycatch mortality has been documented in inland commercial fisheries where

passive fishing gears such as hoop, fyke, and trap nets are used (Michaletz and Sullivan 2002; Horne and others 2003; Barko and others 2004; Carrière 2007; Larocque and others 2012a). Delayed maturity, high juvenile mortality, and low adult mortality are life-history characteristics that make turtles particularly susceptible to population declines, especially in response to small increases in adult mortality (Brooks and others 1990; Congdon and others 1993, 1994; Gibbs and Shriver 2002; Bulté and others 2010). Unfortunately, adult turtles are primarily captured in nets and if the nets are completely submerged, the turtles are at risk of drowning (Ream and Ream 1966; Barko and others 2004; Gamble 2006; Larocque and others 2012a). As a result, bycatch mortality can pose a serious threat to freshwater turtle populations.

In southeastern Ontario, an inland commercial fishery operates using fyke nets. Fyke nets passively funnel organisms, via wings and a lead, into a cylindrical net distended with hoops to catch all organisms that encounter the net and cannot escape through the mesh (Hubert 1996). In Ontario, sunfish (*Lepomis* spp.), yellow perch (*Perca flavenscens*), rock bass (*Ambloplites rupestris*), bullhead (*Ameiurus* spp.), and crappie (*Pomoxis* spp.) are targeted for commercial harvest (Burns 2007). However, many at-risk freshwater turtles share the same habitat as these target fish and risk being captured. For instance, eastern musk turtles (*Sternothernus odoratus*), northern map turtles (*Graptemys geographica*), and common snapping turtles (*Chelydra serpentina*) are at-risk in Canada (COSEWIC 2011) and have been documented as bycatch in the Ontario fyke net fishery (Carrière 2007; Larocque and others 2012a). Currently, there are few regulations controlling the duration for which nets are set or left unsupervised (i.e., soak time), and reporting of bycatch is not mandatory. Regulations allow fishing year round except from the summer solstice until the first Monday of September. Maximum allowable soak times vary seasonally with shorter durations (i.e., 2 days) during the spring and longer durations (i.e., 14 days) during the winter. Even the shortest regulated soak time (2 days) exceeds the capabilities of turtles to survive underwater at moderate temperatures (e.g., 20 °C; Herbert and Jackson 1985a). Thus, inland commercial fyke net fisheries run a high risk of capturing vulnerable turtles which could lead to increased mortality and further population declines.

To ensure the persistence of freshwater turtles, it is important to identify and resolve the threats that face these long-lived reptiles (Gibbons and others 2000). Within the realm of freshwater turtle bycatch, a topic worth further investigation is the potential for olfactory attraction of turtles to fish, particularly deceased fish, in passive fishing gear. Olfactory attraction could lead to increased freshwater turtle bycatch rates, as has been demonstrated in marine turtles (Southwood and others 2008). Turtles are capable of detecting chemical cues in water, which aids in detecting and identifying food (Constantino and Salmon 2003; Southwood and others 2007; Schwenk 2008). As many turtle species are scavengers (Ernst and Barbour 1989; Ernst and others 1994), turtles may be attracted to chemical cues from deceased fish inside nets, which would then act as bait. Baited nets (e.g., with fish) have indeed been used to attract and capture freshwater turtles (Lagler 1943; Ernst 1965; Ream and Ream 1966; Frazer and others 1990; Millar and Blouin-Demers 2011). Although nets are not baited in the Ontario fyke net fishery, fish mortality frequently occurs (Larocque and others 2012a). From a management perspective, if deceased fish were associated with higher bycatch rates of turtles, regulatory agencies would be further encouraged to mandate commercial fishers to check nets more frequently to minimize fish mortality and ensuing turtle bycatch. In this paper, we test the hypothesis that the decomposition of fish inside commercial fyke nets acts as an attractant to freshwater turtles and thus increases bycatch of turtles. By studying this issue across a gradient of water temperatures, we were also able to examine the influence of water temperature on turtle catch rates.

Methods

Study Area

We conducted our study from 1 May to 1 June 2010 in Opinicon Lake (44°34'N, 76°19'W) approximately 100 km south of Ottawa, Ontario, Canada. Opinicon Lake is a 788 ha shallow warm-water lake with a mean depth of 2.8 m. Water temperatures varied from 13.5 to 25.2 °C and turtles were active as our study corresponded with the mating season (Gordon and MacCulloch 1980; Brown and Brooks 1993).

Nets, Sampling Methods, and Data Collection

We used fyke nets of a similar design as those used in the commercial fishery. Each fyke net contained seven 0.91 m diameter steel hoops positioned 0.5 m apart. There were two throats per net, located at the second and fourth hoops. Each net had two wings (4.57 m long and 0.91 m high) and a lead (10.67 m long and 0.91 m high) attached to the front hoop. All the nets, wings, and leads were constructed with 5.08 cm stretch diamond nylon mesh.

We used fishing practices commonly employed by commercial fishers in the area: we set nets in pairs by adjoining two fyke nets by their leads with the net openings facing each other and extending the wings at a

forty-five degree angle from the entrance of the net. In the commercial fishery, fyke nets are set completely submerged along the substrate, in shallow vegetated waters 1–2 m deep and parallel to the shoreline. In our study, however, we placed two plastic floats in the cod-end of each net to create air spaces and prevent turtles from drowning while the net opening remained submerged (Vogt 1980; Larocque and others 2012b). Using floats in nets does not affect fish or turtle entry (Larocque and others 2012b). We set nets in ten areas parallel to the shoreline in vegetated shallows ranging from 1 to 1.75 m in depth (mean ± std. deviation: 1.26 ± 0.18 m). Distance from shore varied between 7 and 97 m. Nets were set for between 24 and 48 h to decrease the time that captured turtles remained in the net and to reduce captured fish mortality. We recorded water temperature when setting and lifting the nets as well as Universal Transverse Mercator (UTM) coordinates via GPS (GPS 76, Garmin). Distance to shore was determined for each net set from UTM coordinates using ArcMap v.9.3. Flow rates could not be used to accurately determine "bait plume" dispersals from decomposed fish due to changing wind speed and direction. Instead, for each sampling location we set one net pair per treatment spaced approximately 50 m apart to prevent interference between net pairs and potential "bait plumes".

Treatments included nets containing: (1) no fish (control), (2) one-day decomposed fish, and (3) five-day decomposed fish. Decomposition durations were chosen to represent short (i.e., one day) and long (i.e., five day) soak times that commercial fishers' use and are also durations that fish would be dead in their nets. Decomposed fish consisted of 1 kg of bluegill (*Lepomis macrochirus*) that was collected from Opinicon Lake with fyke nets. After cerebral percussion, dead bluegill were placed in a mesh bag and submerged in a tank containing slow, continuously circulating lake water for the duration of the decomposition period (one day or five days). As such, the decomposing fish were exposed to similar water temperatures as in the lake. Once the decomposition period was over, we removed the mesh bags from the tank and suspended them from the sixth hoop of each treatment net in the conjoined pair, so that the mesh bag was touching neither the top nor the sides of the net. After the 24–48 h set period, we lifted each of the net pairs and quantified the catch. All fish and turtles captured in the nets were identified to species and tallied.

Data Analyses

We quantified fishing success for both turtles and fish by determining the catch per unit effort (CPUE—in catch/hr) to standardize for differences in set duration. Given that we used a pair of nets per trial, we calculated CPUE for each treatment by summing the total catch from both nets and dividing by the summed durations that each net of the pair were set. If one of the nets in a pair did not fish properly (e.g., holes in the net, net collapsed), we removed that net from the calculation. We calculated the CPUE for the total turtle and fish catches, as well as per species. Mean water temperature was also calculated for each net pair from when they were set and lifted.

As the experiment occurred at haphazard locations in the lake and spanned one month, we included proximity to the shoreline and water temperature as covariates in the analysis. Depth was fairly constant across the study and was thus not included as a covariate. Therefore, to determine if the level of decomposition affected total turtle catches or total fish catches, we used analyses of covariance (ANCOVA). Prior to running the ANCOVAs, the assumptions of normality, homogeneity of variance, and equal slopes were verified. We square root transformed total turtle catches to normalize the data. The ANCOVAs were performed in SPSS Statistics 18.0 (www.spss.com).

We compared the species composition for both turtles and fish, using CPUE values, between the different fish decomposition levels using a blocked multi-response permutated procedure (MRBP; this controlled for site variation) in PC-ORD 5.20 (McCune and Mefford 2011). Using MRBP, we could determine whether the capture rates of individual species were affected by varying fish decomposition levels. For all statistical tests, significance was accepted at $\alpha = 0.05$ and values are reported in means ± 1 std. deviation.

Results

In ten tandem fyke nets set with no decomposed fish (controls) we captured 44 turtles of four species, with the majority being eastern musk turtles, painted turtles (*Chrysemys picta*), and northern map turtles (97.7 %; Table 1). Of the 1,335 fish captured consisting of eight species, the majority were bluegill (40.4 %) and pumpkinseed (*Lepomis gibbosus*; 46.1 %; Table 1). With one-day decomposed fish, ten tandem fyke nets captured a total of 41 turtles of four species, the majority being eastern musk turtles and painted turtles (83 %; Table 1). A total of 1,153 fish were captured of eight species, with bluegill and pumpkinseed forming the majority of the catch (39.5 and 46.9 %, respectively; Table 1). Ten tandem fyke nets set with five-day decomposed fish captured a total of 38 turtles of four species, with the majority again being eastern musk turtles, painted turtles, and northern map turtles (89.5 %; Table 1). Of the 1,627 fish captured consisting of seven

Table 1 Summary of freshwater turtle and fish species captured in ten fyke nets set per treatment in Opinicon Lake, Ontario, Canada with varying levels of decomposing bluegill (*Lepomis macrochirus*)

Species	Control			One day			Five day		
	CPUE	Total catch	%	CPUE	Total catch	%	CPUE	Total catch	%
Eastern musk turtle	0.03 ± 0.05	16	36.4	0.04 ± 0.04	17	41.5	0.03 ± 0.04	14	36.8
Painted turtle	0.02 ± 0.03	14	31.8	0.03 ± 0.03	17	41.5	0.02 ± 0.05	11	28.9
Northern map turtle	0.02 ± 0.03	13	29.5	0.01 ± 0.02	4	9.8	0.02 ± 0.02	9	23.7
Common snapping turtle	0.002 ± 0.01	1	2.3	0.01 ± 0.02	3	7.3	0.01 ± 0.01	4	10.5
Total turtles	0.07 ± 0.09	44		0.08 ± 0.08	41		0.07 ± 0.09	38	
Bluegill	0.89 ± 0.49	539	40.4	1.01 ± 0.84	455	39.5	1.64 ± 2.26	925	56.9
Pumpkinseed	1.00 ± 0.35	616	46.1	1.13 ± 0.84	541	46.9	0.89 ± 0.51	490	30.1
Largemouth bass	0.13 ± 0.08	75	5.6	0.08 ± 0.05	33	2.9	0.15 ± 0.14	74	4.5
Bullhead spp.	0.06 ± 0.11	39	2.9	0.12 ± 0.14	54	4.7	0.14 ± 0.18	78	4.8
Rock bass	0.06 ± 0.10	46	3.4	0.12 ± 0.16	60	5.2	0.08 ± 0.14	42	2.6
Black crappie	0.02 ± 0.02	14	1.0	0.01 ± 0.03	5	0.4	0.02 ± 0.03	11	0.7
Northern pike	0.01 ± 0.01	5	0.4	0.01 ± 0.02	4	0.3	0.01 ± 0.02	7	0.4
Smallmouth bass	0	0	0.0	0.002 ± 0.01	1	0.1	0	0	0.0
Yellow perch	0.002 ± 0.01	1	0.1	0	0	0.0	0	0	0.0
Total fish	2.19 ± 0.74	1335		2.49 ± 1.25	1153		2.92 ± 2.19	1627	

'Control' indicates fyke nets containing no decomposed fish, while 'One day' and 'Five day' indicate nets containing 1 kg of bluegill that were dead for 1 day and 5 days, respectively. Catch per unit effort (CPUE) is mean number of individuals captured ± std. dev. per hour

species, the majority were again bluegill and pumpkinseed (56.9 and 30.1 %, respectively; Table 1).

The addition of fish decomposed for one-day or for five-days did not influence the bycatch rate of turtles (ANCOVA; $F_{2,25} = 0.228$; $P = 0.798$; partial $R^2 = 0.018$; Fig. 1a). Overall a mean of 0.07 ± 0.08 turtles/hour/net were captured (Fig. 1a; Table 1). The species composition of captured turtles did not vary between treatments (MRPB; $A = 0.009$, $P = 0.264$; Table 1). Notably, however, all but one snapping turtle ($N = 8$) were caught in a net containing decomposing fish. Total fish capture rates were the same among the three treatments with an overall mean catch rate of 2.53 ± 1.50 fish/hour/net (ANCOVA; $F_{2,25} = 1.034$; $P = 0.370$; partial $R^2 = 0.076$; Fig. 1b; Table 1). Similarly, species composition of fish captured were the same between treatments (MRPB; $A = -0.010$; $P = 0.653$; Table 1).

The variability in captures seen between sites was not explained by proximity to shore, but was influenced by water temperature. Proximity to shore did not affect total turtle bycatch rates (ANCOVA; $F_{1,25} = 2.885$; $P = 0.102$; partial $R^2 = 0.103$; Fig. 2a) or total fish capture rates (ANCOVA; $F_{1,25} = 1.623$; $P = 0.214$; partial $R^2 = 0.061$; Fig. 2b). There was, however, a positive correlation between water temperature and total turtle bycatch (ANCOVA; $F_{1,25} = 15.319$; $P = 0.001$; partial $R^2 = 0.380$; Fig. 3a). When excluding the other variables, every 1 °C increase in water temperature increased turtle bycatch by 0.024 ± 0.006 turtles per hour per net (Fig. 3a). Total fish capture rates, on the other hand, were unaffected by water temperature (ANCOVA; $F_{1,25} = 0.104$; $P = 0.750$; partial $R^2 = 0.004$; Fig. 3b).

Discussion

Using an inland commercial fyke net fishery in eastern Ontario as a study system, we examined whether the presence of deceased fish at two levels of decay influenced the bycatch rate of turtles. Turtle bycatch rates and fish catch rates were not influenced by the presence of decaying fish in fyke nets. There was some indication that snapping turtles were attracted to nets with dead fish (Table 1), but this trend was not significant as indicated by the MRBP. Lack of statistical significance may be an artefact of a relatively small snapping turtle population in the study area which resulted in low captures. As such, the attraction of snapping turtles to nets containing deceased fish should be tested in water bodies containing high populations of snapping turtles. Of the turtles captured, 65.9 % were considered at risk in Canada according to COSEWIC (COSEWIC 2011). Although we do not know what proportion of the total turtle population was captured, we captured a mean of 3.36 turtles per day per paired net set. Both turtle and fish catch rates in this study were similar to those in a previous study using fyke nets in the same lake (Larocque and others 2012a, b).

Turtles were not attracted to deceased fish in our nets, which may be due to food preferences. Most freshwater turtles in Opinicon Lake (i.e., painted turtles, common

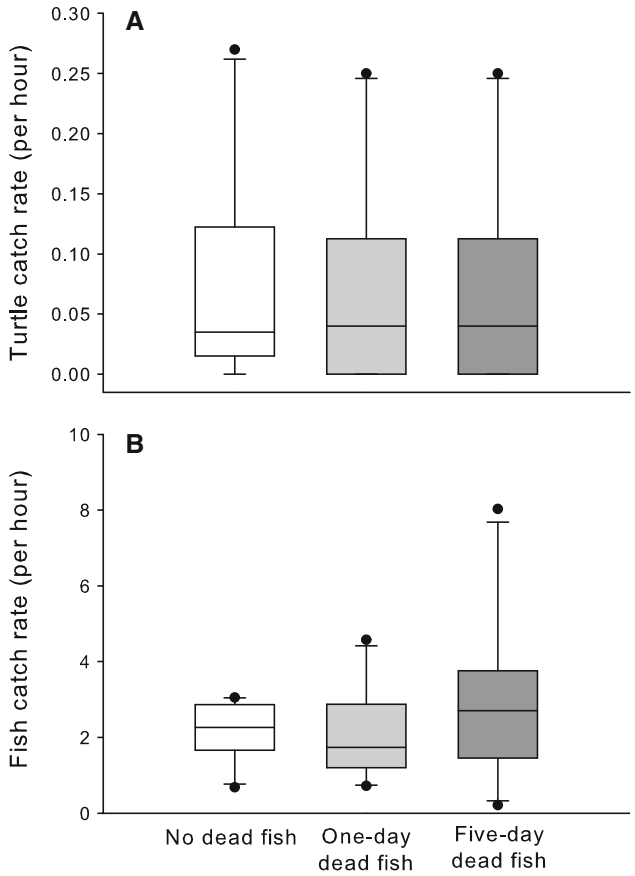

Fig. 1 **a** Freshwater turtle and **b** fish catch rates were unaffected by varying levels of decomposing fish in fyke nets set in Opinicon Lake, Ontario, Canada. 'Control' (*white box plot*) indicates nets containing no decomposed fish, while 'One day' (*gray box plot*) and 'Five day' (*dark gray box plot*) indicate nets containing 1 kg of bluegill (*Lepomis macrochirus*) that were dead for 1 day and 5 days, respectively

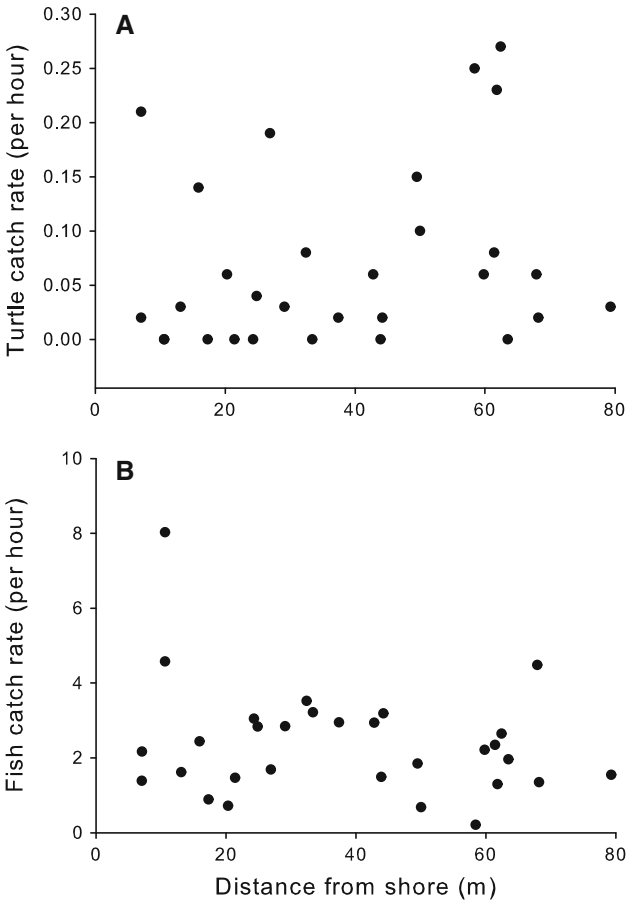

Fig. 2 **a** Freshwater turtle and **b** fish catch rates in fyke nets set in Opinicon Lake, Ontario, Canada were unaffected by distance to shore (m)

snapping turtles, northern map turtles, and eastern musk turtles) eat some carrion (Ernst and Barbour 1989; Ernst and others 1994). Although various types of bait can be used in nets to attract turtles (e.g., chicken liver, watermelon rinds, dead fish; Ernst 1965; Lagler 1943), Lagler (1943) suggests that fresh bait is more attractive. The dead fish in our study were not fresh and this may explain why turtles were not attracted by our bait. The point of our study, however, was to determine whether turtles are attracted to deceased fish that accumulate and decompose in nets over the course of soak times used in the fishery; not to determine the best kind of bait to capture turtles.

The similar turtle capture rates in nets with and without deceased fish could also be due to net design. Even if turtles were attracted to deceased fish, the design of fyke nets, with wings and a lead directed towards a single net opening, would not capture turtles if the net was approached from the wrong direction. Authors of previous studies that have had success with baited nets to capture turtles used two openings on either end of the net and/or did not have wings or a lead on the net (e.g., Ernst 1965; Ream and Ream 1966; Frazer and others 1990; Thomas and others 2008). The wings and lead could have a better ability to corral and capture turtles than bait. Gibbons (1968) and Barko and others (2004) captured more turtles in "swim-in traps" and fyke nets than in baited hoop nets, supporting this idea. Thus, many turtles likely enter fyke nets simply by encountering and following the leads.

Actively swimming turtles encounter nets and are captured more frequently with increases in water temperature. As ectotherms, the metabolism of turtles rises with ambient temperature, and as a result activity levels increase (Herbert and Jackson 1985b; Milton 2008). Thus, increased activity (e.g., swimming) in warm water could increase the encounter rate with nets and explain the increased capture rate of turtles. Alternatively, bycatch rates may be associated with seasonality as water temperatures progressively increased over the period of our study. In spring, turtles start to leave hibernacula and turtle activity increases (Gibbons 1968; Gibbons and others 1990; Ernst and others

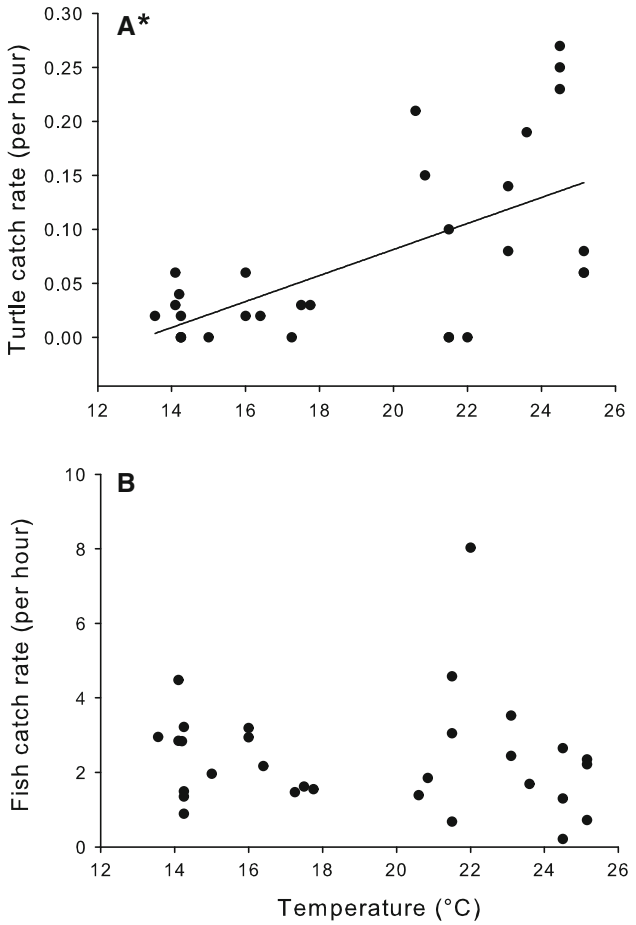

Fig. 3 **a** More freshwater turtles were captured in fyke nets set in Opinicon Lake, Ontario, Canada as water temperature increased, while **b** fish catch rates were unaffected by water temperature. * indicates $P < 0.05$

1994). Increased aquatic movements in spring are often associated with mating, yet turtles can also be foraging and migrating at this time of year (Gibbons and others 1990; Ernst and others 1994). Whether looking for a mate or food, turtles that are actively swimming are captured in fyke nets more frequently as water warms during spring.

Water temperature also affects a turtle's ability to survive while captured in nets. While submerged in nets at high water temperatures, turtles have a high metabolic rate that can be amplified further by the stress of capture (Pough and others 1998). The increased oxygen demand from increased metabolism and stress of capture can dramatically reduce the duration turtles can remain submerged (Herbert and Jackson 1985a; Jackson 2000). Painted turtles cannot survive submersion for more than 12 h at water temperatures above 20 °C in controlled conditions (Herbert and Jackson 1985a), a water temperature that can be reached or surpassed during the commercial fishing season in Ontario. Therefore, water temperature plays a crucial role in freshwater turtle bycatch mortality as it is correlated with the rate at which turtles are caught and affects the duration that turtles can withstand submergence.

The mortality of freshwater turtle bycatch, especially at-risk species, is a conservation concern and the attention of researchers and managers is needed to minimize the influence of freshwater commercial fisheries on turtle populations. In our study, turtle bycatch and fish catch rates were unaffected by the presence of dead fish, but increasing water temperatures increased turtle bycatch. Also, increasing water temperature reduces survival times of submerged turtles. Therefore, maximum water temperatures at which commercial fisheries can operate should be established or at the very least, permitted soak times should be reduced when the water is warm to reduce turtle bycatch and ensuing mortality. Reduced soak times (e.g., one day), however, may not be an economically viable option for commercial fishers. Other turtle bycatch mitigation options have been suggested in the literature (e.g., providing air spaces or various gear modifications; Roosenburg and others 1997; Wood 1997; Lowry and others 2005; Fratto and others 2008; Bury 2011; Larocque and others 2012b), yet few regulations exist to mitigate freshwater turtle bycatch in the Ontario fyke net fishery. Overall, bycatch is a multi-faceted issue and our study contributes to understanding how freshwater fisheries may potentially influence turtle populations. Although having dead fish in nets is unintentional in the commercial fishery, the occurrence of deceased fish does not appear to increase the capture and potential mortality of freshwater turtles. Instead, it is warm water temperatures (e.g., >20 °C) that are of concern for turtle bycatch and caution is warranted when using submerged nets in these conditions to ensure that freshwater turtles, including at-risk species, survive.

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