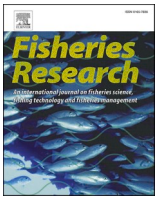
Fisheries Research 234 (2021) 105781

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres



Angler interactions with American eel (*Anguilla rostrata*): Exploring perspectives and behaviors toward an imperiled fish

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ARTICLE INFO

Handled by: B. Morales-Nin

Keywords:
Endangered species
Public perception
Conservation support
Non-target species
Recreational fishing

ABSTRACT

As aquatic biodiversity continues to decline, recreational anglers are interacting more frequently with imperiled species. As a result, management strategies must be developed to balance fisheries management and conservation objectives. Understanding the human dimensions of these encounters is important for both fisheries management and conservation objectives, because decisions made by anglers have a direct impact on the fish. This work explores angler perspectives and behaviors toward American Eel (*Anguilla rostrata*), a species listed as Endangered in the Canadian province of Ontario and globally (IUCN Red Listed as Endangered), and not typically targeted by recreational anglers in Ontario. Interviews with 48 anglers on the Ottawa River revealed that almost half had captured an eel at some point, but few had intentionally killed eels (in each case prior to the eel's Endangered status listing in Ontario). However, a large proportion of respondents were, or would be, uncomfortable handling eels if captured, and almost half of respondents declared a limited or lack of knowledge about the species. These findings suggest that discomfort around eels and limited knowledge about their value (both ecological and economical) do not cause direct harm to eels but may impede full public support for conservation of the species.

1. Introduction

Recreational angling is a popular activity around the globe (Arlinghaus and Cooke, 2009). In many jurisdictions, fisheries managers and resource users work collaboratively to achieve diverse fisheries management objectives, such as the creation of trophy fisheries and maximizing angling opportunities (Cowx, 2002). However, as fish biodiversity and biomass continue to decline (Fu et al., 2003; Hutchings and Baum, 2005; Jelks et al., 2008; Vasilakopoulos et al., 2014), recreational anglers are increasingly interacting with fish that are imperiled and for which reconciling conservation and recreational fisheries goals may be a challenge (Cooke et al., 2016; Cowx et al., 2010). While these encounters are unavoidable, their impact can be minimized with proper understanding of fish biology and human behavior. One path to a solution is to conceptualize recreational fisheries as dynamic socio-ecological systems in which understanding angler behaviors, and the perspectives driving those behaviors, is as critical for effective management as understanding fish biology (Fenichel et al., 2013; Hunt et al., 2013).

Human dimensions studies of anglers have led to a broader understanding of recreational fisheries. For instance, researchers have uncovered behavioral and attitudinal subgroups within angling communities (Nguyen et al., 2013; Quinn, 1992), identified angler knowledge gaps that have implications for management (Gallagher et al., 2015), and assessed levels of support for new fish recovery techniques (Donaldson et al., 2013). Human dimensions studies have also revealed that anglers can be influential advocates for conservation of popular but imperiled species and their habitats (Cooke et al., 2016; Granek et al., 2008), whose persistence is critical for anglers' continued enjoyment of their pastime (Cowx et al., 2010). In contrast, little has been studied about angler perspectives and behaviors towards less popular, non-gamefish species whose persistence may be seen as non-consequential to, or even detracting from, the enjoyment of the pastime. This leaves important conservation questions largely unanswered: What are anglers' opinions

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https://doi.org/10.1016/j.fishres.2020.105781
Received 15 April 2020; Received in revised form 6 September 2020; Accepted 14 October 2020
Available online 5 November 2020

and behaviors towards less desirable species? How do anglers behave when capturing non-target species, particularly when these are imperiled?

The American Eel (*Anguilla rostrata*) is an example of a non-target, imperiled species that may be affected by angling through incidental capture (i.e., bycatch). It is a semelparous, catadromous fish with a complicated life-history. After a panmictic spawning event in the Sargasso Sea, leptocephalus larvae develop as they drift with ocean currents, eventually reaching coastal waters and swimming up rivers ranging from Venezuela to southern Greenland (Benchetrit and McCleave, 2016; Tesch and Thorpe, 2003). Eels were once a considerable portion of the total biomass in the freshwaters of eastern North America (Ogden, 1970; Smith and Saunders, 1955). Anguillid eels are known to serve several ecological roles, including as predators of invertebrates and small fishes (Eberhardt et al., 2015; Ogden, 1970; Schmidt et al., 2006), prey for birds, whales, and sharks (Béguer-Pon et al., 2012; Hodson et al., 1994; McLean and Byrd, 1991; Willard, 1977), host species for a juvenile life stage of at least one freshwater mussel (*Elliptio complanata*) (Galbraith et al., 2018), and important vectors for transport of nutrients, carbon, and other organic matter between marine and freshwater ecosystems (Laffaille et al., 2000; Schmidt et al., 2006). Anguillid eels are also highly valued by humans. In Canada, Indigenous peoples and early European settlers relied on eels as a nutritious food source (MacGregor et al., 2009). While eels maintain their importance in many Indigenous cultures to this day, their non-commercial value as sustenance appears to have been forgotten by most non-Indigenous people in North America by the mid-1900s. For Indigenous groups, including the Algonquins of Ontario, eels were traditionally harvested for medicinal, nutritional, spiritual, and material purposes (Algonquins of Ontario, 2012, 2014a, 2014b). Current harvest of eels by Indigenous people in Canada is difficult to quantify. In Atlantic Canada, some Indigenous communities still hold elver and eel fisheries licenses, however it is unknown to what degree these fisheries are active (Giles et al., 2016). In Ontario, it is possible for Indigenous communities to obtain special authorization under the *Endangered Species Act* to harvest listed species (Endangered Species Act 2007, S.O. 2007, c. 6, 2007), but it is unknown whether this has occurred for eels. In terms of economics, the combined landed value of the Canadian silver, yellow, and glass eel fisheries was $1.4 million (CAD) in 2018 (Fisheries and Oceans Canada, 2020a), with eel exports valued at $89.8 million (CAD) (Fisheries and Oceans Canada, 2020b. In 2016, 79% of exports were shipped to Asia (Fisheries and Oceans Canada, 2018a, 2018b). These yields are primarily from fisheries in Atlantic Canada, because of major reductions in Quebec eel fisheries and complete closures in Ontario since the early 2000s. Prior to fisheries closures in Ontario, the commercial harvest averaged 80.1 metric tons annually between 1950 and 2000 (MacGregor et al., 2013), with the fishery in the Upper St. Lawrence River – Lake Ontario (USLR-LO) constituting 57% of Canada's total catch (MacGregor et al., 2008).

The American Eel has exhibited declines in abundance through much of its American and Canadian range (Brust et al., 2017; Tremblay and Committee on the Status of Endangered Wildlife in Canada, 2012) and is listed as Endangered on the IUCN Red List (Jacoby et al., 2017) and in the province of Ontario, Canada (Casselman, 2003; MacGregor et al., 2013). In the Upper St. Lawrence River – Lake Ontario watershed in Ontario, Canada, juvenile recruitment has declined by >99% since the 1980s, and this dramatic downward trend is primarily attributed to historic commercial overfishing, barriers to migration (e.g., dams), entrainment in turbines, and habitat alteration (MacGregor et al., 2013). The limitations imposed on eels through hydroelectric dams and other riverine barriers are exemplified in the case of the Ottawa River. This river and its tributaries represent 12% of the USLR-LO's drainage and historically contained extensive suitable habitat for eels. However, access to this habitat was drastically reduced between the late 1800s and the 1960s through the construction of many hydroelectric barriers. Today, eels are a rarity in many parts of the watershed where they were historically plentiful and the eels that do travel upstream past barriers face high rates of turbine mortality on their downstream migration. Under the Ontario Endangered Species Act (2007), all fishing for eels has been prohibited for the past 15 years, any incidentally captured eels must be released, and the penalty for a first-time offence is $250,000 (CAD). Although commercial and recreational fishing for the species has been prohibited in Ontario since 2004 and 2005 respectively, there is anecdotal evidence to suggest a possible recreational angling impact on American Eel in the Ottawa River. These anecdotes include stories of anglers disliking or expressing discomfort about eels, in extreme cases leading some to intentionally kill and discard incidentally captured eels despite their conservation status (N.W.R Lapointe, personal communication, 2017). Anglers on the Ottawa River were interviewed in the summer of 2018 to explore the prevalence of this reported dislike and discomfort with eels, and any threat that angler perceptions and behaviors may pose to eels. This research is exploratory, meaning that it is intended to uncover variables and potential associations for future investigation (Stebbins, 2020).

2. Methods

Face-to-face, semi-structured interviews were conducted on 15 days between July and September 2018. Interviews were conducted during this period because it represents part of the peak summer fishing season in the area. Opportunistic sampling was used to recruit participants at public boat launches along the Ontario side of the Ottawa River within 70 km (upstream and downstream) of the City of Ottawa, Ontario. On a given visit, individuals were approached to ask if they fished. If a site was too busy to approach all individuals, anglers who were returning from fishing trips or fishing from shore were targeted, because they were more likely to agree to an interview than anglers about to start fishing. Anglers were asked to participate in an eighteen-question interview about their fishing practices and demographics (four questions), knowledge of American Eel (four questions), experiences capturing eels (seven questions), and their values and beliefs of the environment in general (three questions) (Table 1 – see supplemental material for full interview). Audio recordings of interviews were made and later transcribed. Following transcription, answers were coded using a three-step inductive process, as outlined by Thomas (2006). The first step involved a close reading of the transcriptions to develop categories of codes. Following the initial reading, codes were examined for overlap and, where appropriate, combined to create broader encompassing themes. Transcriptions were then re-read and excerpts were assigned to the themes. This qualitative inductive approach permitted text to be coded to multiple themes, and not all text was assigned a theme (Thomas, 2006). To ensure reliability, a second coder analyzed 19% of the texts using the coding guide developed in step two. Inter-rater agreement percentage was calculated as:

$$(\text{number of agreements for categories/total number of categories}) \times 100\%$$

Inter-rater agreement ranged from 89 to 93% for the four open-ended, long-form questions and ranged from 78 to 100% overall.

Pearson's Chi-Squared Tests were used to examine associations between: (1) prior experience catching eels and knowledge of eels; (2) prior experience catching eels and comfort handling eels; (3) knowledge of eels and comfort handling eels; (3) knowledge of eels and support for cutting the line if a scientific study recommended it; (4) knowledge of eels and support for eel conservation in general; and (5) agreement with three environmental values statements and support for eel conservation. Anglers were asked to indicate agreement or disagreement for these environmental value statements: (1) *nature exists to meet the needs of humans;* (2) *recreational anglers cannot catch enough fish to affect a fish population; and* (3) *anglers should be educated on fish species at risk and how to release them.* A fourth environmental values statement (*environmental degradation is a major problem facing humanity*) was presented, but it was

Table 1
Question category, question, answer format, total sample size for the question (*n*), and response bins with the associated number of people who responded (and percent) for questions used in inferential analyses (see results sub-section entitled 'Influence Factors). See supplemental material for a version of this table that includes all interview questions.

Question category	Question	Answer format	*n*	Response bins	Number of respondents (%)
Experience with eels	4. Have you ever caught an eel while angling?	Yes/No	48	Yes	22 (45.8)
				No	26 (54.2)
	4. a) If yes to question 4: do you feel comfortable handling an eel? ***If no to question 4:*** would you feel comfortable handling an eel if you caught one?	Yes/No	40	Yes	22 (55.0)
				No	18 (45.0)
		Open-ended, long-form expanded answer	28	Themes (31 mentions)	
				Disgust for handling eels	11 (39.3)
				Prefer to use tools	13 (46.4)
				Prefer to cut line	7 (23.0)
Knowledge of eels	11. Can you tell me what you know about the American Eel?	Open-Ended, long-form answer	46	Themes (63 mentions)	
				Angling Knowledge	11 (23.9)
				As Food/Edible	5 (10.9)
				Conservation Status or Threats	10 (21.7)
				Ecology	12 (26.1)
				Invasive	3 (6.5)
				Physical Description	17 (37.0)
				Vigor	5 (10.9)
			46	Lack of knowledge	21 (46.0)
	15. If scientific studies showed that cutting the line as opposed to removing the hook increased survival of eels, would you follow this advice if you caught an eel?	Yes/No/ Depends on the lure	44	Yes	32 (72.7)
				No	8 (18.2)
				Depends on the lure	4 (9.1)
Environmental values & beliefs	**17. I am going to read you some statements about the environment, and I would like you to tell me whether you agree or disagree with them, and why.**				
	17. a) Nature exists to meet the needs of humans.	Agree/ Disagree/ Undecided	35	Agree	6 (17.1)
				Disagree	28 (80)
				Undecided	1 (2.9)
	17. b) Recreational anglers cannot catch enough fish to affect a fish population.	Agree/ Disagree/ Undecided	43	Agree	13 (30.2)
				Disagree	30 (69.8)
				Undecided	0 (0)
	17. d) Anglers should be educated on fish species at risk and how to release them.	Agree/ Disagree/ Undecided	43	Agree	41 (95.3)
				Disagree	2 (4.7)
				Undecided	0 (0)
	18. Do you support current and/or future efforts to increase the eel population in the Ottawa River?	Agree/ Disagree/ Undecided	45	Yes	31 (68.9)
				No	5 (11.1)
				Need more info	7 (15.6)
				Nothing left to support	2 (4.4)

dropped from the final analysis due to unanimous agreement among respondents. In any tests involving support for eel conservation or support for cutting the line if a scientific study recommended it, Monte Carlo simulations were used to create a reference distribution to compensate for the small sample sizes in some of the categories of responses (Hope 1968). Data about respondents' knowledge of eels was collected as a binary variable by assigning 'no knowledge' to anglers who self-attested as having little or no knowledge (even if they provided guesses about eels) and 'knowledge' was assigned to anglers who indicated some knowledge of the species. All p-values were adjusted using Holm's correction for multiple comparisons. Quantitative analyses were conducted using RStudio version 1.1.383 (R Studio Team, 2014) running R (R Core Team, 2017).

3. Results

3.1. Study group

Of the 60 anglers approached, 48 agreed to an interview. However, not all anglers responded to all interview questions (see supplemental material for the number of responses to each question), therefore not all findings are based on 48 respondents. Pairwise exclusion was used to maximize the use of available data. Median interview duration was six minutes (with a range of 3−21 min). In comparison to the national angler profile in Canada (Fisheries and Oceans Canada, 2019), respondents in the present study were skewed towards men (85% compared to 79% in national survey), younger anglers (with an average age of 39 years compared to 47 years in national survey), and anglers who fished more frequently (58.5% of respondents having fished more than 50 days per year compared to an average of 15 days in the national survey). Respondents in the present study were also relatively experienced anglers, with 66.6% of respondents indicating they had fished for more than 20 years.

3.2. Eel capture

Of respondents, 46% reported catching at least one eel at some point and somewhere during their angling history. Reported eel captures had occurred between 1960 and 2018, with the majority being captured during the spring and summer. Most respondents who had captured eels were using live bait (worms and minnows) and targeting Channel Catfish (*Ictalurus punctatus*), Walleye (*Sander vitreus*) or black bass *(Micropterus salmoides* and *M. dolomieu*). Estimates of eel size ranged from 30 to 120 centimetres. When asked about what had been done with captured eels, 86% respondents indicated they had released them. Of the respondents who released eels, 67% mentioned releases that involved removing the hook, 33% mentioned releases that involved cutting the line, and one eel was described as having removed the hook on its own. Only three respondents mentioned intentionally killing eels, two of whom had done so for harvest. The other had killed and discarded eels. The estimated years of occurrence for all three reports of killing eels were prior to the listing of eels under Ontario *Endangered Species Act* in

2008. The respondent who had killed and discarded eels stated, "*We used to just cut the head off,"* and explained this by saying *"We were younger then… we were afraid. You know, thought it was just a giant snake."* When asked about their comfort handling eels, 45% of all respondents indicated that they were, or would be, uncomfortable dealing with an incidentally captured eel. Twenty-eight respondents provided more detail in their answers and these responses frequently expressed disgust for handling eels (due to their slimy texture or the difficulty of holding them) (39%), as well as a preference for using tools (e.g., gloves) (46%) and for cutting the line when handling eels (25%). Respondents frequently expressed statements such as "*I don't handle those things. I just use the pliers and flip it off and away they go."* and "*…we hated touching them because they'd coil themselves around your wrist, we'd just cut the line and let it free."*

3.3. Knowledge of eels

Respondents were asked to tell the interviewer what they knew about the American Eel. Coding revealed the following seven themes, each followed by the percent of interviewed anglers that expressed such knowledge: (1) knowledge of eels in an angling context - 24% (e.g., *"When there's an eel around, the catfish won't bite"*), (2) knowledge of anguillid eels as food -11% (e.g., *"I think they make sushi out of it"*), (3) conservation status - 22% (e.g., *"You should not catch them and I think they're protected"*), (4) ecology - 26% (e.g., *"They're just very deep most of the time and they're always around logs… they'll only mostly come out to feed"*), (5) invasiveness – 7% (*"They eat our smaller fish… and they are invasive"*), (6) physical description - 37% (*"They're… long, almost snake-looking, but have the fins that kind of follow the body line"*), (7) vigor - 11% (e.g., *"They are vicious in the water… they're pretty strong - yeah, they definitely put up a fight"*). However, the overarching theme emerging from the answers was a confessed lack of knowledge (46%). Many respondents who expressed some knowledge qualified their answers with statements such as *"I don't know too much really about them, really and truly I don't."* Seven respondents provided no response other than expressing their lack of knowledge, for example, *"I know nothing about the American Eel… I didn't even know we had it in these waters"*. Most respondents (92%) did not think the American Eel was dangerous to humans, and the remainder were undecided. When asked if the eel population in the Ottawa River was increasing, decreasing or stable, 34% of respondents were undecided and 30% responded that the species was in decline (Fig. 1).

When told that eels were in decline, respondents were asked to speculate on primary causes for their decline. Only three people (6%) directly mentioned dams as a possible cause for decline. Ten respondents (21%) considered habitat degradation as a potential reason for the decline. Habitat alteration is indirectly associated with riverine barriers (i.e., dams) and, as with riverine barriers, is considered a key factor for the species' decline (MacGregor et al., 2013). Many respondents mentioned fishing pressure (36%) and pollution (43%) as possible causes for decline (Fig. 2).

3.4. Support for eel research and conservation

When asked if anglers would follow the advice of a scientific study if it showed that cutting the line increased survival of eels compared to removing the hook, 73% of respondents said they would follow this advice, with the remainder saying they would not follow the advice (18%) or that it would depend on the lure they were using at the time (9%). Of the 45 respondents who were asked if they supported current and/or future efforts to increase the eel population in the Ottawa River, 69% answered yes, 11% answered no, 16% needed more information to decide whether they supported conservation efforts, and 4% of respondents thought that there was nothing left to support. Expanded answers from respondents who supported eel conservation efforts included statements such as *"I'm not a fan of them, but I don't want to see them go extinct"*. The five respondents who did not support eel conservation provided the following answers: (1) *"Because those fish are squirmy"*, (2) *"Because…they would eat a lot of minnows and other kinds of little fishes…"*, (3) *"Because I don't think nature needs our support"*, (4) *"I don't see the benefit of it, in our lakes and as well as for fishermen. Nobody eats eel. It's not a delicacy here"*, (5) *"I don't like them"*. Respondents who said they needed more information to make a decision explained with answers such as *"If I knew the consequences of supporting it and not supporting it, if I had the facts, then I would. Especially what benefits the eel brings to the economy and the ecosystem and all that. But I have to be educated."* Finally, the responses from the two anglers who believed there was nothing left to support were *"You can't [support it]. You can't increase or decrease. It depends how many… come. You can't do nothing."* and *"How can you support the eels now [that] there's none? There used to be. But there's none… past Arnprior [a town upstream of Ottawa] there are a bunch of rivers, we used to catch eels there too but there's nothing now. And not even the small ones, I don't see them anymore."*

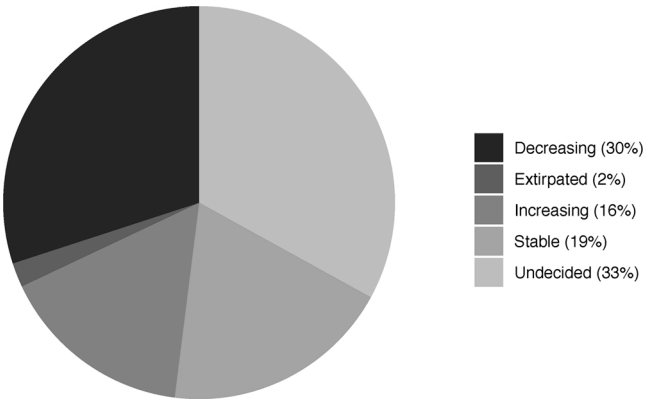

Fig. 1. Angler responses ($n = 44$) to the question: based on what you know, is the American Eel population in the Ottawa River increasing or decreasing or neither.

3.5. Influence factors

There was no evidence to suggest that prior experience catching eels was associated with having some knowledge of eels (χ^2=3.3, df = 1, $P > 0.05$). Additionally, there was no evidence to suggest that previous capture or knowledge of eels increased comfort when handling eels ($\chi^2 = 1.0 \times 10^{-31}$, df = 1, $P > 0.05$, χ^2=0.59, df = 1, $P > 0.05$). Knowledge of eels was not significantly associated with support for line-cutting if a scientific study recommended the practice ($\chi^2 = 0.77$, $P > 0.05$), nor was it associated with support for eel conservation in general ($\chi^2 = 3.44$, $P > 0.05$). An angler's disagreement with the statement "nature exists to meet the needs of humans" was not associated with their willingness to support eel conservation efforts on the Ottawa River ($\chi^2 = 9.84$, $P > 0.05$), nor was their agreement with the statement "anglers should be educated on fish species at risk and how to release them" ($\chi^2 = 12.27$, $P > 0.05$) or the statement "recreational anglers cannot catch enough fish to affect a fish population" ($\chi^2 = 4.23$, $P > 0.05$).

4. Discussion

Interviews suggest that angler behavior when incidentally capturing American Eel is not a direct threat to the species. Although nearly half of respondents had captured eels at some point, only three anglers reported killing eels, either for harvest or discard. For the one report of killing eels for discard, the angler explained that this was done out of fear because of lack of knowledge about eels (i.e., they were mistaken for snakes). Overall, killing and discarding eels appears to be an infrequent occurrence, given that only one angler reported this action. However, the limitations of self-reported data must be considered here, because

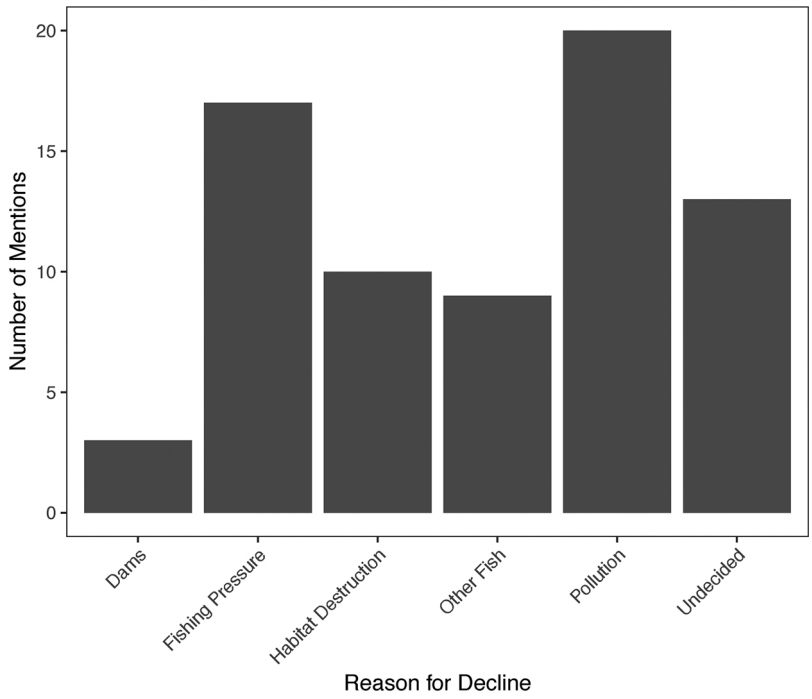

Fig. 2. Potential reasons provided by respondents ($n = 47$) for the decline of American Eel, and the number of mentions by anglers for each reason.

anglers may not have been willing to admit to killing an eel if they were aware that the fine for a first-time offender under Ontario's *Endangered Species Act* is $250, 000 CDN (Endangered Species Act, 2007, S.O. 2007, c. 6, 2007). All three reported incidents of killing eels (for harvest or discard) occurred prior to the closure of the recreational fishery for American Eel in 2005.

If anglers are not directly killing eels upon capture, the survival of an eel following incidental capture is primarily dependent on the handling practices used for its release. These interviews revealed that 46% of respondents were, or would be, uncomfortable handling eels. This is not surprising in the context of the literature; phobias of non-predatory animals (i.e., animals not likely to attack/harm humans) are not unusual (Arrindell, 2000; Batt, 2009; Davey, 1994). Eels specifically have been identified as anxiety or fear-provoking animals in social science surveys (Batt, 2009; Davey, 1994). One potential driver for this heightened anxiety or fear of animals like eels is disgust, which is often associated with sensory cues such as sliminess and with animal discharges like mucus and feces (Bennett-Levy and Marteau, 1984; Curtis and Biran, 2001; Davey, 1994; Phillips et al., 1998; Prokop and Fančovičová, 2010). In the present study, disgust is a plausible source of the discomfort expressed by anglers when handling eels, given that one third of respondents indicated that the eel's slimy texture and handling difficulty contributed to their discomfort. Additionally, a preference was revealed for the use of gloves and tools, which reduce the need for directly touching or handling an incidentally captured eel. This evidence suggests that many anglers would prefer a release method that minimizes the need for directly touching eels. This is corroborated by the existing frequent practice of line cutting by anglers who had previously captured eels. Of anglers who had captured eels in the past, 33% had cut the line, and line cutting was identified as a theme in 25% of the responses to the question about comfort handling eels. Line cutting is a quick method for releasing a fish and it requires little handling (Fobert et al., 2009). As such, it is a viable option for releasing incidentally captured eels with only a limited amount of handling required, given that eels exhibit high survival and hook-shedding rates following line cutting (Litt et al., 2020; Weltersbach et al., 2016, 2018).

These interviews suggest that knowledge of eels and their decline has not been effectively transferred to the public. Anglers are presumably one of the most well-informed segments of the population regarding fish and the threats facing fish and, as revealed by the demographics of the respondents, these interviews captured a highly experienced portion of the angling population. More than two thirds of respondents were fishing prior to the closure of the recreational eel fishery in Ontario and nearly 30% had been fishing since the 1980s, prior to the drastic decline of the eel population. Yet, a large proportion of anglers were uncertain in their knowledge of American Eel and unaware of the species' current status and reasons for its decline. For instance, only 6% of respondents (3 people) suggested dams as a possible contributor to the species' decline, despite all interviews being conducted within 40 km of one or more major river-spanning dams. Since each of these dams has been in operation for more than 80 years, it is not surprising that the interviewed anglers (whose average age was 39 years) do not consider them as potential factors. This may be an example of "shifting baseline syndrome," whereby the perceived importance of environmental events and disruptions fade with time as the resultant changes become part of a "new normal" in the experience of users (see Pauly, 1995; Papworth et al., 2009). Having been in place for decades, dams are part of anglers' baseline perceptions of the river. In contrast, it is well recognized within the scientific community that riverine barriers such as dams are a primary factor contributing to the decline of eels everywhere (MacGregor et al., 2013), including on the Ottawa River where turbine mortality for eels in one tributary was modelled to be as high as 97.2% (MacGregor et al., 2015). Indeed, MacGregor et al. (2008) cited eels as a non-recreational fisheries example of the invisible collapse facing many popular gamefish species. Since then, considerable attention has been focused on the species from science and management (see 148th Annual Meeting of the American Fisheries Society, 2018, for example), however these interviews indicate that the decline of eels remains largely invisible to the public, even in a location where eels were once a significant species for both Indigenous and non-Indigenous peoples (Algonquins of Ontario, 2014b; MacGregor et al., 2009). This invisibility emphasizes the need for understanding the human dimensions components of fisheries. For an imperiled species such as the American Eel, and in a place where the species is as rare as in the Ottawa River, the outcome of a single angling encounter with the species has a potentially large effect on the remaining population relative to the outcome of an angler interaction with a more abundant species. Thus, it is particularly crucial for the management of an imperiled species such as the American Eel to

consider angler attitudes and behaviors and to ensure that each angler is equipped with the knowledge and tools to react appropriately upon their capture. Anglers who supported eel conservation efforts on the Ottawa River explained their stance with statements about the intrinsic value of nature and an inherent importance of conserving species at risk. Almost a third of respondents were undecided or did not support eel conservation and, among these, several questioned the instrumental value of eels (i.e., the tangible benefits of eels for the environment, anglers, and economy). This lack of knowledge about the instrumental value of eels was corroborated by responses to other questions in the interview: only 11% of respondents mentioned eels as a food source when asked about their knowledge of eels and none mentioned the species' economic value. It has previously been suggested that buy-in to conservation action may be best achieved through promotion of instrumental rather than intrinsic value (Justus et al., 2009). In this circumstance, it appears that gaining support for eel conservation may require a variety of approaches – whereas some anglers are led to support eel conservation through appreciating the intrinsic value of biodiversity, others may require more tangible valuations of eels (e.g., economical or specific ecological benefits).

The present findings relate primarily to angler-eel interactions on the Ottawa River and it must be acknowledged that there is spatial variation in human attitudes and behaviors towards wildlife (Bowman et al., 2001; Carter et al., 2014; Karlsson and Sjöström, 2007), so these findings may not be representative of angler-eel interactions across its distribution. Eels in the Ottawa River have been rare for many years and it has been illegal to recreationally target them since 2005, therefore it is not surprising that eels are not well known to anglers in this area. In other regions of the species' range where eel declines are less pronounced, anglers may exhibit increased knowledge about eels. Increased familiarity and knowledge of the species may result in more positive attitudes towards the species, as was found to be the case in research involving another rare and at-risk species, the Eastern Hellbender (*Cryptobranchus alleganiensis*) (Reimer et al., 2014). Regional factors other than eel abundance may also play a role in angler behavior towards the species. For example, direct mortality rates may be higher in areas of Ontario where the range of Endangered American Eel overlaps with the range of invasive Sea Lamprey (*Petromyzon marinus*). Like eels, lamprey have elongated bodies, and are often described as "eel-like" in news articles (e.g., CBC News, 2012; Katz, 2019; Nissen, 2019), educational web pages (e.g., Ministry of Natural Resources and Forestry, 2019; OFAH/OMNRF Invading Species Awareness Program, 2012), and academic literature (Kelly and King, 2001; Sugahara et al., 2015). Ontario's Ministry of Natural Resources and Forestry and Fisheries and Oceans Canada both advise not returning lamprey to water if found (Fisheries and Oceans Canada, 2018a, 2018b; Ministry of Natural Resources and Forestry, 2019). If anglers elsewhere in Ontario are as uncertain in their knowledge of eels as Ottawa River respondents were found to be, it is possible that they may mistake eels for lamprey and unintentionally kill an Endangered species. These examples emphasize the need for caution when extrapolating the findings of the present study to angler-eel interactions elsewhere in the species' range, while also emphasizing the need to account for heterogeneity in human attitudes and behaviors toward wildlife when developing management plans.

The discomfort of many Ottawa River anglers toward American Eel is not extraordinary in comparison to global perspectives on freshwater eels, however many cultures that interact with eels generally value the species, whether it be for nutritional, medicinal, material, or spiritual purposes. In Ireland, European Eel (*Anguilla anguilla*) have a negative image in folklore and popular culture; however, they been harvested for centuries. More recently, Irish eel conservation efforts have increased public awareness of the fascinating life history of eels (McCarthy, 2014). In France, many colloquial sayings employ similes to eels to express sneakiness and surreptitious behavior (Feunteun and Robinet, 2014). However, the species is still economically valued, commonly eaten, and the subject of an extensive recreational fishery (Baisez and Laffaille, 2008; Dorow and Arlinghaus, 2011). There, anglers who recognize the current decline of eels are willing, under certain circumstances, to commit to stricter regulations for eel conservation than currently exist (Dorow et al., 2009). In Polynesia, the inhabitants of Tikopia were documented as being disgusted at the appearance and squirminess of eels, however they simultaneously considered eels as sacred (Firth, 1930). In Japan, the existence of over one hundred names for eels is an indication of their importance to Japanese culture and cuisine, yet eels are also feared because of their mysterious behavior and resemblance to snakes (Kuroki et al., 2014). More locally, the Algonquins of Ontario have put forth several calls for further conservation of American Eel and have emphasized the importance of these efforts by describing the species' value for medicinal, nutritional, spiritual and material purposes (Algonquins of Ontario, 2012, 2014a, 2014b). This study did not compare the potentially differing responses between Indigenous and non-Indigenous respondents because we did not elicit information on ethnicity. This brief overview of varied cultural perspectives on freshwater eels emphasizes the global relationships between humans and eels, in which the complex and unique life history of eels elicits both discomfort and appreciation. The respect and value allotted to eels by other cultural groups suggests that if sought, support for eel conservation by Ottawa River anglers is possible to achieve with outreach.

This exploratory research suggests that discomfort and lack of knowledge do not seem to cause a significant direct threat (i.e., injury or death) to eels from anglers but may have implications for the conservation of the species. Conservation support has been linked to societal attention and species charisma, with most research and effort focused on popular and attractive species (Bonnet et al., 2002; Clark and May, 2002; Jarić et al., 2019). Additionally, conservation case studies suggest that knowledge can improve public attitudes towards species' conservation (O'Bryhim and Parsons, 2015; van der Ploeg et al., 2011; Tisdell and Wilson, 2004). Thus, for a species with a discomfort-inducing nature and a lack of public knowledge about it, conservation prospects may be particularly dire. However, if increased support for conservation is desired, this situation can be improved, given that 16% of respondents expressed a need for more information to decide if they supported eel conservation efforts.

Exploratory research involves identifying variables and general factors that may influence phenomena that are not yet well-understood (Stebbins, 2020). This research is an exploratory investigation of angler and eel interactions, focused on collecting preliminary data on factors known to influence angler behavior (i.e., perceptions, knowledge and beliefs, and social processes, etc.). Further research is necessary to refine research design and to develop this field of inquiry. The open-ended questions and inductive coding approach used in this study permitted the emergence of a wide range of new themes, whereas a more traditional survey structure with close-ended questions would not have permitted participants to introduce ideas not previously conceived by the researchers. For example, researchers anticipated anglers to have negative feelings toward handling eels and anticipated that this would be largely due to eels' snake-like body shapes. Although some respondents mentioned snakes, coding of the open-ended responses revealed that discomfort when handling eels was more frequently associated with disgust at their slimy texture and difficulty holding them. Through concatenated exploration (a set of linked studies that build toward grounded or inductively generated theory), this broad exploration can be subsequently narrowed while simultaneously improving design elements (i.e., sampling structure, validity) (Stebbins, 2020). In other words, future work can build off this initial exploration by developing a more structured questionnaire that targets a subset of the ideas presented here. In particular, this field of inquiry could benefit from further investigation of potential spatial and temporal differences in knowledge and perspectives toward eels in Ontario, a comparison of Indigenous and non-Indigenous perspectives and behaviors toward eels, and a deeper study of factors influencing support for conservation of eels.

CRediT authorship contribution statement

M. Aline Litt: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Visualization, Project administration. **Nathan Young:** Conceptualization, Methodology, Validation, Writing - review & editing. **Nicolas W.R. Lapointe:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition. **Steven J. Cooke:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are grateful to the anglers who participated in the interviews. Additionally, four anonymous reviewers' comments on earlier versions of this manuscript helped to improve its quality. This work was funded by the Canadian Wildlife Federation. Cooke is further supported by NSERC and the Canada Research Chairs Program. Additional support was provided by Project Learning Tree. The study was approved and conducted in accordance with the Carleton University Research Ethics Board.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.fishres.2020.105781.

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