Transactions of the American Fisheries Society 151:322–332, 2022

ISSN: 0002-8487 print / 1548-8659 online
DOI: 10.1002/tafs.10349

FEATURE ARTICLE

Catch-and-Release Ice Fishing: Status, Issues, and Research Needs

Michael J. Lawrence and **Ken M. Jeffries**
Department of Biological Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

Steven J. Cooke
Department of Biology and Institute of Environmental and Interdisciplinary Science, Carleton University, Ottawa, Ontario K1S 5B6, Canada

Eva C. Enders
Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6, Canada

Caleb T. Hasler
Department of Biology, The University of Winnipeg, Winnipeg, Manitoba R3B 2E9, Canada

Christopher M. Somers
Department of Biology, University of Regina, Regina, Saskatchewan S4S 0A2, Canada

Cory D. Suski
Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana–Champaign, Urbana, Illinois 61801, USA

Michael J. Louison
Division of Science and Mathematics, McKendree University, Lebanon, Illinois 62254, USA

Abstract
Catch-and-release (C&R) ice fishing is a popular form of recreational angling. At present, there is a considerable deficiency in our understanding of how ice angling affects the physiology, behavior, and survival of fish. Thus, the purpose of this review was to summarize our current knowledge of the consequences of winter C&R fishing on fish biology and to identify key knowledge gaps. Our synthesis revealed that in addition to the typical stressors encountered from C&R fishing during the open-water season, fish that are caught through the ice are subject to several unique challenges, including exposure to subzero air temperatures upon landing as well as unique gear types that are not commonly used in the summer (i.e., passive angling techniques). We currently understand that while C&R angling causes a generalized stress response, cold environments may mute or delay these effects and may also come with additional deleterious consequences, such as tissue freezing. Interestingly, reported mortality can be low following release but can be influenced by gear type, barotrauma, and hooking location. Postrelease behaviors and the spatial ecology of ice-angled fish are poorly understood, but technologies such as telemetry and biologgers and an intensification of research on the topic are starting to produce new insights in this area. As it stands, research on the consequences of winter C&R angling is largely restricted to a handful of popular sport fish species, and these consequences are likely

*Corresponding author: m_lawrence27@live.ca
Received April 28, 2021; accepted December 20, 2021

not being considered in management and conservation contexts. Given the increasing popularity of the sport, furthering our understanding of C&R impacts in the winter represents a timely and important area of inquiry and can be used to develop more informed and effective C&R guidelines and management practices.

Recreational ice fishing is a popular winter activity in northern climates (Sellers 2003; Koprash 2019; Martino 2019; Butala 2020; OMNRF 2020; Rumball 2020), representing a multi-billion-dollar industry contributing greatly to local economies. For example, winter angling activities are thought to contribute in excess of US$23 million annually in Minnesota, USA (Gartner et al. 2002), and the recreational ice fishery for Walleye *Sander vitreus* in Lake Winnipeg, Manitoba, Canada, is estimated to contribute hundreds of millions of dollars to the economy through direct and indirect expenditures (Manitoba Wildlife Federation 2018). Ice fishing also represents an important cultural pastime for many inhabitants of regions with long, cold winters (Toivonen et al. 2000; Breining 2008; McIntosh 2011; Van Assche et al. 2013; Orru et al. 2014). For example, numerous large festivals centered around ice fishing occur throughout North America (e.g., Orillia Perch Festival on Lake Simcoe, Ontario; International Eelpout Festival in Walker, Minnesota) and beyond (e.g., Inje Icefish Festival on Soyang Lake, South Korea; Chagan Lake Ice and Snow Fishing Festival in Songyuan, China).

In its most basic form, ice fishing generally involves cutting a hole in the ice through which fish are captured using a variety of active and passive fishing methods. Passive fishing devices, such as tip-ups, handlines, and "dead sticks," are common and involve presenting fish with live or dead bait on a hook. In contrast, active fishing methods involve the presentation of lures or baits (e.g., jigs, spoons, plastics, and crank baits) in an effort to entice a fish to strike. Regardless of the techniques used, recreational ice fishing involves both catch-and-release (C&R) and harvest fisheries (Orru et al. 2014; OMNRF 2019; Government of Saskatchewan 2020; NYSDEC 2020; Eva Thorstad, Norwegian Institute for Nature Research, personal communication). However, fisheries managers are generally lacking scientific information to make decisions when it comes to ice fishing regulations, particularly when considering the live release of fish for conservation purposes.

Despite the economic importance and widespread popularity of C&R ice fishing, little has been published on how it affects the physiology and behavior of captured fishes. Even basic information, such as hooking mortality estimates, is lacking in the winter (Arlinghaus et al. 2007). This bias toward open-water C&R research likely stems from the challenges in conducting studies outdoors during winter and the need for specialized equipment (e.g., ice augers, snowmobiles, heated shelters, on-ice safety). Ice fishing also has some unique challenges that are not present in the open-water season, such as cold water temperatures, cold air exposures, and a potentially higher use of passive fishing gear, which may affect the outcome of the capture event. As recreational ice fishing increases in popularity (e.g., Dix et al. 2019; Martino 2019), understanding its impact on fish biology will become an important area for fisheries science. To that end, the purposes of this review are to (1) summarize the current state of knowledge on the impacts of C&R ice fishing on the biology of fishes; (2) propose predicted directions of effects based on the current understanding of C&R angling in data-deficient fisheries; and (3) provide recommendations for fisheries researchers and managers on critical areas of study in which foundational work is still needed. Our scope encompasses physiological, behavioral, and ecological aspects, with a particular emphasis on the mechanisms underlying the associated effects of C&R ice fishing on fish and fish populations.

PHYSIOLOGICAL RESPONSES FROM THE EFFECTS OF CAPTURE AND AIR EXPOSURE

The capture of a fish through the ice involves a distinct series of events, all of which contribute to increasing the animal's stress burden. A typical angling event involves a successful hook set, a fight period during which the fish attempts to evade the angler, and the landing of the fish above the ice's surface. After landing, the hook is removed and, in some circumstances, a picture or size measurement of the fish is taken, followed by the animal's release. During this time, the fish may also come into contact with snow and ice if it is set down on the surface at any point. Hook set, handling, and air exposure all represent acute stressors that in combination induce a generalized stress response in the fish. The main purpose of this acute stress response is to re-establish or maintain homeostasis, which is achieved through a coordinated physiological response involving the production and secretion of stress hormones—namely corticosteroids and catecholamines (Wendelaar Bonga 1997; Schreck and Tort 2016). These hormones initiate a variety of secondary responses that include increased perfusion of gill lamellae, the production of glucose by the liver, the release of red blood cells into the bloodstream, and increases in cardiac output and metabolic rate, which collectively coordinate increased oxygen distribution and energy availability (Pagnotta and Milligan 1991; Randall and Ferry 1992; Wang et al. 1994; Reid et al. 1998; Rodnick and Planas 2016; reviewed by Schreck and Tort 2016). Indeed, ice-angled fish have been shown to exhibit elevated stress indices after capture, including higher circulating levels of cortisol and glucose (Louison et al. 2017a, 2017b; Twardek et al. 2018; Logan et al. 2019; Althoff et al. 2021). For example, in Northern Pike *Esox lucius*, resting glucose levels remained at about 3 mmol/L, reaching peak values close to 8 mmol/L by 4 h postangling for fish caught through the ice (water temperature ~1°C; Louison et al. 2017a). In comparison, Northern Pike that were subjected to a handling and air exposure event (akin to an angling interaction) at 19°C (i.e., summertime water temperature) had glucose levels of approximately 11 mmol/L at 4 h post-stress (Schwalme and Mackay 1985), suggesting that although they are still being stressed, winter-caught fish may have lower peak stress response levels. However, unlike with fish caught in open water (reviewed by Siepker et al. 2007), the generalized stress responses are poorly characterized in ice-angled fish.

The landing and hook removal phases of the angling event represent the most unique challenges to ice-angled fish. In general, the metabolic rate of a fish decreases with declining water temperatures (Figure 1; Gibson and Fry 1954; Beamish 1970; Clarke and Fraser 2004); consequently, the cold water temperatures that are typically encountered during the winter induce a slowdown in metabolic processes and hormonal production (Wilkie et al. 1997; Davis 2004; Hasler et al. 2009), which affects the timing and sensitivity of the stress response. For example, a muted and delayed stress response was observed in winter-caught Northern Pike relative to what would be expected in summer-caught fish (Louison et al. 2017a). Indeed, peak levels of blood metabolites indicative of stress were observed around 1–2 h post-stress in Northern Pike at 19°C (Schwalme and Mackay 1985). Similar effects were observed in Bluegill *Lepomis macrochirus* and Yellow Perch *Perca flavescens* (Louison et al. 2017b). Fish also experience major shifts in environmental temperatures as they are pulled through colder surface waters (i.e., bottom waters are typically warmer than surface layers), and upon landing, they may be exposed to subzero air temperatures (Figure 2). This process can induce cold shock, which, alongside hypoxia (Cook et al. 2015), can lead to impaired neuronal function, delayed recovery from stress, and aberrant swimming (Hyvärinen et al. 2004; Donaldson et al. 2008). Furthermore, fish that are exposed to subzero air temperatures are at risk of tissue damage, especially to soft exposed tissues, such as the eyes, gills, and fins (Warrenchuk and Shirley 2002; Van Tamelen 2005; Card et al., in press). Tissue freezing during landing has been documented to occur in ice-angled Lake Trout *Salvelinus namaycush* (Rowe and Esseltine 2001; Card et al., in press). Furthermore, the skin temperatures of ice-angled Largemouth Bass *Micropterus salmoides* were positively correlated with the windchill temperature, suggesting that air exposure presents a significant threat to winter-caught fish (LaRochelle et al. 2021). This risk of damage can also be enhanced by handling practices that are unique to ice angling—particularly the tendency for anglers to place fish directly on the ice or snow as the angler removes the hook, takes photos, and decides whether or not to release the fish (Louison et al. 2017a; Twardek et al. 2018; Logan et al. 2019). Together, these factors create major circumstances that may increase the impact of air exposure on ice-angled fish.

BAROTRAUMA CONSIDERATIONS

One potential consequence of C&R ice fishing that has yet to be fully explored is the incidence of barotrauma. The rapid decompression of gases in the blood and organs of fish as they are brought toward the surface from depth (Figure 1) can lead to barotrauma, which may result in hemorrhaging of the gills, fins, and mouth; impaired swimming; noticeable distension in the body cavity (particularly the swim bladder); bulging of the eyes (exophthalmia); and eversion of organs through the mouth or anus (Campbell et al. 2010; Drumhiller et al. 2014; Ferter et al. 2015). Ice fishing can occur in deeper waters as some fish species tend to congregate in these areas during the winter (Blanchfield et al. 2009; Gillis et al. 2010), and many species are targeted by jigging or presenting baits near the lake bottom, thus increasing the risk of barotrauma (Pyzer 2013, 2014; Lamont 2017). Consequently, barotrauma can be prevalent in an ice fishing setting (Rowe and Esseltine 2001; Eberts et al. 2018a; Twardek et al. 2018; Althoff et al. 2021). The high prevalence of barotrauma in ice fishing may be problematic as barotrauma was thought to be one of the determining factors affecting mortality in ice-fished Walleye (Rowe and Esseltine 2001). In the latter study, 97% of Walleye that suffered mortality after ice angling were associated with swim bladder overexpansion, which was thought to be the key factor in determining mortality. Besides physical injuries, barotrauma can be challenging as the fish may have difficulty swimming back down the hole after release or they may end up trapped in the cold water at the water–ice boundary. Although these outcomes are potentially detrimental for angled fish, the only published research to date that has examined barotrauma in ice-angled freshwater fish found that Bluegill and Black Crappie *Pomoxis nigromaculatus* angled from relatively shallow depths (i.e., 5 m) are likely to suffer from barotrauma (Althoff et al. 2021), which could lead to the aforementioned issues with

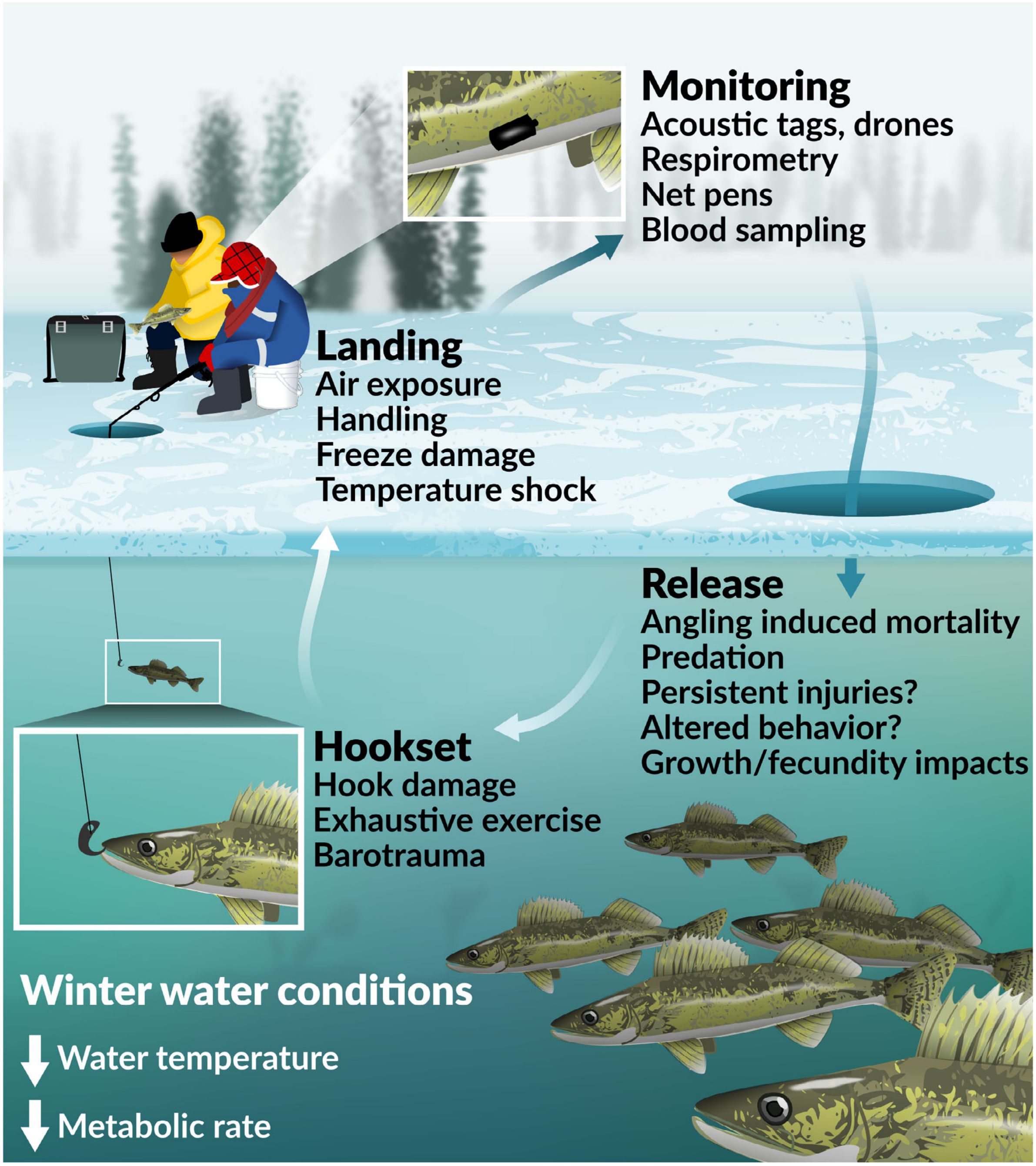

FIGURE 1. Summary of the challenges facing ice-angled fish and the technologies and biological endpoints that can be used to measure fisheries-associated impacts.

redescending to depth and being trapped at the water–ice interface. Given the potential importance of barotrauma for the postrelease survival of ice-angled fish, a better understanding of the fundamental biology associated with barotrauma risk factors, mitigation strategies, and long-term implications for populations is key in a management context.

POSTRELEASE MORTALITY UNDER ICE

Postrelease mortality is an important consideration for managing open-water C&R fisheries. In numerous open-water settings, mortality estimates have been quantified and are variable among species and contexts (Donaldson et al. 2011; Rapp et al. 2012; Lewin et al. 2018; Weltersbach et al. 2018; Litt et al. 2020). It is currently believed that the primary cause underlying postrelease mortality can be attributed to hooking location in fish (Bartholomew and Bohnsack 2005; Hühn and Arlinghaus 2011; Figure 2A). Furthermore, the cumulative impact of multiple sublethal stressors (e.g., ion and acid base disturbances, energy substrate depletion associated with exhaustive exercise and/or air exposures; Wood et al. 1983; Ferguson and Tufts 1992; Kieffer et al. 2002) can also contribute to postrelease mortality. In addition, predation upon release (reviewed by Raby et al. 2014) and other angling-related effects, such as barotrauma and blood loss, are also important in open-water fisheries (Gravel and Cooke 2008; Schreer et al. 2009; Eberts et al. 2018b). At finer scales, mortality can be mediated by several risk factors, including the gear type and hooking location (Schisler and Bergersen 1996; Cooke and Suski 2004; Horodysky and Graves 2005; Weltersbach et al. 2018) and environmental characteristics (e.g., water O_2, hardness, and temperature; Schramm et al. 1987; Lee and Bergersen 1996; Schisler and Bergersen 1996; Kieffer et al. 2002). Thus, postrelease mortality in an open-water setting represents a complex interaction of angler practices and biotic and abiotic features.

In an ice fishing setting, several correlates of mortality have been identified across a handful of popular sport fish species (see Table 1). Hook type and location (i.e., deep hooking), as well as levels of bleeding, were found to be significant factors influencing the likelihood of mortality in Northern Pike (DuBois et al. 1994), Walleye (Rowe and Esseltine 2001; Twardek et al. 2018), and Lake Trout (Dextrase and Ball 1991; Persons and Hirsch 1994). In Walleye, barotrauma appeared to have mixed effects on predicting mortality: it either had no effect (Twardek et al. 2018) or was positively related to mortality (Rowe and Esseltine 2001). Despite the subzero air temperatures during winter, air temperature in a few studies appeared to have no impact on postrelease survival (Dextrase and Ball 1991; Rowe and Esseltine 2001; Twardek et al. 2018). While these works represent some of the foundational studies assessing factors that influence mortality in an ice fishing setting, additional work is still needed to address longer-term assessments of mortality (i.e., >48 h; Scanlon and Taras 2005) and to examine a wider variety of species and contexts. The former point is especially important given that infection of damaged tissues (Cooke and Hogle 2000; Margenau 2006; Schramm and Davis 2006; Teffer et al. 2017) or compromised aerobic capacity (i.e., gill damage; Pauley and Thomas 1993; Cooke and Hogle 2000) could result in delayed mortality. At this time, the small pool of research on the topic limits our ability to make any definitive statements regarding the specific proximate mechanism(s) underlying postrelease mortality from ice fishing.

POSTRELEASE BEHAVIORS AND LONG-TERM CONSEQUENCES

To date, we lack information on what happens to ice-angled fish after they are released. Specifically, behavioral responses to ice angling and the potential for prolonged effects are almost completely unstudied. This paucity of information hinders the ability of fisheries managers and other stakeholders to ensure that populations are managed appropriately. There are three outcomes of C&R angling during the winter that could potentially have lasting effects on released fish, including stress impacts on behavior, slowed metabolism that may delay recovery and healing, and increased metabolic expenditures that may affect growth and reproduction (Figure 1). Below, we explore these potential outcomes in more detail; however, given

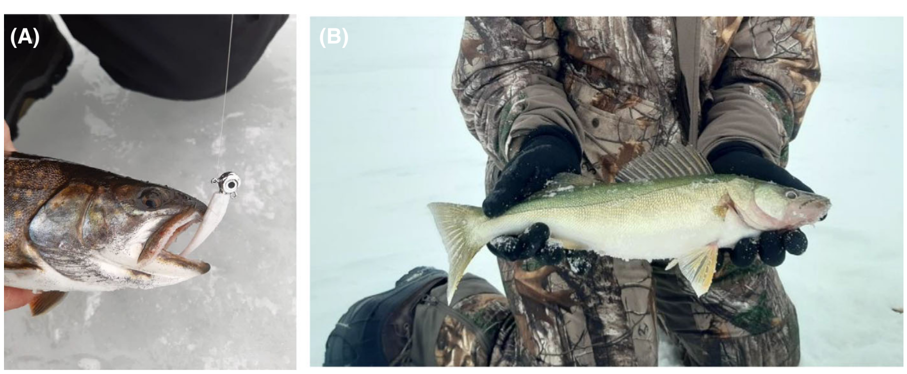

FIGURE 2. Photographs of **(A)** a splake (Lake Trout *Salvelinus namaycush* × Brook Trout *S. fontinalis*) and **(B)** a Walleye being landed on the ice. During this time, fish are exposed to a variety of stressors, including air exposure, handling, and subzero air temperatures, which can induce the stress response in the animal. In the case of the splake (panel A), the bait is still hooked in the animal's mouth and needs to be removed. The hook set is shallow and minor and is unlikely to cause any postrelease mortality. Many anglers like to display and photograph their catches (panel B), which has the potential to extend air exposure durations. (Photo credit: Michael Lawrence.)

TABLE 1. Summary of studies addressing hooking mortality in ice fishing settings.

Species	Location	Primary objectives	Mortality correlates	Postrelease mortality rate(s)	Reference
Northern Pike *Esox lucius*	Long Lake, Lipsett Lake, and Lake Mendota, Wisconsin	Characterized acute mortality with gear type	Hook type Deep hooking Bleeding	Pike hook: 33.3% Treble: 0.6% Overall: 4.9%	DuBois et al. (1994)
Lake Trout *Salvelinus namaycush*	Little Raleigh Lake, Ontario	Characterized acute mortality	Blood loss Deep hook sets No effect of air temperature	10%	Dextrase and Ball (1991)
	Gunflint Lake, Minnesota	Characterized acute mortality with gear type	Hooking location Gear type	Setlines: 32% Jigging: 9% Overall: 24%	Persons and Hirsch (1994)
Walleye *Sander vitreus*	Lac Des Mille Lacs, Ontario	Characterized acute mortality		Maximum of 10%	Cano et al. (2001)
	Lake Nipissing, Ontario	Characterized acute mortality	Swim bladder overexpansion No effect of surface conditions or body size	24 h: 23% 48 h: 3% Overall: 19%	Rowe and Esseltine (2001)
	Lake Nipissing	Characterized acute mortality with gear type	Deep hooking No effect of hook type, body size, barotrauma, gear type, or air temperature	Overall: 6.9%	Twardek et al. (2018)
	Lake Nipissing	Effects of handling stress on mortality and physiology		0%	Logan et al. (2019)
Roach *Rutilus rutilus*	Lakes Sarąg and Serwent, Poland	Characterized mormyshka jigging on hooking locations		0%	Czarkowski and Kapusta (2019)
Eurasian Perch *Perca fluviatilis*	Lakes Sarąg and Serwent	Characterized mormyshka jigging on hooking locations		Two fish	Czarkowski and Kapusta (2019)

the lack of published studies, the take-home message is that more research on winter C&R is needed.

The first major physiological outcome of C&R angling is activation of the stress response, which may influence short-term behaviors like movement and habitat use. Delayed onset of the stress response has been observed in Bluegill, Yellow Perch, Northern Pike, and Walleye caught during the winter months (Louison et al. 2017a, 2017b; Twardek et al. 2018), and an immediate impairment of reflexes was also documented (Louison et al. 2017a). The length of time that it takes for recovery to occur has not been studied, but presumably, if a fish is experiencing changing physiological parameters and reflex impairment upon release, mobility and buoyancy regulation may be negatively affected (Raby et al. 2012). A variety of studies have shown relatively minor behavioral responses to C&R angling in open water (e.g., Klefoth et al. 2008; Thompson et al. 2008; Arlinghaus et al. 2009; Landsman et al. 2011). However, some fish become behaviorally impaired and significantly change their movement and habitat use after release (e.g., Thorstad et al. 2007; Richard et al. 2014; Havn et al. 2015). Additionally, there is the potential for longer-term consequences if impairment continues beyond hours and days as "normal behavior" is required for routine activities such as predator avoidance (Danylchuk et al. 2007), feeding (Stålhammar et al. 2014), and habitat selection (Klefoth et al. 2008). The duration of the stress response and behavioral impairment and whether there are any long-term consequences have not been studied in winter. Consequently, there is a need for studies that directly monitor postrelease behaviors and movement in winter fisheries.

Potential long-term consequences of C&R ice fishing include decreased growth and fecundity, slow-healing injuries, and infection (Figure 1). Energetic demands increase and a stress response occurs after C&R in open-water studies (Cooke et al. 2002; Suski et al. 2004; Lawrence et al. 2018). In combination, these changes may deplete metabolic reserves (Kieffer et al. 1995; Wilkie et al. 1996; Suski et al. 2004) and ultimately hinder growth (Meka and Margraf 2007; Klefoth et al. 2011). In addition, there is the potential for tissue damage, which, in warm conditions, can lead to infection (Margenau 2006; Schramm and Davis 2006; Teffer et al. 2017). In winter conditions, fish may experience tissue damage from gear (e.g., hook damage) and also from angler practices. Swim bladder venting or fizzing to relieve barotrauma is also a potential source of injury (reviewed by Eberts and Somers 2017). Like metabolism, healing is slowed at colder temperatures (Roberts et al. 1971; Knights and Lasee 1996; Jensen et al. 2015), and how this slower healing rate influences long-term outcomes for fish is unclear. To date, no research has characterized healing rates of tissue damage in ice-angled fish, although some groups have started to characterize the potential effects of subfreezing temperature exposure on various tissues (Card et al., in press). As more is learned about fish physiology during the winter, best practices for reducing the negative consequences of angling should be developed.

ENHANCING ICE FISHING CATCH-AND-RELEASE SCIENCE AND FUTURE DIRECTIONS

One of the main challenges with C&R studies in winter is specific to physiological endpoints. Deciphering the effects of C&R is already challenging given the complexity of physiological time courses (Cooke et al. 2013), and this challenge is further complicated in winter as such time courses have not been defined for most fish species. For example, when do different physiological endpoints like cortisol and lactate peak after C&R in the winter, and how long does it take to recover? Relatedly, what are the consequences of physiological alterations in winter relative to other periods? These questions are largely unanswered and impede the ability to design studies. Addressing these questions could provide foundational knowledge for the impacts of C&R ice fishing while also providing comparative baselines for future study. The use of both laboratory and field studies will likely be complementary to address specific questions of interest. To that end, there is a need for laboratory studies in which fish can be held under conditions that emulate winter environments to establish relevant baselines and to optimize study design and sampling protocols. As highlighted throughout this review, there is some evidence to suggest that the timing of the stress response in ice-angled fish can differ from that in open-water-caught fish (e.g., Louison et al. 2017a, 2017b). Given that fish are ectotherms, the colder water temperatures could suggest that these effects are the product of a different metabolic physiology that changes on a seasonal basis (Karaås 1990). Similar considerations may also be made for postrelease recovery dynamics and mortality as water temperature and metabolism are often the driving mechanisms behind these processes. Thus, experiments that hold the fish over a long period of time may be useful in addressing the effects of seasonality, environmental considerations, and interspecific variation in responses to the stresses encountered during the ice fishing season.

More research is needed to understand behavioral responses to angling during cold temperatures and whether any of the documented impairments have consequences for condition and survival. Long-term behavioral assessments after ice angling would require either active monitoring via underwater cameras or the use of electronic devices such as transmitters (radio or acoustic). Telemetry technology enables the monitoring of activity levels (e.g., when equipped with acceleration sensors) as well as depth and water temperature (e.g., Eberts et al. 2018a, 2018b), which may be key factors for evaluating important influences on postrelease behavior in the winter. Telemetry has been used recently to track Northern Pike movements under the ice after ice angling, which shows promise that this technology can be successfully implemented in such studies (Somers et al. 2021). Underwater drones could also be potentially used to visually monitor fish under the ice, as this technology has been implemented in recording fish behavior and community composition assessments previously in aquatic environments, albeit under ice-free conditions (Skomal et al. 2015; Hawkes et al. 2020; Raoult et al. 2020; Maslin et al. 2021). Under-ice net-pens, such as those used by Twardek et al. (2018), can also be used to hold and monitor fish over acute durations. Passive methods, such as mark–recapture techniques, would allow us to infer survival and to conduct at least a coarse-scale assessment of fish behavior (e.g., general movements and habitat use). Mark–recapture methods can also be used to determine whether individual fish are caught and released once versus multiple times within a given period, which may modify the risk of behavioral impairment. In addition, mark–recapture enables longitudinal assessment of growth, condition, and vital rates, which would be valuable for quantifying the potential long-term consequences of ice angling. There is clearly a need for long-term monitoring of fish after winter C&R by using transmitters and tags.

As illustrated throughout this review, taxonomic diversity in ice fishing research is poor. The current state of research consists of a handful of species that are usually among the most popular recreational fishes in North America (e.g., Walleye, Bluegill, Northern Pike, and Lake Trout). Other species are being targeted by anglers during winter, and our current knowledge about their basic biology or how they respond to angling stressors—even in the open-water season—is deficient (e.g., Burbot *Lota lota* and ciscoes *Coregonus* spp.). Directing future research initiatives should include characterizing the responses of popular recreational species as well as atypical or bycatch species. To that end, establishing more detailed and regular winter creel surveys could prove to be a useful tool in determining likely targets of ice fishing activities with respect to nontarget species.

Given the highly context-specific and species-specific nature of angler–fish interactions (Cooke and Schramm 2007), further exploration of ice-fishing-related impacts is necessary not only to advance our fundamental understanding of the winter biology of fishes, but also to develop more effective management practices. Moreover, there is a need to develop best practices or C&R guidelines that can be shared with ice anglers. The dearth of biological information for winter C&R fisheries is likely an issue for management agencies due to the large uncertainty concerning winter C&R postrelease mortality, alterations in ecological and spatial use patterns, short-term physiological impairments, and longer-term impacts on individual fitness and population dynamics. Indeed, there may be seasonal carryover effects from winter angling events that could have consequences for summer angling seasons, particularly if there are metabolic-related impacts associated with angling (e.g., O'Connor et al. 2010; Midwood et al. 2015). Thus, quantifying winter C&R impacts will be useful in directing more informed fisheries management decisions during both winter and open-water fishing seasons.

ACKNOWLEDGMENTS

C. T. Hasler was supported by grants from the Fisheries and Wildlife Enhancement Fund (FES 19-010; FES 20-006). C. T. Hasler, K. M. Jeffries, and S. J. Cooke were also supported by the Discovery Grant Program of the Natural Sciences and Engineering Research Council of Canada. We thank Dr. Eva Thorstad as well as the two anonymous reviewers for providing helpful comments and insight on this review. We are also grateful to Dr. Chloé Schmidt for producing Figure 1. There is no conflict of interest declared in this article.

ORCID

Michael J. Lawrence https://orcid.org/0000-0002-4801-1580
Eva C. Enders https://orcid.org/0000-0003-2103-0359
Caleb T. Hasler https://orcid.org/0000-0003-3242-7415
Cory D. Suski https://orcid.org/0000-0001-8280-873X

REFERENCES

Althoff, A. L., C. D. Suski, and M. J. Louison. 2021. Depth-based barotrauma severity, reflex impairment and stress response in two species of ice-angled fish. Fisheries Management and Ecology 28:383–392.

Arlinghaus, R., S. J. Cooke, J. Lyman, D. Policansky, A. Schwab, C. Suski, S. G. Sutton, and E. B. Thorstad. 2007. Understanding the complexity of catch-and-release in recreational fishing: an integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. Reviews in Fisheries Science 15:75–167.

Arlinghaus, R., T. Klefoth, S. J. Cooke, A. Gingerich, and C. Suski. 2009. Physiological and behavioural consequences of catch-and-release angling on Northern Pike (*Esox lucius* L.). Fisheries Research 97:223–233.

Bartholomew, A., and J. A. Bohnsack. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Reviews in Fish Biology and Fisheries 15:129–154.

Beamish, F. W. H. 1970. Oxygen consumption of Largemouth Bass, *Micropterus salmoides*, in relation to swimming speed and temperature. Canadian Journal of Zoology 48:1221–1228.

Blanchfield, P. J., L. S. Tate, J. M. Plumb, M.-L. Acolas, and K. G. Beaty. 2009. Seasonal habitat selection by Lake Trout (*Salvelinus namaycush*) in a small Canadian Shield lake: constraints imposed by winter conditions. Aquatic Ecology 43:777–787.

Breining, G. 2008. A hard-water world: ice fishing and why we do it. Minnesota Historical Society, St. Paul.

Butala, T. 2020. Where is ice fishing most popular? Outdoor Troop. Available: https://outdoortroop.com/where-is-ice-fishing-most-popular/. (October 2020).

Campbell, M. D., R. Patino, J. Tolan, R. Strauss, and S. L. Diamond. 2010. Sublethal effects of catch-and-release fishing: measuring capture stress, fish impairment, and predation risk using a condition index. ICES (International Council for the Exploration of the Sea) Journal of Marine Science 67:513–521.

Cano, T., J. Wright, and L. Tarini. 2001. Mortality of live released Walleye during a shallow water ice fishing derby on Lac Des Mille Lacs, Ontario. Ontario Ministry of Natural Resources, Northwest Science and Information Aquatics Update 2001-2, Peterborough.

Card, J. T., J. Beiber, M. J. Louison, C. D. Suski, and C. T. Hasler. In press. An examination of freezing in Yellow Perch (*Perca flavescens*) following ice fishing using a histological approach. Journal of Applied Ichthyology. https://doi.org/10.1111/jai.14304.

Clarke, A., and K. P. P. Fraser. 2004. Why does metabolism scale with temperature? Functional Ecology 18:243–251.

Cook, K. V., R. J. Lennox, S. G. Hinch, and S. J. Cooke. 2015. Fish out of water: how much air is too much? Fisheries 40:452–461.

Cooke, S. J., M. R. Donaldson, C. M. O'Connor, G. D. Raby, R. Arlinghaus, A. J. Danylchuk, K. C. Hanson, S. G. Hinch, T. D. Clark, D. A. Patterson, and C. D. Suski. 2013. The physiological consequences of catch-and-release angling: perspectives on experimental design, interpretation, extrapolation and relevance to stakeholders. Fisheries Management and Ecology 20:268–287.

Cooke, S. J., and W. J. Hogle. 2000. Effects of retention gear on the injury and short-term mortality of adult Smallmouth Bass. North American Journal of Fisheries Management 20:1033–1039.

Cooke, S., and H. Schramm. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. Fisheries Management and Ecology 14:73–79.

Cooke, S. J., J. F. Schreer, D. H. Wahl, and D. P. Philipp. 2002. Physiological impacts of catch-and-release angling practices on Largemouth Bass and Smallmouth Bass. Pages 489–512 *in* D. P. Philipp and M. S.

Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Cooke, S., and C. Suski. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? Aquatic Conservation: Marine and Freshwater Ecosystems 14:299–326.

Czarkowski, T. K., and A. Kapusta. 2019. Catch-and-release ice fishing with a mormyshka for Roach (*Rutilus rutilus*) and European Perch (*Perca fluviatilis*). Croatian Journal of Fisheries 77:235–242.

Danylchuk, S. E., A. J. Danylchuk, S. J. Cooke, T. L. Goldberg, J. Koppelman, and D. P. Philipp. 2007. Effects of recreational angling on the post-release behavior and predation of Bonefish (*Albula vulpes*): the role of equilibrium status at the time of release. Journal of Experimental Marine Biology and Ecology 346:127–133.

Davis, K. B. 2004. Temperature affects physiological stress responses to acute confinement in sunshine bass (*Morone chrysops* × *Morone saxatilis*). Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology 139:433–440.

Dextrase, A. J., and H. E. Ball. 1991. Hooking mortality of Lake Trout angled through the ice. North American Journal of Fisheries Management 11:477–479.

Dix, A., C. Freesmeier, E. Helgesen, and M. Pattsner. 2019. Lake of the Woods sustainability assessment. Master's thesis. University of Minnesota, Minneapolis.

Donaldson, M. R., S. J. Cooke, D. A. Patterson, and J. S. Macdonald. 2008. Cold shock and fish. Journal of Fish Biology 73:1491–1530.

Donaldson, M. R., S. G. Hinch, D. A. Patterson, J. Hills, J. O. Thomas, S. J. Cooke, G. D. Raby, L. A. Thompson, D. Robichaud, K. K. English, and A. P. Farrell. 2011. The consequences of angling, beach seining, and confinement on the physiology, post-release behaviour and survival of adult Sockeye Salmon during upriver migration. Fisheries Research 108:133–141.

Drumhiller, K. L., M. W. Johnson, S. L. Diamond, M. M. Reese Robillard, and G. W. Stunz. 2014. Venting or rapid recompression increase survival and improve recovery of Red Snapper with barotrauma. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science [online serial] 6:190–199.

Dubois, R. B., T. L. Margenau, R. S. Stewart, P. K. Cunningham, and P. W. Rasmussen. 1994. Hooking mortality of Northern Pike angled through ice. North American Journal of Fisheries Management 14:769–775.

Eberts, R. L., J. C. Butt, and C. M. Somers. 2018a. Unexplained variation in movement by Walleye and Sauger after catch-and-release angling tournaments. North American Journal of Fisheries Management 38:1350–1366.

Eberts, R. L., and C. M. Somers. 2017. Venting and descending provide equivocal benefits for catch-and-release survival: study design influences effectiveness more than barotrauma relief method. North American Journal of Fisheries Management 37:612–623.

Eberts, R. L., M. A. Zak, R. G. Manzon, and C. M. Somers. 2018b. Walleye responses to barotrauma relief treatments for catch-and-release angling: short-term changes to condition and behavior. Journal of Fish and Wildlife Management 9:415–430.

Ferguson, R. A., and B. L. Tufts. 1992. Physiological effects of brief air exposure in exhaustively exercised Rainbow Trout (*Oncorhynchus mykiss*): implications for "catch and release" fisheries. Canadian Journal of Fisheries and Aquatic Sciences 49:1157–1162.

Ferter, K., M. S. Weltersbach, O.-B. Humborstad, P. G. Fjelldal, F. Sambraus, H. V. Strehlow, and J. H. Vølstad. 2015. Dive to survive: effects of capture depth on barotrauma and post-release survival of Atlantic Cod (*Gadus morhua*) in recreational fisheries. ICES (International Council for the Exploration of the Sea) Journal of Marine Science 72:2467–2481.

Gartner, W. C., L. L. Love, D. Erkkila, and D. C. Fulton. 2002. Economic impact and social benefits study of coldwater angling in Minnesota. Tourism Center, University of Minnesota Extension Service, St. Paul.

Gibson, E. S., and F. E. J. Fry. 1954. The performance of the Lake Trout, *Salvelinus namaycush*, at various levels of temperature and oxygen pressure. Canadian Journal of Zoology 32:252–260.

Gillis, N. C., T. Rapp, C. T. Hasler, H. Wachelka, and S. J. Cooke. 2010. Spatial ecology of adult Muskellunge (*Esox masquinongy*) in the urban Ottawa reach of the historic Rideau Canal, Canada. Aquatic Living Resources 23:225–230.

Government of Saskatchewan. 2020. Regulations 2: ice fishing. Government of Saskatchewan, Regina. Available: https://www.saskatchewan.ca/residents/parks-culture-heritage-and-sport/hunting-trapping-and-angling/angling/copy-of-regulations#ice-fishing. (October 2020).

Gravel, M.-A., and S. J. Cooke. 2008. Severity of barotrauma influences the physiological status, postrelease behavior, and fate of tournament-caught Smallmouth Bass. North American Journal of Fisheries Management 28:607–617.

Hasler, C. T., C. D. Suski, K. C. Hanson, S. J. Cooke, D. P. Philipp, and B. L. Tufts. 2009. Effect of water temperature on laboratory swimming performance and natural activity levels of adult Largemouth Bass. Canadian Journal of Zoology 87:589–596.

Havn, T. B., I. Uglem, Ø. Solem, S. J. Cooke, F. G. Whoriskey, and E. B. Thorstad. 2015. The effect of catch-and-release angling at high water temperatures on behaviour and survival of Atlantic Salmon *Salmo salar* during spawning migration. Journal of Fish Biology 87:342–359.

Hawkes, L., O. Exeter, S. Henderson, C. Kerry, A. Kukulya, J. Rudd, S. Whelan, N. Yoder, and M. Witt. 2020. Autonomous underwater videography and tracking of Basking Sharks. Animal Biotelemetry [online serial] 8(1):article 29.

Horodysky, A., and J. Graves. 2005. Application of pop-up satellite archival tag technology to estimate postrelease survival of White Marlin (*Tetrapturus albidus*) caught on circle and straight-shank ("J") hooks in the western North Atlantic recreational fishery. U.S. National Marine Fisheries Service Fishery Bulletin 103:84–96.

Hühn, D., and R. Arlinghaus. 2011. Determinants of hooking mortality in freshwater recreational fisheries: a quantitative meta-analysis. Pages 141–170 *in* T. D. Beard Jr., R. Arlinghaus, and S. G. Sutton, editors. The angler in the environment: social, economic, biological, and ethical dimensions. American Fisheries Society, Symposium 71, Bethesda, Maryland.

Hyvärinen, P., S. Heinimaa, and H. Rita. 2004. Effects of abrupt cold shock on stress responses and recovery in Brown Trout exhausted by swimming. Journal of Fish Biology 64:1015–1026.

Jensen, L. B., T. Wahli, C. McGurk, T. B. Eriksen, A. Obach, R. Waagbø, A. Handler, and C. Tafalla. 2015. Effect of temperature and diet on wound healing in Atlantic Salmon (*Salmo salar* L.). Fish Physiology and Biochemistry 41:1527–1543.

Karaås, P. 1990. Seasonal changes in growth and standard metabolic rate of juvenile Perch, *Perca fluviatilis* L. Journal of Fish Biology 37:913–920.

Kieffer, J., M. Kubacki, F. Phelan, D. Philipp, and B. Tufts. 1995. Effects of catch-and-release angling on nesting male Smallmouth Bass. Transactions of the American Fisheries Society 124:70–76.

Kieffer, J. D., A. M. Rossiter, C. A. Kieffer, K. Davidson, and B. L. Tufts. 2002. Physiology and survival of Atlantic Salmon following exhaustive exercise in hard and softer water: implications for the catch-and-release sport fishery. North American Journal of Fisheries Management 22:132–144.

Klefoth, T., A. Kobler, and R. Arlinghaus. 2008. The impact of catch-and-release angling on short-term behaviour and habitat choice of Northern Pike (*Esox lucius* L.). Hydrobiologia 601:99–110.

Klefoth, T., A. Kobler, and R. Arlinghaus. 2011. Behavioural and fitness consequences of direct and indirect non-lethal disturbances in a catch-and-release Northern Pike (*Esox lucius*) fishery. Knowledge and Management of Aquatic Ecosystems 403:article 11.

Knights, B. C., and B. A. Lasee. 1996. Effects of implanted transmitters on adult Bluegills at two temperatures. Transactions of the American Fisheries Society 125:440–449.

Koprash, M. 2019. The "game" panfish. Northern Ontario Travel Magazine (February 8).

Lamont, D. 2017. Hardwater Lake Trout. Hooked Magazine (January 6). Available: https://www.hookedmagazine.ca/hardwater-lake-trout/. (October 2020).

Landsman, S. J., H. J. Wachelka, C. D. Suski, and S. J. Cooke. 2011. Evaluation of the physiology, behaviour, and survival of adult Muskellunge (*Esox masquinongy*) captured and released by specialized anglers. Fisheries Research 110:377–386.

LaRochelle, L., A. D. Chhor, J. W. Brownscombe, A. J. Zolderdo, A. J. Danylchuk, and S. J. Cooke. 2021. Ice-fishing handling practices and their effects on the short-term post-release behaviour of Largemouth Bass. Fisheries Research 243:106084.

Lawrence, M. J., S. Jain-Schlaepfer, A. J. Zolderdo, D. A. Algera, K. M. Gilmour, A. J. Gallagher, and S. J. Cooke. 2018. Are 3 minutes good enough for obtaining baseline physiological samples from teleost fish? Canadian Journal of Zoology 96:774–786.

Lee, W. C., and E. P. Bergersen. 1996. Influence of thermal and oxygen stratification on Lake Trout hooking mortality. Fisheries Management 16:175–181.

Lewin, W.-C., H. V. Strehlow, K. Ferter, K. Hyder, J. Niemax, J.-P. Herrmann, and M. S. Weltersbach. 2018. Estimating post-release mortality of European Sea Bass based on experimental angling. ICES (International Council for the Exploration of the Sea) Journal of Marine Science 75:1483–1495.

Litt, M., B. Etherington, L. Gutowsky, N. Lapointe, and S. Cooke. 2020. Does catch-and-release angling pose a threat to American Eel? A hooking mortality experiment. Endangered Species Research 41:1–6.

Logan, J. M., M. J. Lawrence, G. E. Morgan, W. M. Twardek, R. J. Lennox, and S. J. Cooke. 2019. Consequences of winter air exposure on Walleye (*Sander vitreus*) physiology and impairment following a simulated ice-angling event. Fisheries Research 215:106–113.

Louison, M. J., C. T. Hasler, M. M. Fenske, C. D. Suski, and J. A. Stein. 2017a. Physiological effects of ice-angling capture and handling on Northern Pike, *Esox lucius*. Fisheries Management and Ecology 24:10–18.

Louison, M. J., C. T. Hasler, G. D. Raby, C. D. Suski, and J. A. Stein. 2017b. Chill out: physiological responses to winter ice-angling in two temperate freshwater fishes. Conservation Physiology 5:cox027.

Manitoba Wildlife Federation. 2018. Economics of the recreational fishery on Lake Winnipeg. Manitoba Wildlife Federation, Winnipeg.

Margenau, T. L. 2006. Effects of angling with a single-hook and live bait on Muskellunge survival. Pages 155–162 *in* J. S. Diana and T. L. Margenau, editors. The Muskellunge symposium: a memorial tribute to E. J. Crossman. Springer, Dordrecht, The Netherlands.

Martino, J. 2019. Popularity of ice fishing on rise. Kokomo Tribune (February 17).

Maslin, M., S. Louis, K. Godary Dejean, L. Lapierre, S. Villéger, and T. Claverie. 2021. Underwater robots provide similar fish biodiversity assessments as divers on coral reefs. Remote Sensing in Ecology and Conservation 7:567–578.

McIntosh, P. 2011. Fishing—a sport for all seasons. English Teaching Forum 49:34–43.

Meka, J. M., and F. J. Margraf. 2007. Using a bioenergetic model to assess growth reduction from catch-and-release fishing and hooking injury in Rainbow Trout, *Oncorhynchus mykiss*. Fisheries Management and Ecology 14:131–139.

Midwood, J. D., M. H. Larsen, M. Boel, K. Aarestrup, and S. J. Cooke. 2015. An experimental field evaluation of winter carryover effects in semi-anadromous Brown Trout (*Salmo trutta*). Journal of Experimental Zoology Part A: Ecological Genetics and Physiology 323:645–654.

NYSDEC (New York State Department of Environmental Conservation). 2020. Freshwater fishing regulations. NYSDEC, Albany. Available: https://www.dec.ny.gov/outdoor/31416.html. (October 2020).

O'Connor, C. M., K. M. Gilmour, R. Arlinghaus, C. T. Hasler, D. P. Philipp, and S. J. Cooke. 2010. Seasonal carryover effects following the administration of cortisol to a wild teleost fish. Physiological and Biochemical Zoology 83:950–957.

OMNRF (Ontario Ministry of Natural Resources and Forestry). 2019. Ontario fishing regulations summary. OMNRF, Toronto. Available: https://www.ontario.ca/document/ontario-fishing-regulations-summary. (October 2020).

OMNRF (Ontario Ministry of Natural Resources and Forestry). 2020. 2010 survey of recreational fishing in Canada: results for fisheries management zones of Ontario. OMNRF, Fish and Wildlife Policy Branch, Toronto.

Orru, K., K. Kangur, P. Kangur, K. Ginter, and A. Kangur. 2014. Recreational ice fishing on the large Lake Peipsi: socioeconomic importance, variability of ice-cover period, and possible implications for fish stocks. Estonian Journal of Ecology 63:282.

Pagnotta, A., and C. L. Milligan. 1991. The role of blood glucose in the restoration of muscle glycogen during recovery from exhaustive exercise in Rainbow Trout (*Oncorhynchus mykiss*) and Winter Flounder (*Pseudopleuronectes americanus*). Journal of Experimental Biology 161:489–508.

Pauley, G. B., and G. Thomas. 1993. Mortality of anadromous Coastal Cutthroat Trout caught with artificial lures and natural bait. North American Journal of Fisheries Management 13:337–345.

Persons, S. E., and S. A. Hirsch. 1994. Hooking mortality of Lake Trout angled through ice by jigging and set-lining. North American Journal of Fisheries Management 14:664–668.

Pyzer, G. 2013. Ice fishing Lake Trout. In-Fisherman (January 14). Available: https://www.in-fisherman.com/editorial/ice-fishing-lake-trout/153710. (October 2020).

Pyzer, G. 2014. How to find big Walleye mid-winter. Outdoor Canada (January 6). Available: https://www.outdoorcanada.ca/how-to-find-big-walleye-mid-winter/. (October 2020).

Raby, G. D., M. R. Donaldson, S. G. Hinch, D. A. Patterson, A. G. Lotto, D. Robichaud, K. K. English, W. G. Willmore, A. P. Farrell, M. W. Davis, and S. J. Cooke. 2012. Validation of reflex indicators for measuring vitality and predicting the delayed mortality of wild Coho Salmon bycatch released from fishing gears. Journal of Applied Ecology 49:90–98.

Raby, G. D., J. R. Packer, A. J. Danylchuk, and S. J. Cooke. 2014. The understudied and underappreciated role of predation in the mortality of fish released from fishing gears. Fish and Fisheries 15:489–505.

Randall, D. J., and S. F. Ferry. 1992. Catecholamines. Pages 255–300 *in* W. S. Hoar, D. J. Randall, and A. P. Farrell, editors. Fish physiology, volume 12, part B: the cardiovascular system. Academic Press, San Diego, California.

Raoult, V., L. Tosetto, C. Harvey, T. M. Nelson, J. Reed, A. Parikh, A. J. Chan, T. M. Smith, and J. E. Williamson. 2020. Remotely operated vehicles as alternatives to snorkellers for video-based marine research. Journal of Experimental Marine Biology and Ecology 522: 151253.

Rapp, T., J. Hallermann, S. J. Cooke, S. K. Hetz, S. Wuertz, and R. Arlinghaus. 2012. Physiological and behavioural consequences of capture and retention in carp sacks on Common Carp (*Cyprinus carpio* L.), with implications for catch-and-release recreational fishing. Fisheries Research 125–126:57–68.

Reid, S. G., N. J. Bernier, and S. F. Perry. 1998. The adrenergic stress response in fish: control of catecholamine storage and release.

Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology 120:1–27.

Richard, A., L. Bernatchez, E. Valiquette, and M. Dionne. 2014. Telemetry reveals how catch and release affects prespawning migration in Atlantic Salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 71:1730–1739.

Roberts, R. J., H. Ball, A. Munro, and W. Shearer. 1971. Studies on ulcerative dermal necrosis of salmonids: III. The healing process in fish maintained under experimental conditions. Journal of Fish Biology 3:221–224.

Rodnick, K. J., and J. V. Planas. 2016. The stress and stress mitigation effects of exercise: cardiovascular, metabolic, and skeletal muscle adjustments. Pages 251–294 *in* C. B. Schreck, L. Tort, A. P. Farrell, and C. J. Brauner, editors. Fish physiology, volume 35: biology of stress in fish. Academic Press, London.

Rowe, R., and K. Esseltine. 2001. Post catch-and-release survival of Lake Nipissing Walleye during ice fishing. Ontario Ministry of Natural Resources, draft report, Toronto.

Rumball, E. 2020. A massive ice fishing festival has officially kicked off in South Korea. Mapped (January 20). Available: https://dailyhive.com/mapped/inje-ice-fishing-festival-south-korea/. (October 2020).

Scanlon, B. P., and B. D. Taras. 2005. An investigation of hooking mortality of Lake Trout angled through ice. Alaska Department of Fish and Game, Juneau.

Schisler, G. J., and E. P. Bergersen. 1996. Postrelease hooking mortality of Rainbow Trout caught on scented artificial baits. North American Journal of Fisheries Management 16:570–578.

Schramm, H. L. Jr., and J. G. Davis. 2006. Survival of Largemouth Bass from populations infected with largemouth bass virus and subjected to simulated tournament conditions. North American Journal of Fisheries Management 26:826–832.

Schramm, H. L. Jr., P. J. Haydt, and K. M. Portier. 1987. Evaluation of prerelease, postrelease, and total mortality, of Largemouth Bass caught during tournaments, in two Florida lakes. North American Journal of Fisheries Management 7:394–402.

Schreck, C. B., and L. Tort. 2016. The concept of stress in fish. Pages 1–34 *in* C. B. Schreck, L. Tort, A. P. Farrell, and C. J. Brauner, editors. Fish physiology, volume 35: biology of stress in fish. Academic Press, London.

Schreer, J. F., J. Gokey, and V. J. DeGhett. 2009. The incidence and consequences of barotrauma in fish in the St. Lawrence River. North American Journal of Fisheries Management 29:1707–1713.

Schwalme, K., and W. C. Mackay. 1985. The influence of exercise–handling stress on blood lactate, acid–base, and plasma glucose status of Northern Pike (*Esox lucius* L.). Canadian Journal of Zoology 63:1125–1129.

Sellers, I. 2003. Ice fishing gaining popularity in Utah County. The Daily Universe (January 15). Available: https://universe.byu.edu/2003/01/15/ice-fishing-gaining-popularity-in-utah-county/. (October 2020).

Siepker, M. J., K. G. Ostrand, S. J. Cooke, D. P. Philipp, and D. H. Wahl. 2007. A review of the effects of catch-and-release angling on black bass, *Micropterus* spp.: implications for conservation and management of populations. Fisheries Management and Ecology 14:91–101.

Skomal, G., E. Hoyos-Padilla, A. Kukulya, and R. Stokey. 2015. Subsurface observations of White Shark *Carcharodon carcharias* predatory behaviour using an autonomous underwater vehicle. Journal of Fish Biology 87:1293–1312.

Somers, C. M., U. Goncin, S. Hamilton, M. Chupik, and R. Fisher. 2021. Chasing Northern Pike under ice: long-distance movements following catch-and-release ice angling. North American Journal of Fisheries Management 41:1341–1350.

Stålhammar, M., T. Fränstam, J. Lindström, J. Höjesjö, R. Arlinghaus, and P. A. Nilsson. 2014. Effects of lure type, fish size and water temperature on hooking location and bleeding in Northern Pike (*Esox lucius*) angled in the Baltic Sea. Fisheries Research 157:164–169.

Suski, C. D., S. S. Killen, S. J. Cooke, J. D. Kieffer, D. P. Philipp, and B. L. Tufts. 2004. Physiological significance of the weigh-in during live-release angling tournaments for Largemouth Bass. Transactions of the American Fisheries Society 133:1291–1303.

Teffer, A. K., S. G. Hinch, K. M. Miller, D. A. Patterson, A. P. Farrell, S. J. Cooke, A. L. Bass, P. Szekeres, and F. Juanes. 2017. Capture severity, infectious disease processes and sex influence post-release mortality of Sockeye Salmon bycatch. Conservation Physiology 5:cox017.

Thompson, L. A., S. J. Cooke, M. R. Donaldson, K. C. Hanson, A. Gingerich, T. Klefoth, and R. Arlinghaus. 2008. Physiology, behavior, and survival of angled and air-exposed Largemouth Bass. North American Journal of Fisheries Management 28:1059–1068.

Thorstad, E. B., T. F. Næsje, and I. Leinan. 2007. Long-term effects of catch-and-release angling on ascending Atlantic Salmon during different stages of spawning migration. Fisheries Research 85:316–320.

Toivonen, A.-L., H. Appelblad, B. Bengtsson, P. Geertz-Hansen, G. Gudbergsson, D. Kristofersson, H. Kyrkjebø, S. Navrud, E. Roth, P. Tuunainen, and G. Weissglas. 2000. Economic value of recreational fisheries in the Nordic countries. Nordic Council of Ministers, Copenhagen, Denmark.

Twardek, W. M., R. J. Lennox, M. J. Lawrence, J. M. Logan, P. Szekeres, S. J. Cooke, K. Tremblay, G. E. Morgan, and A. J. Danylchuk. 2018. The postrelease survival of Walleyes following ice-angling on Lake Nipissing, Ontario. North American Journal of Fisheries Management 38:159–169.

van Assche, K., R. Beunen, J. Holm, and M. Lo. 2013. Social learning and innovation. Ice fishing communities on Lake Mille Lacs. Land Use Policy 34:233–242.

van Tamelen, P. G. 2005. Estimating handling mortality due to air exposure: development and application of thermal models for the Bering Sea snow crab fishery. Transactions of the American Fisheries Society 134:411–429.

Wang, Y., G. Heigenhauser, and C. M. Wood. 1994. Integrated responses to exhaustive exercise and recovery in Rainbow Trout white muscle: acid–base, phosphogen, carbohydrate, lipid, ammonia, fluid volume and electrolyte metabolism. Journal of Experimental Biology 195:227–258.

Warrenchuk, J. J., and T. C. Shirley. 2002. Estimated mortality of snow crabs *Chionoecetes opilio* discarded during the Bering Sea fishery in 1998. Alaska Fishery Research Bulletin 9:44–52.

Weltersbach, M. S., H. V. Strehlow, K. Ferter, T. Klefoth, M. de Graaf, and M. Dorow. 2018. Estimating and mitigating post-release mortality of European Eel by combining citizen science with a catch-and-release angling experiment. Fisheries Research 201:98–108.

Wendelaar Bonga, S. E. 1997. The stress response in fish. Physiological Reviews 77:591–625.

Wilkie, M. P., M. A. Brobbel, K. G. Davidson, L. Forsyth, and B. L. Tufts. 1997. Influences of temperature upon the postexercise physiology of Atlantic Salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 54:503–511.

Wilkie, M. P., K. Davidson, M. A. Brobbel, J. D. Kieffer, R. K. Booth, A. T. Bielak, and B. L. Tufts. 1996. Physiology and survival of wild Atlantic Salmon following angling in warm summer waters. Transactions of the American Fisheries Society 125:572–580.

Wood, C. M., J. D. Turner, and M. S. Graham. 1983. Why do fish die after severe exercise? Journal of Fish Biology 22:189–201.