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Best practices for catch-and-release recreational fisheries – angling tools and tactics

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ABSTRACT

Catch-and-release angling is an increasingly popular conservation strategy employed by anglers voluntarily or to comply with management regulations, but associated injuries, stress and behavioural impairment can cause post-release mortality or fitness impairments. Because the fate of released fish is primarily determined by angler behaviour, employing ‘best angling practices’ is critical for sustainable recreational fisheries. While basic tenants of best practices are well established, anglers employ a diversity of tactics for a range of fish species, thus it is important to balance science-based best practices with the realities of dynamic angler behaviour. Here we describe how certain tools and tactics can be integrated into recreational fishing practices to marry best angling practices with the realities of angling. While the effects of angling practices vary considerably across contexts and conditions, we also outline available methods for assessing fish condition by examining physical injuries and reflexes, which enable recreational anglers to make educated real-time decisions related to angling practices, as well as when, where, and whether to release captured fish based on their probability of survival. In cases where fish are in poor condition, there are recovery tactics available that can improve survival, although this is among the most understudied aspects of angling practices.

1. Introduction

Recreational fishing is highly popular worldwide (Cooke and Cowx, 2004; Arlinghaus and Cooke, 2009; Arlinghaus et al., *In Press*), and a dominant use of many fish stocks (Arlinghaus et al., 2002; Coleman et al., 2004; FAO, 2012). While recreational fisheries were traditionally harvest-dominated (Arlinghaus et al., 2007), catch-and-release (C&R) has become a major practice in many developed countries (Cowx, 2002; Brownscombe et al., 2014a), and is increasingly popular in developing countries and emerging economies (FAO, 2012; Freire et al., 2012). C&R angling is a management and conservation strategy that assumes a large proportion of released fish survive and experience limited fitness consequences (Wydoski, 1977). However, fishing-related stressors (hooking, handling, exhaustive physical exercise, air exposure) often elicit physiological disturbances, physical injuries, and behavioural impairments that can lead to immediate or delayed mortality or reduced fitness (Davis, 2002; Arlinghaus et al., 2007; Cooke and Schramm, 2007). It is therefore essential to understand the mechanisms that contribute to these negative effects and outcomes for individual fish (Cooke and Sneddon, 2007), and provide anglers with tools and methods to develop conservation- and welfare-minded practices to ensure the sustainability of recreational fisheries.

The fate of an angled fish upon release is primarily determined by angler behaviour (e.g., gear selection, handling time, admiration period) and therefore adopting certain angling practices can improve fish survival and reduce fitness consequences. While much research has gone into developing ‘best angling practices’ for recreational angling (reviewed in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Pelletier et al., 2007), the fate of released fish is the result of complex interactions between aspects of the angling process (e.g., gear types), environmental (e.g., water temperature, water chemistry) and ecological (e.g., predator burden, disease) conditions, and the characteristics of the species/population/individual being angled. Not surprisingly, generating a simple set of best practices for anglers to minimize their impacts on released fish is challenging.

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Further, assessments of the effects of various angling practices are currently limited to certain species, regions, and ecosystems, primarily in North America, Europe, and Australia (Arlinghaus et al., 2007; Pelletier et al., 2007). Nonetheless, there are best angling practices that apply generally across all species; for example, types of terminal tackle, air exposure times, and water temperatures have significant impacts on stress, injury, and mortality in angled fish (Cooke and Suski, 2005; Bartholomew and Bohnsack, 2005; Pelletier et al., 2007).

These basic tenants for maximizing survival and welfare of angled fish are effective, but must be balanced with the realities of angler priorities and behaviours. For example, anglers aim to capture fish as effectively as possible, and the lures that minimize hooking injury are not always conducive with catching the most fish (e.g., barbed vs. barbless hooks). Anglers often admire the fish they catch, measure their weight and/or length, and take pictures or video, which typically involve air exposure. Despite this, C&R fishing by specialized anglers (i.e., those who specifically target one species using specialized gear) generally results in the lowest rates of post-release mortality (<5%; Policansky, 2002), which supports the notion that when anglers are prepared with the appropriate tools and tactics to effectively C&R fish, negative impacts can be minimized. Generally, the most stressful and negatively impactful angling events are often a result of the angler being unprepared, both in tools and tactics (including knowledge and experience in effective angling practices) to effectively hook, land, unhook, document/admire, and release captured fish with minimal stress and injury (recognizing that it is impossible to capture a fish without causing some level of injury and stress; Cooke and Sneddon, 2007).

Once fish are captured, anglers must decide what to do with their catch, which depending on regulations, could be either harvested for consumption or released. In some cases it might be advantageous to release the fish immediately while in other situations it may be beneficial to retain fish for a short period prior to release to allow time to recover (e.g., in ecosystems with high predator burden or fast water flow; Brownscombe et al., 2013; Donaldson et al., 2013). The appropriate course of action ultimately depends on fish condition and probability of survival; therefore the ability of anglers to assess fish condition plays a key role in this context. However, to date few systematic methods for assessing fish condition are prevalent in angling culture. Development of such tools started in the context of commercial fisheries with injury scores and reflex tests (e.g., Davis and Ottmar, 2006; Davis, 2010), and recent research has started applying them to recreational angling scenarios (Diamond and Campbell, 2009; Brownscombe et al., 2013, 2014b; Cooke et al., 2014; Danylchuk et al., 2014). As these methods continue to develop, they should provide anglers with the ability to assess fish condition, make educated decisions on the likely fate of their catch, and modify their behaviour in real time.

The sustainability of C&R angling hinges upon angler attitude and behaviour, which can have a major effect on fish condition upon release. While traditionally angler interests can be at odds with fish welfare (e.g., admiring fish in air), increasingly specialized and conservation-minded anglers are showing that using certain tools and tactics can minimize the negative impacts of angling in C&R fisheries. When the decision is to release fish, anglers should consider that their actions are inherently conservation oriented, that is, the intention is to allow the fish to survive. Indifferent attitudes toward conservation and subsequent action or inaction by the angler can have profound consequences for the fitness of their catch. Here, we summarize available angling tools and tactics that can be employed by anglers to minimize impacts on fish and play a key role in sustainable recreational fisheries. We also outline methods for assessing fish condition prior to release. In instances where there is an onus to release impaired fish, recovery tactics exist that may alleviate negative fitness consequences.

2. Tools and tactics for minimizing impacts of catch-and-release angling

Various tools and related tactics can reduce negative impacts of the angling process (Fig. 1), which may include terminal tackle (e.g., hook types), retrieval tools (e.g., rods, reels, fishing line), landing gear (e.g., nets), unhooking tools (e.g., pliers, spreaders), documentation tools (e.g., weighing scales), and holding/recovery gear (e.g., livewells, recovery bags). When used correctly, fight times, air exposure, handling, physiological stress, and physical injury can all be reduced, ultimately resulting in improved fish survival and fitness if the fish is to be released.

2.1. Hooking

Lure and hook types are one of the most important choices for recreational anglers given that they greatly influence catch rates (Cooke et al., 2012), and hooking injury is considered the primary cause of angling-related mortality (reviewed and synthesized by Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Cooke and Wilde, 2007; Pelletier et al., 2007; Huehn and Arlinghaus, 2011). The general intention when angling is to hook the anterior portion of the mouth near the lips, comprised of bone, cartilage, skin and some muscle (amount varies among species). Evidence suggests hooking injury in these cases typically results in little more than a small puncture wound; however, fish may also be unintentionally hooked in more sensitive tissues (i.e., esophagus, stomach, gills, eyes, or body) causing physical damage and bleeding that may lead to mortality (Pelzman, 1978; Lyle et al., 2007; Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005). Furthermore, terminal tackle also influences the difficulty of unhooking the fish prior to release, which can result in increased air exposure and handling, particularly for inexperienced anglers (see *Unhooking* below).

The degree of hooking-related injury and unhooking stress is determined by a complex interaction among many factors including fish species, fish size, water temperature, lure type, hook type and configuration, angling tactics, and angler experience (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Arlinghaus et al., 2007; Cooke and Wilde, 2007; Huehn and Arlinghaus, 2011). There is also an enormous range of lure types available to recreational anglers, which can be broadly categorized into organic baits (i.e., live or dead invertebrates or vertebrates or other organic baits like dough or corn), soft baits (e.g., soft plastic jigs or worms), hard baits (e.g., plastic, wooden, or metal plugs, crankbaits, stickbaits, spinners, spoons, pilks, or poppers) and flies (i.e., natural or artificial fibers tied to a hook). Each of these lure or bait types can be outfitted with a range of hook types and sizes. Typical hook types include traditional J-shaped, octopus, or circle hooks, which can take the form of single, double, or treble hooks, and each can have variable gap lengths (length of bend portion of the hook relative to the shank) or be offset (angle of bend in relation to hook shank) to varying degrees. Hooks may also be 'appendaged'; a short wire extends the hook toward the posterior portion of the lure.

Lure and hook choice are a key factor that can be adjusted and even regulated (e.g., restrictions on various hook types or bait types) to meet conservation goals. Generally, using fewer (i.e., overall number or single instead of treble) hooks of appropriate size for the target species effectively reduces physical injury and unhooking times (Muoneke and Childress, 1994). Hook size is considered a critical factor affecting hooking depth and injury (Wilde et al., 2003; Alós, 2008). Barbless hooks reduce injury and unhooking times, and

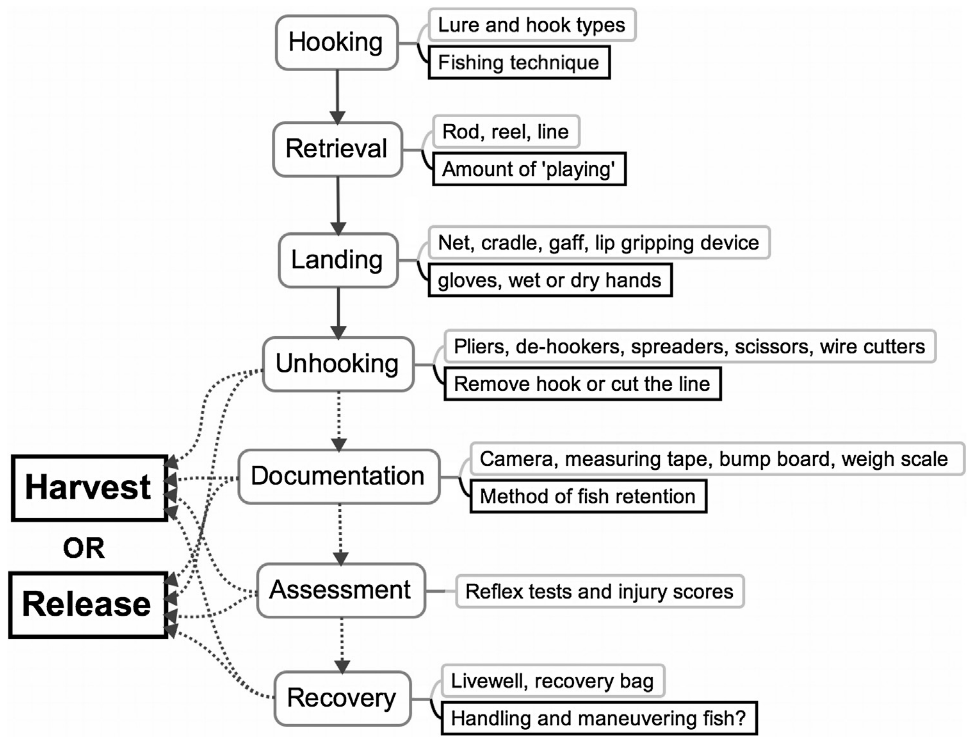

Fig. 1. Conceptual diagram of potential stages of a recreational angling event (from Hooking to Recovery) including considerations (angler choices) on angling tools (grey boxes), and tactics (black boxes), ultimately resulting in either the harvest or release of the captured fish. Solid connectors represent obligatory steps; dotted lines indicate potential steps dependent on angler choices.

hence are made mandatory in many C&R fisheries; however, there is little evidence that barbless hooks reduce mortality (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005). Circle or octopus hooks also typically reduce incidences of hooking injury over traditional J-style or treble hooks, particularly when using natural or soft baits (Siewert and Cave 1990; Cooke et al., 2001; Prince et al., 2002; Cooke and Suski 2004). Bergmann et al. (2014) found that appendaged circle hooks also reduced deep hooking, while simultaneously increasing hooking success for black sea bass (*Centropristis striata*). Appendaged hooks might be a very effective method for reducing deep hooking in species that are particularly vulnerable (e.g., *Lutjanus* and *Pagrus* spp.) without compromising hooking success, although more research is required. Another hook variation, offset circle hooks, have generally been found less effective than non-offset circle hooks at reducing hooking-related injury, and increase capture rates in some instances but not others (Prince et al., 2002; Cooke and Suski 2004; Ostrand et al., 2005). ‘Wide gap’ hooks also resulted in low hooking injury in the few studies that have tested them (Cooke et al., 2003; Lennox et al., 2015a,b). In fact, Lennox et al. (2015b) found that they resulted in no deep hooking in fat snook (*Centropomus parallelus*), even when fishing passively with bobbers and organic bait, which typically result in high rates of deep hooking.

Using natural baits tends to increase hooking injury over artificial baits as do soft plastics compared to harder baits such as spinners, plugs, or crankbaits (Schisler and Bergersen 1996; Diggles and Ernst 1997; Stålhammar et al., 2014). In particular, fishing with organic bait and J-style hooks can be injurious to fish (e.g., Margenau 2007). However, there are certainly discrepancies; for example, Mandelman et al. (2014) found jigging spoons with treble hooks caused greater injury and mortality than organic bait on J-hooks in Atlantic cod (*Gadus morhua*). Dunmall et al. (2001) found that scented soft plastic lures treated with chemical fish attractants did not increase incidences of deep hooking over unscented baits in smallmouth bass. Likely masking the effect of lure type is lure and hook size, where smaller lures and hooks generally increase incidence of deep hooking (Wilde et al., 2003; Alós, 2008). This could explain why in some cases single hooks are actually more likely to deep hook fish than treble hooks (Muoneke and Childress, 1994), or why fishing with flies can result in deeper hooking than soft plastics (Stålhammar et al., 2014). Indeed, lure size may be the primary factor influencing hooking injury in recreational fisheries. Importantly, hook size also influences hooking efficacy in many species (Cooke et al., 2005; Alós, 2008). Larger lures often decrease catch rates, particularly of smaller fish; each fish species (or perhaps even population or age class) likely has an ideal lure size that balances the probability of capture success and hooking injury.

Angling tactics also play an important role in avoiding hooking injury. Passive fishing methods (e.g., bobbers or drifting bait) often enable fish to consume the bait more deeply prior to the hook set and result in greater incidences of deep hooking (Schisler and Bergersen, 1996; Grixti et al., 2007; Alós, 2009; Lennox et al., 2015a,b). These methods also tend to use natural or soft plastic baits, which also lead to greater hooking injury. Angler experience level is also a highly relevant and underappreciated factor in the condition and fate of angled fish. For example, Meka (2004) found that novice anglers injured significantly more rainbow trout during the angling process, but attributed this to the unhooking process (see *Unhooking* below). Interestingly, Dunmall et al. (2001) found that experienced anglers actually have higher incidences of deep hooking than novice anglers when using scented soft plastic lures for smallmouth bass (*Micropterus dolomieu*). Presumably this is related to the fact that experienced anglers have learned that delaying the hook set increases capture rates.

In an ideal C&R fishery, anglers would use the least harmful lure type (e.g., artificial lures with minimal, appropriately sized, barbless hooks fished actively). However, in many cases the ideal lure or bait type for fish welfare does not agree with the most effective way for catching fish. For example, organic baits and J-style hooks are often the most effective angling methods, but also lead to deep hooking (Schaeffer and Hoffman, 2002). Further, while circle hooks generally minimize hooking injury, there are some scenarios where hooking efficacy or landing rates are reduced, or injury rates are similar to other hook types (Meka, 2004; Ostrand et al., 2006; Cooke et al., 2012; Sullivan et al., 2013). Using circle hooks also requires anglers to learn a slightly different technique for setting the hook, which could influence the adoption of this hook type. While the efficacy of hook types at minimizing fish injury and stress has been tested in many studies (Reviewed in Cooke and Suski, 2005), fish species have a wide diversity of mouth morphology and dentition, and there are numerous combinations of hook sizes and shapes that may be tested to this end. While the effects of lure and hook types have been the focus of the majority of recreational angling research, much more can be done to determine optimal terminal tackle for the vast diversity of species targeted by recreational anglers around the world. The reality is that hooking injury is the result of complex interactions among fish species, fish size, water temperature, angling tactics, and angler experience. It is important to recognize the complex, dynamic nature of hooking injury, and that ideal fishing methods may not always be realized in practice. To be adaptive with management and angling strategies, some potentially important tools are fish condition assessment methods, which anglers can use to adapt their tactics and managers can use to attain estimates of hooking mortality (see **Assessing fish condition** below).

2.2. Retrieval

Once hooked, fish are retrieved using angling gear including fishing rods, reels, and line. During this period between hooking and landing, also termed 'the fight' where anglers 'play' the fish, during which the fish resist capture through burst swimming and anaerobic exercise (Kieffer, 2000). The duration of the fight often correlates with physiological stress levels post-capture (Gustaveson et al., 1991; Skomal, 2007; Suski et al., 2007; Sepulchro et al., 2012). In addition, fish may become in contact or entangled in line or become hooked by additional hooks on the lure during retrieval, causing injury (Colotelo and Cooke, 2011; Stokesbury et al., 2011). Thus it is recommended that anglers use retrieval gear of appropriate strength to minimize fight times (Cooke and Suski, 2005). There is a large range in strengths of retrieval gear (fishing rods, reels, and line) available to anglers that are developed to target certain fish species based on their size and fighting abilities. However, the reality is that non-target species are hooked in almost all aquatic ecosystems and if gear is too light for the non-target species, fish may experience a prolonged fight. For example, an angler targeting black bass with ultra-light gear could potentially hook a trophy muskellunge (*Esox masquinongy*). In some specialized fisheries, minimum gear strength requirements are enforced to avoid prolonged fights; this tactic could be applied more widely in a variety of fisheries.

While experimental evidence shows that longer retrieval durations increases physiological stress responses of angled fish, many studies using appropriate retrieval gear for the target species have found little correlation between retrieval time and fish condition. For example, while Gustaveson et al. (1991) showed in experimental simulations that longer angling times (up to 5 min) caused significantly greater physiological stress in largemouth bass (*Micropterus salmoides*), in real angling scenarios, Brownscombe et al. (2014c) found no association between physiological stress or reflex impairment with retrieval times or total fish fight intensity in this species using typical largemouth bass angling gear (medium strength rods and 7 kg break strength line). Other studies have had similar findings using typical gear for the target species in both freshwater and marine species (Landsman et al., 2011; Thorstad et al., 2003; Danylchuk et al., 2007; Danylchuk et al., 2011). Conversely, retrieval duration appears to be a more important

Fig. 2. Anglers using a rubberized landing net to hold a largemouth bass in water during the unhooking process.

factor in larger fish species with extended fight times (e.g., exceeding 20 min), for e.g., sharks, tunas, and billfishes (Skomal, 2007). While the relationships between retrieval duration and physiological stress is unclear, the reality is that stress responses by fish are the result of complex factors (i.e., water temperature, fish species, size), and to our knowledge, no study has been able to untangle these effects because of their interactions. For example, large fish consistently have longer fight times and fight more intensely (Meka and McCormick, 2005; Brownscombe et al., 2014c). While more research needs to be done on optimal retrieval speeds for small target species (e.g., black bass), anglers that target large species should use appropriately robust gear while considering that for a given species and the environmental conditions from which it can be angled, long retrievals in high water temperatures may result in greater anaerobic respiration, physiological stress, and lengthier recovery times.

2.3. Landing

'Landing' fish, referred broadly here as bringing fish into a boat, on land, or simply handling fish in water, is a critical aspect of angling because it can lead to air exposure, as well as physical injury from contact with the landing device, the handler, or other abrasive surfaces (e.g., bottom of boat, shore). A key consideration during the landing process is minimizing air exposure by keeping fish in water as much as possible. This can often be accomplished by using a large (relative to target species) landing net, or fish cradle (Figs. 1 and 2; Barthel et al., 2003) although this can be accomplished by hand depending on the extent to which the fish is exhausted from the fight and the ability to restrain fish in the water (e.g., some fish are too large or have dentition that influences their ability to be restrained easily). Appropriately sized holding vessels not only increase the probability of effectively landing a hooked fish, but may also serve as a vessel for retaining the fish, submerged in water, for a short period while other tools are prepared for unhooking, measurement, and/or picture taking/admiration (Fig. 2). By doing so, anglers can reduce air exposure times, which is critical to the survival of the fish. Important considerations for landing vessels are size and material, because they must be large enough to retain the fish comfortably (ideally not contorted) for a short period. While all net types cause some epithelial damage, rubber nets seem to minimize these impacts (Barthel et al., 2003; Colotelo and Cooke, 2011). For larger fish, cradles are also popular holding vessels, which may serve a similar purpose to nets if air exposure and slime loss/abrasion are minimized by use of knotless nylon or rubberized netting materials. In some fisheries (i.e., large species; billfish, sharks) landing is not advisable if fish are to be released due to their large size, so all releases should occur at the side of the boat. In fisheries such as wading the flats for bonefish (*Albula* spp.) or rivers for salmonids, anglers typically do not 'land' fish in traditional ways, but simply handle the fish in water to unhook them. In some cases anglers will use lip gripping devices or gaffs to land fish; this is generally not advisable if fish are to be released because these devices often cause injury (Danylchuk et al., 2008; Gould and Grace, 2009).

2.4. Handling

Fish are typically handled to some degree during landing, unhooking, and documentation/admiration prior to release, which cause slime loss that may lead to fungal infections and mortality (Steeger et al., 1994; Barthel et al., 2003; Colotelo and Cooke, 2011). Physical injuries can also occur to internal organs or vertebrae from the weight of the fish's body when held in air (Gould and Grace, 2009). While many anglers believe handling fish with gloves is an effective mitigation tactic, few scientific studies have addressed this issue, and none we are aware of have shown they reduce slime loss over bare hands. In fact, Murchie et al. (2009) found slime loss was similar between bare and gloved hands. However, Hannan et al. (2015) showed that sunscreen-coated hands cause significantly greater fungal infections than wet hands when handling bonefish. Clean, wet hands or non-abrasive gloves both likely serve well for handling fish.

Fish lacking sharp teeth (e.g., black basses) can be secured by the lip between the thumb and forefinger, although it is important to support the fish's body with the other hand to avoid damage to the jaw or vertebrae. Gould and Grace (2009) showed that barramundi (*Lates calcarifer*), a larger-bodied fish species, hung vertically by lip gripping devices had misaligned vertebrae. Handling and air exposure should always be minimized, and ideally, fish can be unhooked while held submerged in water (e.g., contained within a landing net or livewell; see *Landing* above; Fig. 2; Landsman et al., 2011).

Mechanical lip-gripping devices have recently emerged on the market as a method for handling and weighing fish. Anglers should exercise caution when using these devices, particularly on fish with more fragile mouths. Danylchuk et al. (2008) showed mechanical gripping devices cause significant physical damage to mouth structures in bonefish, including injuries as severe as broken jaws and separation of the tongue from the floor of the mouth. While all of these fish survived 48 h post-release, their ability to forage would undoubtedly be compromised, likely resulting in delayed mortality or reduced long-term fitness. Gould and Grace (2009) found these devices caused more minor injuries in barramundi. Intuitively, mechanical gripping devices likely cause less damage to species with strong, bony mouths such as tigerfish (*Hydrocynus vittatus*), although goliath tigerfish (*Hydrocynus goliath*) reach large sizes >60 kg, and hanging from the jaw may damage mouth structures or vertebrae. Clearly, more research should be conducted to understand the effects of lip gripping devices on fish condition across species of different size and with different dentition and mouth anatomy.

2.5. Unhooking

The process of hook removal is also a crucial aspect of angling because it greatly influences hooking and handling-related injuries, as well as air exposure times (Barthel et al., 2003; Cooke and Sneddon, 2007). Pliers or specially designed unhooking devices are often essential for quickly removing hooks from fish tissue (to reduce handling time) and with minimal damage. These tools are especially useful for unhooking fish species with sharp teeth or bony mouth parts (e.g., muskellunge, tigerfish, dorado *Salminus brasiliensis*, or great barracuda *Sphyraena barracuda*), and generally in instances where fish are hooked deep in the mouth. However, if fish are hooked in sensitive tissues (most commonly the esophagus), cutting the hook or line and leaving the hook in the tissue often results in less injury, physiological disturbance, and greater survival than hook removal (Mason and Hunt, 1967; Warner, 1979; Fobert et al., 2009). For example, Fobert et al. (2009) found that removing the hook from the esophagus of bluegill (*Lepomis macrochirus*) resulted in 40% mortality (corrected for controls) after 48 h, while cutting the line only resulted in 9% mortality, and 46% of these deeply hooked fish were able to expel the hook within 48 h. Indeed, many studies suggest fish are capable of expelling hooks fairly rapidly (Schill, 1996; Diggles and Ernst, 1997; Aalbers et al., 2004; Tsuboi et al., 2006; DuBois and Pleski, 2007). The relative fitness consequences (i.e., ability to feed, grow, reproduce, avoid predators) of this practice are not well understood (but see Pullen, 2013). While not widely tested across species, there is strong evidence that cutting the line and leaving the hook imbedded in the tissue increases survival over hook removal. However, recent advances in hook materials (e.g., tungsten, high carbon steel) likely delay corrosion times and may render this method less effective. During unhooking, fish can be retained in water (Fig. 2), to avoid air exposure that causes physiological stress.

As in all aspects of fishing, angler experience plays a role in whether fish are injured when being unhooked. For example, Meka (2004) found that novice anglers injured significantly more rainbow trout, and attributed this to the unhooking process. Newman et al. (1986) found that novice anglers took significantly longer to unhook angled muskellunge than experienced anglers. It is intuitive that less experienced anglers would be less effective at removing hooks quickly and without injuring fish, likely due to a combination of a lack of knowledge and motor skills for the procedure. While there is no substitute for experience, angler education is a primary mechanism by which effective angling practices can be implemented.

2.6. Fish measurement and documentation

Once landed and unhooked, anglers typically measure (i.e., length or weight) and document (i.e., take pictures) fish, which has the potential to induce air exposure and handling related injuries (see *Handling* above). Measurement and documentation is most prevalent when larger fish are captured. Given that large individuals are disproportionately important for stock recruitment due to their high reproductive output, it is particularly important to minimize angling impacts if these fish are to be released (Shiffman et al., 2014). Similar to the hook removal processes (see *Unhooking* above), length measurements can be conducted with the fish submerged in water (i.e., in a livewell or landing net) to minimize air exposure. For length measurements, the handles of many fish cradles often include a ruler to facilitate length measurement with the fish wholly or partly submerged. Alternatively, bump boards are useful because they provide a rigid structure for restraining fish for quick measurement and minimized handling.

Weighing fish is a well-established tradition in angling culture as a standardized method for quantifying catch size (Arlinghaus et al., 2007). Traditional weighing protocols typically involve hanging fish vertically from a scale using a large hook or gripping device slung by the base of the operculum or lower lip. This process can be detrimental to fish health because it is potentially damaging to gills or mouth structures (Danylchuk et al., 2008), while hanging fish vertically may damage internal organs and vertebrae, tear opercular tissue, while also involving air exposure (see *Handling* above). For this reason, there is currently a movement toward changing standard fish measurements from weight to length (Shiffman et al.,

Fig. 3. Anglers using a landing net to weigh a fish, minimizing weighing injury and stress.

2014). As research continues to develop species-specific length-weight ratios, anglers can still attain estimates of the weight of their fish without actually weighing it. However, one conservation-minded method of weighing fish is using a landing net or similar vessel (Fig. 3). Anglers can weigh fish within landing nets by gripping the top of the net instead of the fish, and simply tare the scale to the weight of the net to get actual fish weight. Using this method, physical damage related to the weighing process can be reduced to that of net abrasion, which is already present if the fish is landed and retained in such a vessel. Further, the chance of fish falling onto abrasive surfaces is minimized, as is the potential for air exposure.

Taking pictures of captured fish typically involves handling and air exposure, and is most common with larger fish. Retaining fish in water (e.g., in a landing net or livewell) while preparing for pictures is important for minimizing air exposure. It is common practice in specialized common carp (*Cyprinus carpio* L.) fisheries to use a 'carp sack', a knotless cloth bag, to retain fish prior to photographing. Rapp et al. (2012) found this practice does increase physiological stress in common carp, and longer retention periods resulted in greater external injuries (fin abrasion), although no mortality was observed. In some cases, gear marketed to anglers as fish care tools may not necessarily be beneficial for the fish, especially when unnecessary handling or retention are involved. Generally, minimizing fish handling and retention times is advisable, with priority given to reducing fish air exposure. Realistically, picture taking can involve only a brief moment of air exposure for the picture before returning fish to water.

2.7. Release

The release, where fish are transferred from an angler's possession back into the water, represents a crucial transitional period. Released fish are often stressed to some degree and disoriented after becoming displaced from familiar habitat, and must reorient themselves back into their environment while avoiding opportunistic predators. Fish condition is an important consideration for anglers to take appropriate courses of action upon release (see **Assessing fish condition** below). In most cases, when best angling practices are being exercised, fish will experience limited physiological stress and behavioural impairment, so releasing fish as soon as possible with minimal handling and air exposure is the best course of action. In cases where fish are, for example, unable to maintain an upright orientation, anglers can apply the appropriate recovery tactic(s) to maximize the chances of post-release survival (see **Recovery tools and tactics** below). There is also the decision of where to release fish back into the environment. It is intuitive to release fish at the same location of capture, or at minimum a similar habitat. Certain situations can make release challenging and stressful for fish (e.g., fishing from shore with large break waves or off of a tall bridge). If practicing C&R, anglers should think ahead about how fish will be released with minimal harm.

3. Assessing fish condition

Given how much fish condition and survival vary across conditions and fishing practices, the ability to assess fish condition prior to release has important applications for adjusting angling practices or deciding the fate of a captured fish based on its probability of survival. While fish vitality is largely based on physiological condition, which is difficult to assess without invasive procedures (e.g., phlebotomy) and specialized equipment, there are external indicators that reflect fish vitality. For example, if a fish is hooked in more sensitive tissue (e.g., esophagus or stomach) causing damage and bleeding, it is less likely to survive (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005). If a fish has lost its ability to maintain upright orientation, or does not respond to handling, this reflects underlying physiological condition that may lead to post-release mortality (Davis and Ottmar, 2006; Davis, 2007, 2010; Raby et al., 2012; Brownscombe et al., 2013). While some of these indicators are intuitive and used by anglers, there has yet to be a systematic framework developed for assessing fish condition after capture by recreational angling. By examining physical injuries and reflexes, recreational anglers can make educated decisions relating to angling practices, as well as when, where, and whether to release captured fish based on their probability of survival.

3.1. Physical injury indicators

Physical injuries are well-established predictors of mortality in all types of fisheries (Muoneke and Childress, 1994; Chopin and Arimoto, 1995; Cooke and Suski, 2005). In recreational fisheries, 'deep hooking', where the hook(s) enter deeply into the fishes mouth, hooking the esophagus, stomach, or gills, is recognized as the predominant cause of mortality for many species (see *Hooking* above; reviewed by Muoneke and Childress, 1994; Cooke and Suski, 2005). Recent research also found that hooking in the bahsiyal (tongue) was highly correlated with post-release mortality in lemon sharks (*Negaprion brevirostris*; Danylchuk et al., 2014). Generally, deeply hooked fish have a significantly lower probability of survival than those hooked closer to the lips, although cutting the hook or line results in significantly reduced mortality compared to removing the hook (see *Unhooking* above). Regardless, if anglers are fishing to harvest, it is advisable to keep deeply hooked individuals over individuals with lesser hooking injuries if regulations permit. If deep hooking rates are high and the intention is to catch-and-release, anglers can adjust their tactics, for example, lure and hook types and sizes (see *Hooking* above) to reduce hooking injury and mortality.

While most studies have focused on hooking injuries, angled fish may also experience epithelial damage due to line rolling while on the hook, contact with abrasive surfaces such as landing nets, the substrate (e.g., sand beach or rocks) boat surfaces (e.g., carpets), handling during unhooking, or contact with retention devices such as livewells, which can lead to fungal, bacterial, or viral infections, and mortality (Plumb et al., 1988; Steeger et al., 1994; Barthel et al., 2003; Colotelo and Cooke, 2011). While these injuries are clearly detrimental to fish health and should be avoided, the relative contribution of these types of injuries to fish survival and fitness remains poorly understood. This is likely because external

Fig. 4. Anglers testing reflex impairment using equilibrium (left; inverting fish to observe its ability to regain upright orientation) with a dorado, photo credit: Francisco Mariani, tail grab (top right; grabbing the tail to test for a swimming escape response) with a permit (*Trachinotus falcatus*), photo credit: Tyler Gagne, VOR (bottom right; Vestibular-Ocular Response; rolling the fish side to side watching for eye movement) with a northern pike (*Esox lucius*), photo credit: William Nalley.

damage from net abrasion, for example, is more minor than a hooking injury to the esophagus, and so while fish typically survive short term from these minor external injuries, longer-term fitness effects are substantially more challenging to quantify.

When fish are captured from greater water depths, they experience a change in pressure that can cause physical damage. For physoclistous fishes (species lacking a duct between their swim bladder and alimentary tract) rapid ascent from depth causes gasses within the swim bladder to expand rapidly, potentially causing small tears in the swim bladder that allows gasses to enter the viscera and cranium, resulting in a condition known as barotrauma (Gotshall, 1964). Fish suffering from barotrauma may become positively buoyant and struggle to return to depth, inhibiting dispersion and leaving fish vulnerable to surface predation, light exposure, and high temperatures (Collins, 1996; Bruesewitz et al., 1993; Nguyen et al., 2009; McLennan et al., 2014). Anglers can assess barotrauma visually by noting a bulging of the body cavity, prolapsed alimentary tract either from the buccal cavity or anus, exopthalmia, cutaneous hemorrhaging, and/or excessive bouyancy (Gotshall, 1964; Feathers and Knable, 1983; Butcher et al., 2013; McLennan et al., 2014; Ferter et al., 2015). Internally, tears in the swim bladder and hemorrhaging of circulatory components are common and can result in immediate mortality depending on severity (Casillas et al., 1975; Feathers and Knable, 1983; Rummer and Bennett, 2005). Barotrauma is most likely to occur when anglers are targeting fish >30 m in depth (e.g., pink snapper, McLennan et al., 2014), however it can occur in as little as 5 m of water depending on the susceptibility of the target species (e.g., smallmouth bass; Morrissey et al., 2005). In many species, the greater the pressure differential upon capture (i.e., the deeper the fish within its range), the greater the likelihood of observable signs of barotrauma and post-release mortality. For example, both internal and external symptoms of barotrauma were significantly related to capture depth in Atlantic cod *Gadus morhua* (Ferter et al., 2015). Red snapper *Lutjanus campechanus* demonstrated a consistent positive correlation between capture depth and probability of post-release mortality (Campbell et al., 2014), and survival was low for canary rockfish captured at depths >75 m and declined acutely >135 m (Hannah et al., 2014). It is important to note that slow retrieval speed does not dampen the effects of barotrauma, though this is widely believed in the sport fishing community (Butcher et al., 2012).

Observable symptoms of barotrauma can be a strong indicator of fish condition and mortality risk. As surface condition was found to be predictive of delayed mortality in red snapper (Diamond and Campbell, 2009), Campbell et al. (2009) developed a systematic method for quantifying the presence and degree of barotrauma symptoms termed Barotrauma Reflex (BtR). These measures have only been developed and tested on red snapper and require a species-specific approach as not all fishes exhibit barotrauma symptoms that predict mortality (e.g., rockfish species, Jarvis and Lowe, 2008; Hannah et al., 2014). Proper diagnosis and a species-specific approach are crucial for ensuring high post-release survival in deep-water fishes – misdiagnoses can lead to fish being released without appropriate treatment, or treatment occurring when it is unnecessary (Butcher et al., 2012). Details on effective techniques anglers can use to mitigate barotrauma are detailed below (see Section 4.3).

3.2. Reflex impairment indicators

Physical injuries are important external indicators of fish vitality, but they often fail to capture the internal physiological stress that can occur independent of injury (e.g., long fight or air exposure times). Physiological stress metrics (e.g., blood lactate, glucose, ionic concentrations) alone commonly fail to predict mortality, likely due to the complexities of physiological responses, our abilities to measure them, and diverse combinations of stressors (Wood et al., 1983; Davis, 2002). Although measuring the physiological condition of a fish is unfeasible for recreational anglers, fish reflexes – involuntary motor responses to external stimuli that are consistently present unless physiologically impaired – are a suitable alternative for assessing impairment (Davis, 2010). For fish, these include responses such as self-righting when inverted and moving its eyes to track level when rotated. Reflex tests have been validated as highly predictive measures of mortality in many fisheries scenarios (Clark et al., 1992; Williams and Wilderbuer, 1995; Davis and Ottmar, 2006; Davis, 2007, 2010; Raby et al., 2012), post-release behavioural impairment (Cooke et al., 2014; Brownscombe et al., 2013, 2014b), and physiological stress (G.D. Raby, unpublished data), however, the congruency of reflexes and physiological stress indices is more tenuous (ICES, 2000; Parker et al., 2003; Davis and Schreck, 2005).

The use of reflex impairment (RI) indicators to assess the condition of captured fish began in commercial fisheries bycatch, primarily under the codification 'reflex action mortality predictors' (RAMP; Davis and Ottmar, 2006; Davis, 2007). Commercial fishery stressors are similar in many ways to recreational, and may include physical damage due to net abrasion, strenuous physical exercise, and air exposure during netting procedures (Chopin and Arimoto, 1995). Many RIs (~20) have been tested in this context ranging from less invasive measures such as an escape response to tail grabbing, to more involved assessments such as restraining fish to measure body flexing response to a stimulus, or using instruments to probe the esophagus and measure gag reflexes (Davis and Ottmar, 2006; Davis, 2010; Depestele et al., 2014). Traditionally RI tests have been used as a cumulative condition score, based on the proportion of reflexes that are impaired (0 = no impairment, 1 = full). For example, Davis and Ottmar (2006) and Davis (2007) identified critical RAMP score thresholds where a number of north Pacific Ocean fish species were significantly more likely to experience immediate or delayed mortality with a high level of consistency.

Given there are many similarities between commercial and recreational fishing stressors (e.g., exhaustive physical exercise, air exposure), the knowledge gained from testing commercially captured fish is highly transferable to recreational fisheries, and recent studies have begun to validate RI tests specifically in this context (e.g., Cooke et al., 2014; Brownscombe et al., 2013, 2014a,b; Danylchuk et al., 2014; McArley and Herbert, 2014; Lennox et al., 2015a,b). These studies have focused mainly on a subset of reflex tests that are likely most valuable for assessing fish condition, and practical for recreational anglers to adopt (Table 1; Fig. 4). While pioneering recreational fisheries-oriented studies have used primarily sub-lethal endpoints involving physiology and behaviour, fish reflex responses have been very consistent with those in commercial fisheries studies. Perhaps one of the greatest barriers for adopting reflex tests by recreational anglers is the time commitment and practicality of conducting a range of reflex tests. Fortunately, individual RI measures are useful indicators in themselves, with consistent between-predictor patterns in their order of impairment across many contexts.

In a gradient from good to poor condition (high to low probability of survival), RI tests tail grab and body flex are typically the first to become impaired, and indicate lower levels of impairment than others (Fig. 5; Table 1; Davis, 2010; Raby et al., 2012; Brownscombe et al., 2013, 2014b). These impairments alone are not totally indicative of delayed mortality due to physiological stress alone, but they do assess the escape response of the fish to an approaching threat, and are likely indicative of the fishes ability to avoid predators (Brownscombe et al., 2013, 2014b), which is ecologically relevant, particularly in environments where predation risk is high (e.g., in bonefish in shallow, sub-tropical oceans; Cooke and Philipp, 2004; Danylchuk et al., 2007; Brownscombe et al., 2013). For the sake of rapid assessment, tail grab may serve as the better measure because it is less invasive (involves less handling and air exposure) and also appears as a more consistent response across species (Fig. 5; Davis, 2010; Lennox et al., 2015a,b).

Equilibrium loss is typically next to become impaired along the gradient of increased stress, and is likely the most informative RI test for anglers (Table 1; Figs. 4 and 5). The inability of fish to maintain upright orientation is a critical sign that fish are in poor physiological condition and have little to no ability to avoid predators. For example, bonefish that have lost equilibrium are six times more likely to experience predation within the first 30 min post-release (Danylchuk et al., 2007). Equilibrium loss is also a strong predictor of behavioural impairment in great barracuda (Brownscombe et al., 2014b), and of delayed mortality in bluegill (*Lepomis macrochirus*; Gingerich et al., 2007) and coho salmon (*Oncorhynchus kisutch*; Raby et al., 2012). The amount of time until fish regain equilibrium (aka 'revival time') may also be useful indicator. For example, Hueter et al. (2006) developed a condition score for predicting shark survival after longline capture that included the amount of recovery time sharks required to regain equilibrium, as well as how vigorous they were upon release. Time until equilibrium gain was also a significant predictor of bonefish swimming capabilities post-release from angling-related stressors, which is highly relevant for survival from predation (Danylchuk et al., 2007; Brownscombe et al., 2013).

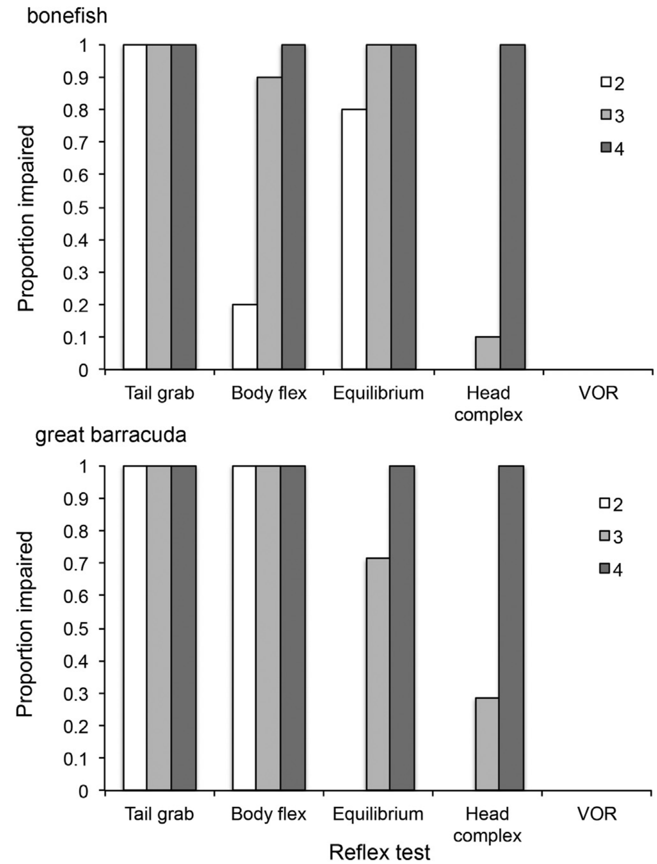

Fig. 5. Proportion of reflex impairment (see Table 1 for descriptions of tests) across a range of reflex impairment scores (2–4 reflexes impaired out of 5) in bonefish and great barracuda. Data is adapted from Brownscombe et al. (2013, 2014b).

Head complex (consistent, active opercular ventilation) and Vestibular Ocular Response (VOR) impairment typically indicate the highest levels of physiological impairment and are often the last to become impaired in angled fish. A loss of these reflexes indicates extreme physiological stress, neurological and behavioural impairment, and mortality risk (Davis, 2007; Raby et al., 2012; Brownscombe et al., 2013). While some other indicators (e.g., tail grab and body flex) are termed 'reflexes', there is a more voluntary component to them, where an exhausted, but conscious fish may simply choose not to swim away from the handler. Conversely, head complex and VOR are governed by the autonomic nervous system. When these reflexes are impaired, it indicates neurological

Table 1
Selected reflex tests potentially useful for assessing fish condition prior to release from catch-and-release recreational fisheries.

Reflex test	Method	Positive response	Notes and Interpretation
Tail grab	Grab fish's tail by hand while fish is submerged in water	Swimming escape response	Tests escape response to an approaching threat. Mimics predation threat and is likely highly relevant in this ecological context
Body flex	Grasp the fish by center of the body, holding briefly in air	Flexes body in attempt to escape	Similar to tail grab, it tests an escape response
Equilibrium	Invert the fish in water	Fish rights itself and retains upright orientation	Strong indicator of moderate-high physiological stress levels, behavioural impairment, and mortality risk
Head complex	Observe opercula for respiratory movement	Regular, consistent opercular beats	Indicates relatively high stress, but not consistent across all species
Vestibular-ocular response (VOR)	Roll fish side-to-side on the longitudinal axis and observe eye movement	Eye tracks angler or level plane	Consistent indicator of very high stress levels, behavioural impairment, and mortality risk
Bite	Place a probing device into fish's mouth	Bites down on probe	Useful for select species. May be observed while using unhooking tools
Mouth close	Mouth forced open by hand	Fish closes mouth	Tested on very few species, consistency unclear
Fin erection	Grab or restrain fish, observe dorsal fin	Dorsal fin becomes erect	Tested on very few species, consistency unclear
Stabilizing	Create water movement, observe for stabilization	Fish stabilizes or supports itself against container	Useful indicator for benthic-oriented species such as flatfish. Untested in context of recreational angling
Nictitating membrane	Spray or splash water into fish's eye	Nictitating membrane closes	Useful for elasmobranchs, which have the membrane. May be particularly useful for large sharks, which are challenging to test with other measures

impairment and lack of consciousness of the fish. When a fish is not responsive to VOR, it is likely highly stressed and near death. Where regulations permit, anglers may choose to harvest fish that lack these reflexes.

This predictor-specific pattern is fairly consistent across fish species from a range of taxa and types of stressors (Fig. 5; Davis and Ottmar, 2006; Davis, 2007, 2010; Raby et al., 2012; Brownscombe et al., 2013, 2014b;). There are, however, some species (e.g., flatfish) where these tests are less effective and others can be employed (see Depestele et al., 2014). Anglers can easily adopt these simple tests to assess the condition of their catch based on reflex impairment scores key indicators (e.g., equilibrium), and cumulative impairment scores based on a number of reflex tests. To date, most studies testing RI scores have focused on the proportion of a range of RIs that are impaired, while little focus has been paid to which RI scores are most effective at predicting survival. In the context of recreational angling, identifying the minimum reflex tests required to assess fish condition may be a critical step in getting anglers to adopt assessment strategies. Scientists should also continue to explore the relationship between RI indicators and mortality in a range of species and environmental conditions. The relationship between RI and morality, although well established in the context of commercial fisheries (e.g., Davis 2010; Raby et al., 2012), is more tentative in recreational angling scenarios. Reflex tests may be valuable not only for anglers to utilize in making informed decisions on the fate of their catch, but also for managers to acquire estimates from anglers on the survival probability of released fish. As C&R fishing grows in popularity, it is becoming increasingly important to include comprehensive estimates of angling mortality in fish stock management.

3.3. Toward condition scores

The fate of a released fish is related to its overall condition, which encompasses physical, physiological, and behavioural states. However, to date, assessments of fish condition in recreational fisheries have largely developed separately as injury scores and reflex impairment tests. Given the clear evidence that both injuries (e.g., deep hooking) and reflexes (e.g., equilibrium) are both predictive of condition and mortality, a combination of the two, as an all-inclusive 'condition score' would likely provide a more comprehensive assessment. Such measures have been applied in a few commercial fisheries (e.g., Davis and Ottmar, 2006; Depestele et al., 2014; Benoît et al., 2015), although not in a systematic framework. To date, a few studies have integrated RI measures and hooking injury in the context of recreational fisheries (but see Danylchuk et al., 2014). Combining the two could provide anglers and fisheries managers with convenient and non-invasive methods for assessing fish condition and predicting survival. For example, a deeply hooked fish without any reflex impairment may still have a reasonably strong chance of survival, while a deeply hooked fish that is also unable to maintain upright orientation may not.

4. Recovery tools and tactics

There are some instances where angled fish are in poor condition (i.e., highly unresponsive to reflex tests or injured) but must be released. Harvest regulations such as closed seasons, harvest restrictions, or size limitations often make release mandatory, while sometimes anglers are unwilling to harvest their catch due to lack of interest in consumption over concerns of potential flesh contamination (e.g., heavy metals, methylmercury; Birke et al., 1972; Castro-González and Méndez-Armenta, 2008), biotoxin or parasite transmission (e.g., ciguatera, trematode parasites; Lange, 1994; Chai et al., 2005), or social pressures surrounding C&R fisheries (Bagnis et al., 1979; Arlinghaus et al., 2007). For example, bonefish and Atlantic tarpon (*Megalops atlanticus*) anglers (among many others) target these species almost entirely for sport, and harvest is often considered socially unacceptable, or is illegal (Ault, 2008). In these cases recovery tactics, including temporarily holding fish or maneuvering them in certain ways, may be beneficial prior to release. These tactics are particularly useful in habitats with high predator burden and post-release predation risk (e.g., bonefish in tropical habitats; Danylchuk et al., 2007; Brownscombe et al., 2013), or systems with high water flow (e.g., salmonids in rivers; Donaldson et al., 2013).

4.1. By-hand recovery tactics

There are reliable pre-release tools for assessing fish condition (e.g., RAMP), but what should be done in these cases when fish in poor condition still must be released? When fish lose equilibrium (a RAMP indicator) they are unable to maintain upright posture and typically do not swim away from the handler. In these cases it is often recommended to 'recover' the fish by hand (Pelletier et al., 2007). In flowing water systems (e.g., rivers or tidal regions), putatively, fish should be held upright, facing current flows to flush gills with fresh oxygenated water. However, Robinson et al. (2013, 2015) found this tactic was ineffective at facilitating metabolic recovery or improving survival in sockeye salmon (*Oncorhynchus nerka*). In more static water (e.g., lakes or reservoirs), it is often recommended that fish be maneuvered by hand through the water in various patterns; but Brownscombe et al. (2016) found this tactic conferred no benefits to physiological or behavioural recovery in largemouth bass or brook trout (*Salvelinus fontinalis*). It was noted that despite a loss of equilibrium, fish were still actively ventilating, which may maximize oxygen uptake and metabolic recovery on its own. In fact, hyperoxic conditions are not beneficial for physiological recovery (Shultz et al., 2011). Handling is in itself stressful for fish, and to date no evidence supports the use of by-hand recovery tactics.

4.2. Temporary retention

When fish are behaviourally impaired, rather than handling the fish further, it may be more beneficial to retain them for a short period to allow for recovery. For example, in environments with high predator burden, angled fish experience increased predation risk for a short period post-release (Danylchuk et al., 2007; Cooke et al., 2014; Brownscombe et al., 2013). Retention can also be beneficial in fast-flowing rivers, where behaviourally impaired fish can be swept down river, reducing migration success (e.g., in salmonids, Raby et al., 2012; Donaldson et al., 2013). Where applicable, there are a number of tools available to anglers to retain fish for a short time period. When angling from a boat, fish may be retained in livewells. It had been suggested that colder water temperatures or hyperoxic water may reduce physiological impacts; however, both seem to exacerbate physiological stress, and normoxic water at ambient temperature is most beneficial for recovery (Suski et al., 2006; Shultz et al., 2011). When anglers do not have a livewell, ‘recovery bags’, or ‘fish bags’ (rubberized mesh bag) may be used to retain the fish (Donaldson et al., 2013). Recovery bags can be strapped to the angler’s belt, or even the back of boats to facilitate recovery, and offer a low-tech, low-cost recovery solution. In fact, Brownscombe et al. (2013) found retaining bonefish in recovery bags for 15 min prior to release significantly reduced behavioural impairment post release, and retained fish also experienced lower predation risk.

In some fisheries it is common to hold fish in livewells for several hours (e.g., black bass tournaments), which combined with angling-related stressors, can have negative impacts on fish welfare and survival (Wilde, 1998). Holding fish at a low density, in circulating water, at ambient temperature and oxygen levels is ideal for fish survival (Suski et al., 2006; Shultz et al., 2011). There is also a range of commercially available water additives commonly used by anglers, which contain diverse chemical ingredients aimed at decreasing physiological stress and/or injury-related infection, and ultimately survival (Harnish et al., 2011). Some studies have found additives were beneficial to fish survival (Plumb et al., 1988; Gilliland, 2003), but Cooke et al. (2002) suggest they negatively impact physiological recovery. In studies on aquaculture operations, water additives significantly improved fish survival during transport due to reduced infection and physiological stress (Swanson et al., 1996; Wedemeyer, 1996). While some additives may be beneficial in the context of holding fish in livewells during recreational angling, there is a huge diversity in additives available, and very little research on the subject to date.

4.3. Barotrauma relief

For fish suffering barotrauma, mitigation techniques aim to assist fish to return to neutral buoyancy as quickly as possible. Two types of barotrauma relief are currently used: surface relief of pressure (e.g., venting) or rapid recompression and release under water (e.g., bottom release devices). The most commonly used method to expel expanded gasses at the surface is lateral venting, also known as “fizzing”, during which a hollow needle – generally 16 gauge – is inserted through the dorsal musculature to the swim bladder allowing expanded gasses to escape. This method is controversial and research is divided on its efficiency, which appears to be largely species specific (Burns and Restrepo, 2002; Wilde, 2009; Campbell et al., 2014). A meta-analysis conducted by Wilde (2009) led the author to suggest lateral venting be prohibited; survival rates observed in the majority of species are not improved and may be reduced, making the practice potentially detrimental to conservation efforts. Wilde (2009) argues that the potential to perforate organs and additional tearing of tissue associated with puncturing through the side of the fish outweigh perceived positive effects. Conversely, other studies have indicated little to no mortality is caused by venting and suggest it as a viable recovery method (e.g., Wilson and Burns, 1996; Nguyen et al., 2009; McLennan et al., 2014). However, studies assessing the efficacy of venting as a recovery tool often look at short-term mortality (i.e., days rather than weeks). Campbell et al. (2014) found short-term mortality estimates for vented fish higher than non-vented fish, while long-term mortality estimates were lower for vented fish. This suggests the effects of venting may be delayed, and long-term, species-specific studies are required to understand whether this technique is a viable recovery option. Because of the possibility of inadvertently damaging vital organs upon puncture, many authors and agencies agree that less invasive techniques should be further investigated and applied. In species where barotrauma causes the swim bladder to push the stomach past the esophagus and through the buccal cavity (e.g., pink snapper *Pagrus auratus*), ‘buccal venting’ may be a viable relief alternative to lateral venting (McLennan et al., 2014). This practice involves manually pinching the fish’s teeth against the stomach to pierce the stomach tissue and release expanded gases. This method had high short-term (3 day) survival rates similar to lateral venting in this species, but is thought to be superior because stomach epithelium heals relatively quickly and there is less potential for accidental harm to the fish (McLennan et al., 2014). In any case where anglers or agencies are promoting the use of venting, extensive education regarding correct techniques and size of venting needles for the species must be available to anglers to ensure that unintended damage does not occur (Roach et al., 2011).

Descending devices are typically more effective than surface venting, as venting does not necessarily remove all gas within the fish’s soft tissue, while rapid recompression returns internal gasses to appropriate pressure gradients quickly (Butcher et al., 2012). Both artificial recompression in hypobaric chambers (Pribyl et al., 2012; Drumhiller et al., 2014) and field research (Roach et al., 2011; Butcher et al., 2012) have indicated rapid recompression is as or more effective than surface gas release for treatment of barotrauma symptoms. Descending devices also eliminate additional tissue damage required by surface venting and potential for unintended organ puncture. Consequently, many agencies are now advocating for recompression via weighted releases over venting. Devices generally consist of weighted lines with inverted hooks or clamps, or weighted cages with open bottoms that return fish to depth and allow them to be released from the gear when appropriate buoyancy is achieved. Because potential negative consequences of improper recompression (i.e., release too shallow or too deep) are less substantial compared to venting, and symptoms of barotrauma are often cryptic and thus difficult to diagnose, forced descent of captured deep-water fish has great potential to increase survival in catch-and-release fisheries.

Logically, recovery strategies ought to be followed by rapid reassessment and release when possible. While recovery strategies show promise for improving survival of angled fish in relevant situations, their effectiveness is species- and context- specific. Under some circumstances retaining a fish can actually cause further stress due to fear (perceived threat), or injury from contact with the retention gear (e.g., in livewells during fishing tournaments). More research is required to identify appropriate recovery times and gears for relevant species across environmental contexts.

5. Summary

Catch-and-release angling has become popular as a management and conservation strategy, yet releasing a fish may not guarantee its survival. Angler behaviour and tactics play an extremely important role in the condition and fate of released fish, and hence, employing certain angling practices and procedures is important for the conservation of exploited fish species and the sustainability of recreational angling. Research has identified many key principles for sustainable C&R angling (e.g., avoiding air exposure, deep hooking), although at times optimal tactics may not mesh completely with angler priorities. Recreational anglers also employ a diversity of tactics for catching a wide range of fish species in a numerous environments, which all interact to present unique challenges for minimizing C&R impacts on exploited fish. Despite this, the fact that specialized fisheries have such low post-release mortality (Policansky, 2002) is evidence of the importance of appropriate tools and tactics to effectively C&R fish.

Here we have provided a synthesis of tools and tactics available to recreational anglers that play a key role in maximizing fish welfare. For example, a large, non-abrasive net is useful for retaining fish, in water, during unhooking and measuring fish to minimize fish stress and injury. There are also tools that enable anglers to assess fish condition upon capture (i.e., reflex test and injury scores) and make educated decisions about how to proceed (i.e., release, recover, or harvest), and also alter their tactics accordingly if practicing C&R. To date, injury and reflex tests have been largely developed separately, and we propose that future research should aim to develop an effective 'condition score' based on quick and simple tests that recreational anglers can employ to assess fish condition (i.e., probability of mortality and degree of fitness loss) prior to release. Such tools will likely be species or taxa specific due to variability in animal and environmental conditions, but ultimately provide a key tool for anglers and fisheries managers.

As catch-and-release grows in popularity, so must angler education and implementation of best angling practices to ensure the sustainability of this practice and conservation of fish and aquatic environments. Sustainable catch-and-release angling is a joint venture where it is the responsibility of management agencies and scientists to communicate and evaluate the best angling practices, while anglers need to be educated and use the correct tools and tactics to maximize the likelihood that released fish survive. In this regard, catch-and-release angling is perhaps among the most successful and rewarding conservation partnerships.

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