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Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources?

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Abstract. Catch-and-release recreational angling has become very popular as a conservation strategy and as a fisheries management tool for a diverse array of fishes. Implicit in catch-and-release angling strategies is the assumption that fish experience low mortality and minimal sub-lethal effects. Despite the importance of this premise, research on this topic has focused on several popular North American sportfish, with negligible efforts directed towards understanding catch-and-release angling effects on alternative fish species. Here, we summarise the existing literature to develop five general trends that could be adopted for species for which no data are currently available: (1) minimise angling duration, (2) minimise air exposure, (3) avoid angling during extremes in water temperature, (4) use barbless hooks and artificial lures/flies, and (5) refrain from angling fish during the reproductive period. These generalities provide some level of protection to all species, but do have limitations. Therefore, we argue that a goal of conservation science and fisheries management should be the creation of species-specific guidelines for catch-and-release. These guidelines would take into account the inter-specific diversity of fishes and variation in fishing techniques. As recreational angling continues to grow in popularity, expanding to many developing countries, and targeting alternative species, it is important that reasonable data appropriate for specific fish and fisheries are available. The sustainable use and conservation of recreational fishery resources will depend upon the development and dissemination of effective catch-and-release angling strategies based upon sound science to stakeholders around the world.

Introduction

Angling has become an important recreational activity for people around the globe, generating substantial income for regional and national economies (Cowx 2002; Pitcher and Hollingworth 2002). While some anglers do harvest a portion of the fish they capture, many fish are captured and immediately released. Fish may be released because they are viewed as bycatch (low food value, unwanted size, species, or gender), because the angler practices catch-and-release under the assumption that the released fish will survive to be caught again in the future, or due to ethical considerations (Quinn 1996; Aas et al. 2002). Indeed, for some specialised recreational fisheries, voluntary release rates approach 100% (Policansky 2002). In some jurisdictions, regulations are in place that mandate catch-and-release angling in an attempt to conserve fisheries resources (Quinn 1996), and catch-and-release has been shown to benefit fisheries in many different situations (Noble and Jones 1999). Although the reason for releasing fish varies, it is clear that many fish that are captured by anglers are released.

Implicit in the widespread adoption of catch-and-release is the general assumption that the released fish will survive (Wydoski 1977). Because most fish that die from catch-and-release angling do so some time after release (Muoneke and Childress 1994), some anglers and fisheries managers assume that mortality arising from catch-and-release angling is negligible. Although this may be the case for some species, others may indeed experience incredibly high, often unnoticed, levels of mortality. In a review of hooking mortality studies, Muoneke and Childress (1994) reported that mortality rates for released fish ranged from 0 to 89% across many marine and freshwater species. In addition, there can also be a suite of sub-lethal physiological, behavioural, and fitness impairments that can arise from catch-and-release angling (see Cooke et al. 2002a). Sub-lethal stressors are rarely considered by managers that are focused primarily on population level processes (Wydoski 1977; Cooke et al. 2002a). The body of literature evaluating the impacts of catch-and-release angling is rapidly expanding. However, this research has typically focused on species or groups of fish that are economically important, readily caught by the majority of anglers, and the subject of attention by outdoor media (see Muoneke and Childress 1994). In addition, the majority of these studies have been focused on freshwater fisheries in North America (Barnhart 1989; Muoneke and Childress 1994). Therefore, we currently have a reasonable understanding of how several species respond to catch-and-release angling, a rudimentary understanding for some species, and no knowledge about many species that are commonly caught-and-released.

The focus of this paper is to explore the need for developing species-specific guidelines for catch-and-release angling. We reason that there are some generalities that can be derived from existing studies that could be broadly applied to most fish species, and we present those generalities here. However, we also caution that the diversity of fish form and function and the techniques used by anglers for different species requires some level of specialised guidelines. The purpose of this paper is to provide direction to those fisheries managers and conservationists faced with developing guidelines, eracting regulations, and making management decisions based upon limited data from other, often distantly related species, and to direct future research activities to increase the sustainability of catch-and-release angling.

Current knowledge

In our opinion there are only five species of fish for which we have a reasonable understanding of catch-and-release angling effects at present time (Table 1). All of these species are freshwater (largemouth bass, *Micropterus salmoides*; walleye, *Sander vitreus*) or anadromous (rainbow trout, *Oncorhynchus mykiss*; striped bass, *Morone saxatilis*; Atlantic salmon, *Salmo salar*) and are endemic to North America, aside from Atlantic salmon which are also endemic to Europe (Berra 2001). Both

Table 1. Comparison of the catch-and-release research activities among well-studied and poorly studied recreationally important fishes. Habitat acronyms represent: FW, freshwater; A, anadromous; E, estuarine; SW, saltwater. The prevalence of catch-and-release angling for each species was categorised as 'Common' or 'Sometimes'. The number of published catch-and-release studies that are relevant to mortality, behaviour, physiology, and fitness are listed for each species. The total is a sum of all published studies. For instances when a paper covered two categories, it was placed in a single category that best represented the purpose of the paper. The studies were located by searching Fish and Fisheries Worldwide (coverage from 1971 to December 2002) and included only articles published in English.

Species	Habitat	Endemic	Prevalence of C and R	Number of published studies				
				Mortality	Behaviour	Physiology	Fitness	Total
Well-studied								
Largemouth bass, *Micropterus salmoides*	FW	NA	Common	22	2	4	4	32
Walleye, *Sander vitreus*	FW	NA	Sometimes	9	1	3	0	13
Striped bass, *Morone saxatilis*	A	NA	Sometimes	11	3	4	2	20
Atlantic salmon, *Salmo salar*	A	NA, EU	Common	9	4	9	2	26
Rainbow trout, *Oncorhynchus mykiss*	FW/A	NA	Sometimes	10	1	5	2	19
Poorly studied								
Bonefish, *Albula vulpes*	SW	O	Common	1	1	0	0	2
Sailfish, *Istiophorus platypterus*	SW	O	Sometimes	1	1	0	0	2
Barramundi, *Lates calcarifer*	EST	AU	Common	0	0	0	0	0
Peacock bass, *Cichla ocellaris*	FW	SA	Common	0	0	0	0	0
Common carp, *Cyprinus carpio*	FW	AS	Sometimes	2	0	3	0	5

rainbow trout and largemouth bass have been widely introduced around the world, greatly expanding their ranges (Berra 2001). However, almost all of the catch-and-release research on these species has been conducted in North America. There is no question that these species do represent some of the most popularised recreational fisheries and thus on an absolute basis, more of these fish are perhaps caught and released than any other species. For example, in the United States, all five of the species listed here were ranked highly as the preferred target of anglers, collectively contributing more than 35 billion US dollars annually to the US economy (U.S. Department of the Interior 2001). Largemouth bass are also popular in other locations such as Africa and Japan (Robbins and MacCrimmon 1974). Globally, Atlantic salmon represent one of the more popular recreational fisheries (Mills 1992).

For these five species, there have been numerous studies that have focused on mortality associated with angling. Factors frequently associated with mortality in these species include hooking injuries (Muoneke and Childress 1994), water temperature (Wilde 1998), and cumulative stress from hooking, fighting and landing the fish (Wood et al. 1983). Mortality studies are generally rather easy to conduct on fish, provided that sufficient numbers can be captured and held in some form of enclosure/tank/cage/pond to assess mortality over time (Muoneke and Childress 1994). There are fewer studies, however, that focus on other sub-lethal disturbances. Sub-lethal behavioural disturbances include changes in activity patterns, swimming speeds, movement, or habitat use. Studies of such effects generally require the use of conventional telemetry or activity telemetry (Cooke et al. 2002a). Sub-lethal physiological disturbances associated with catch-and-release angling include osmoregulatory imbalances, depletion of energy stores, build-up of metabolic wastes, tissue damage, hormonal changes and cardiovascular disturbances (e.g., Kieffer 2000; Schreer et al. 2001; Suski et al. 2003a). Sub-lethal fitness disturbances are assessed by looking at changes in gamete size, gamete quality, gamete quantity, parental care ability, mating success, reproductive success or other fitness oriented measures (Pankhurst and van der Kraak 1997; Cooke et al. 2002a). Collectively, these sub-lethal studies are more complex than simple hooking mortality assessments and require specialised equipment and expertise (Wydoski and Wedemeyer 1976). Although we still do not have a complete understanding of the sub-lethal effects of catch-and-release angling on these five species, they are still better understood than all other species of fish.

To contrast the amount of information we have concerning the reasonably well-studied species outlined above, we also examined the amount of information available for five other fish species (Table 1). All of these less-studied species (bonefish, *Albula vulpes*; peacock bass, *Cichla ocellaris*; barramundi, *Lates calcarifer*; common carp, *Cyprinus carpio*; sailfish, *Istiophorus platypterus*) are recreationally valuable, occur in varied environments, and in different parts of the world. Despite being popular recreational fisheries and the frequent subject of catch-and-release, it is evident that negligible information is available on the effects of catch-and-release angling on these species at any level. Several of these species have been the subject of hooking mortality studies, but very few have been studied with a focus on sub-lethal stressors. The total number of catch-and-release studies on the well-studied species ranged from 13 to 32, whereas for the poorly studied species, the maximal number was 5 (common carp). Two species (barramundi and peacock bass) have had no catch-and-release studies published to date, although these fisheries contribute substantial income to the Australian (Barramundi; Thorne 2002) and South American (peacock bass) economies. This disparity among the well-studied and poorly-studied species is even more distinct if we were to include species that are caught-and-released, but not nearly as popular as the poorly studied species we listed here. Due to the lack of information on catch-and-release angling, anglers, guides, and managers are forced to draw on information from studies conducted on other species of fish that differ with respect to ecology, physiology, behaviour, and morphology.

Generalisations on catch-and-release

There are five patterns that are clear from the research conducted to date on catch-and-release that should be applicable to virtually any catch-and-release fishery. These generalisations should reduce the application of inappropriate data from one species to another and include: (1) the duration of the angling event increases the physiological disturbance, (2) air exposure is harmful to fish and should be minimised, (3) extreme water temperatures magnify the level of disturbance and angling should be avoided at those temperatures, (4) barbless hooks and artificial lures or flies can greatly reduce handling time, hooking injuries, and likelihood of mortality, and (5) angling immediately prior to or during the reproductive period could affect fitness and should be avoided. Beyond these five patterns, there are few other generalisations that can be broadly applied to catch-and-release fisheries. We briefly discuss these generalisations by providing supportive evidence.

Angling duration

There is general consensus among the current body of catch-and-release research that the duration of the actual angling event experienced by the fish correlates positively with the magnitude of physiological disturbance and the time required for recovery. Angling is essentially a combination of aerobic and anaerobic exercise that results in a series of physiological changes including a depletion of energy stores and an accumulation of lactate, as well as acid/base changes and osmoregulatory disturbances (Wood 1991).

Evidence supporting the notion that the duration of angling influences the degree of sub-lethal disturbances can be found for several fish species, and the general physiological processes that result in this response should hold true for most fishes. Gustaveson et al. (1991) angled largemouth bass for various durations ranging from 15 s to several minutes. These authors determined that physiological disturbances including increases in plasma glucose, chloride, osmolarity and lactate were generally more severe with increasing angling duration. Similar haematological disturbances (increase in plasma lactate and decrease in blood pH) were correlated with the duration of angling in Atlantic salmon (Thorstad et al. 2003). In a study of smallmouth bass (*Micropterus dolomieu*), Kieffer et al. (1995) determined that white muscle disturbance including increases in lactate and metabolic protons and decreases in energy stores were more severe in fish angled for 2 min than those only angled for 20 s. The length of time required for smallmouth bass cardiovascular variables to return to resting levels increased for exhaustively angled fish relative to briefly angled fish (Schreer et al. 2001). However, the magnitude of the cardiovascular changes did not differ with angling duration. Nonetheless, longer periods of elevated cardiovascular variables indicated heightened metabolic rates, as fish replenished their oxygen debt (Scarabello et al. 1991). During this period of recovery, elevated metabolic rates increase the chance of metabolic rate dependent mortality and reduce the ability of fish to respond to other stressors (Priede 1985) such as additional disturbances associated with catch-and-release angling (e.g., air exposure), predator avoidance or prey capture.

Based on this evidence, we conclude that anglers should attempt to land fish as rapidly as possible to minimise the duration of exercise and the concomitant physiological disturbance. Although we only present data for several groups of fish, the basic physiological principles underlying the effects of exercise on fish (see Kieffer 2000) suggest that the general message should be widely applicable to most fishes. Techniques for achieving short duration angling events are generally focused on choice of equipment. Anglers should chose optimal equipment matched to the size of fish that are expected to be encountered. There is substantial evidence supporting the notion that the size of fish is positively correlated with the duration of the angling event (Thorstad et al. 2003). Efforts to intentionally prolong the angling event through the use of light line or rods should be dissuaded.

Air exposure

No matter what the species, air exposure is harmful for fish. Air exposure occurs upon capture when anglers remove hooks, weigh and measure fish, and/or hold fish for photographic opportunities. During air exposure, gill lamellae collapse leading to the adhesion of the gill filaments (Boutilier 1990) and several major physiological changes occur. For example, in rainbow trout, blood oxygen tension and the amount of oxygen bound to haemoglobin both fell by over 80% during brief air exposure (Ferguson and Tufts 1992), causing severe anoxia. Furthermore, those fish exposed to air typically experienced greater acid/base disturbance than those fish that were exercised but not exposed to air (Ferguson and Tufts 1992). Several researchers have also monitored cardiovascular variables for fish exposed to air. Cooke et al. (2001) subjected rock bass (*Ambloplites rupestris*) to either 30 or 180 s of air exposure. When fish were exposed to air for longer periods, all cardiac variables measured (cardiac output, stroke volume, heart rate) required significantly longer to return to basal levels. Similar studies on smallmouth bass determined that the duration of air exposure was correlated with the time required for cardiovascular variables to recover (Cooke et al. 2002b). Extended air exposure beyond some species-specific timing threshold eventually results in permanent tissue damage. Mortality rates can also be inflated by exposing fish to air. Short-term mortality (12 h) was negligible for control rainbow trout and low for trout that were exercised to exhaustion but not exposed to air (12%; Ferguson and Tufts 1992). When trout were exposed to air for either 30 or 60 s following exhaustive exercise, mortality increased to 38 and 72%, respectively.

Based on these studies, it appears that air exposure, especially in fish that have experienced physiological disturbances associated with angling, can be extremely harmful. Although different fish species will vary in their sensitivity to air exposure, we recommend that whenever possible, anglers attempt to eliminate air exposure by handling fish that are to be released in the water. When fish must be exposed to air, we urge that anglers do everything possible to minimise the air exposure duration due to the overwhelming negative consequences associated with that action.

Water temperature

In species for which data exists across a gradient of water temperatures, angling at extreme water temperatures (especially high) is correlated with increased physiological disturbances and the probability of mortality. Because most fish are ectothermic, changes in ambient water temperatures are realised throughout the animal, and can have pronounced impacts on cellular function (Prosser 1991), protein structure (Somero and Hofmann 1996), enzyme activity, diffusion rates and metabolism (Fry 1971). In addition, the quantity of oxygen dissolved in water decreases at higher temperatures. For example, Atlantic salmon exhibit low levels of mortality when angled at water temperatures between ~ 8 and 18 °C, but as water temperatures increase above 18 °C, the risk of angling-induced mortality increases exponentially (Thorstad et al. 2003). Underlying the mortality at high temperatures in Atlantic salmon are limitations in maximal cardiovascular performance as fish approach their maximal metabolic rate (Anderson et al. 1998) and extreme biochemical alterations (Wilkie et al. 1996). Wilkie et al. (1997) determined that while warmer water may facilitate post-exercise recovery of white muscle metabolic and acid–base status in Atlantic salmon, extremely high temperatures increased vulnerability to mortality. Greater oxygen debt may also be correlated with higher water temperatures (McKenzie et al. 1996). Mortality following angling is also strongly correlated with water temperature for largemouth bass (Wilde 1998).

Individual species exhibit different thermal tolerances (Beitinger et al. 2000) and this must be considered for each species, population, and location. However, there is a period of the year where water temperatures are their highest, and it is during this period that catch-and-release angling has the potential to be particularly harmful. Under these scenarios, if anglers do continue to fish, both the duration of the fight and handling time should be minimised. Ideally, fishing should be restricted during extreme water temperatures. For Atlantic salmon in eastern Canada, Atlantic salmon rivers are temporarily closed to recreational angling during excessive water temperatures (Department of Fisheries and Oceans 1998). Because water temperature exerts important control over almost all physiological processes in fish (Fry 1971), extreme water temperatures are undoubtedly one of the periods where fish are particularly susceptible to mortality.

Bait type, terminal tackle, and hooking injury

The equipment used by anglers to capture fish can play a large role in determining the severity of injury and chance of mortality. Hooks serve as the point of contact between the angler and the fish. There are a multitude of hook designs and configurations, with one of the largest determinants of injury and mortality being the presence of a barb (Muoneke and Childress 1994). Barbless hooks reduce the amount of time that is required by the angler to remove the hook by increasing the ease of removal (Cooke et al. 2001), regardless of whether hooks are single or treble (Falk et al. 1974). Some researchers also suggest that barbless hooks also reduce tissue damage at the point of hook entry. A synthesis of hooking mortality studies across taxa (Muoneke and Childress 1994) concluded that barbless hooks consistently were less injurious and resulted in reduced mortality. We echo their conclusions and suggest that barbless hooks should be widely adopted by anglers.

Another important factor is the choice of bait. Artificial lures or flies tend to superficially hook fish, allowing expedited hook removal with minimal opportunity for damage to vital organs or tissue (Muoneke and Childress 1994). Organic baits (excluding artificial flies) including live bait are typically ingested deeper than artificial lures resulting in longer hook removal times (Siewert and Cave 1990; Cooke et al. 2001). In addition, hooks that are ingested more deeply are more likely to harm lethal organs such as the heart or become lodged in the gut (Pelzman 1978). Anglers utilising barbless hooks and reducing emphasis on the use of organic baits will generally lead to minimal injuries, reduced handling time, and lowered chance of mortality.

Angling and the reproductive period

The fitness consequences of stress, and in particular, angling related stressors, have received very little attention from researchers. Disparate results obtained from the few existing reports create a continued need for studies that investigate fitness impacts (e.g., Booth et al. 1995). However, several studies have documented clear fitness impacts associated with catch-and-release angling activities (Pankhurst and Dedual 1993). There are many different ways in which catch-and-release angling could alter fitness (see Table 1 in Cooke et al. 2002a). Because the reproductive period is essential for generating offspring to contribute to the populations, it is only logical to do everything possible to minimise sub-lethal stress during the reproductive period and allow the maximum contribution of offspring to subsequent year classes.

Largemouth bass are perhaps the best studied with respect to the sub-lethal effects of catch-and-release angling on fitness. This species provides sole male parental care. Evidence suggests that when nesting males are angled from the nest, even for a short period, the unprotected offspring are quickly consumed by predators, directly decreasing fitness (Philipp et al. 1997). However, even if fish are released after angling, Cooke et al. (2001) determined that when nesting males return to the nest, they exhibit impairments in locomotory activity for over 24 h, and Suski et al. (2003b) showed that angling reduced the level of care provided to offspring by the attending male. A study by Ostrand et al. (in press) determined that largemouth bass exposed to a simulated fishing tournament immediately prior to the spawning period produced fewer and smaller offspring than control fish. In the aquaculture literature, there is overwhelming data suggesting that salmonids exposed to acute and chronic stressors exhibit endocrine alterations that depress fitness (Campbell et al. 1992). Similar hormonal changes have been shown to occur in largemouth bass following bouts of angling (Suski et al. 2003a), but the extent to which these angling-induced hormonal changes can impact fitness have yet to be explored.

Fitness studies are very difficult to undertake in field settings (Cooke et al. 2002a). For this reason, it will probably be many decades before there is a large body of work on this topic. Based upon the negative consequences associated with angling during the reproductive period as outlined above, it is only prudent for catch-and-release and catch-and-harvest fisheries to avoid capturing fish during the reproductive period, unless data is generated that suggests that negative consequences are not observed for the species of interest.

Are generalisations enough?

Are these generalisations sufficient to ensure the conservation of fisheries resources in species for which no catch-and-release studies exist? In our opinion, the answer is likely dependent upon the characteristics of different fish and fisheries. Substantial inter-specific variation in behaviour, physiology, ecology, and morphology exist within fishes (Helfman et al. 1997). Similarly, species of fish vary in terms of sensitivity to different stressors including those associated with catch-and-release angling (Muoneke and Childress 1994). Even within sympatric freshwater teleost fishes examples of major physiological differences exist. For example, northern pike (*Esox lucius*) and largemouth bass are both popular sportfish that occur sympatrically, yet exhibit substantial differences in how they respond to catch-and-release angling. Northern pike have little red (aerobic) muscle and large tissue energy stores, and hence, exhibit massive lactate build-up and huge acid base disturbances post-exercise (Schwalme and MacKay 1985). Conversely, largemouth bass possess red (aerobic) and white (anaerobic) muscle along with smaller tissue energy stores, and only exhibit moderate increases in white muscle lactate post-exercise (Kieffer et al. 1996). These disparities among distantly related species with different life-histories are expected, and differences of an even greater magnitude may exist between marine and freshwater fishes, highlighting the challenge of applying catch-and-release generalisations across species.

Interestingly, similar levels of variation in response to catch-and-release angling are also evident among congenerics. For example, in a recent study of largemouth bass and smallmouth bass exposed to hypoxic conditions simulating catch-and-release tournaments, researchers determined that these congeneric species have very different sensitivities to hypoxia (Furimsky et al. 2003). Currently, smallmouth bass and largemouth bass are grouped collectively as 'black bass' by anglers, tournament organisers, and even some catch-and-release researchers. If fisheries managers prescribed livewell oxygen levels using data for the hypoxia tolerant largemouth bass, the more hypoxia intolerant smallmouth bass would suffer and possibly die. Indeed, Hartley and Moring (1995) determined that post-tournament survival rates differed markedly between smallmouth bass and largemouth bass; smallmouth bass had higher mortality rates. In addition to physiological differences, closely related species can have different mouth morphologies and modes of feeding that affect hooking mortality. Circle hooks are designed to minimise deep hooking (See Cooke and Suski, in press), and do so for some species such as billfish (Prince et al. 2002) and Atlantic bluefin tuna (*Thunnus thynnus*; Skomal et al. 2002). However, when researchers compared the effects of circle hooks in two congeneric lepomid fishes, bluegill (*Lepomis macrochirus*) and pumpkinseed (*Lepomis gibbosus*), the circle hooks performed quite differently with substantial differences in hooking depth, eye injury, bleeding occurring between the species, highlighting how variation in mouth morphology, dentition, and feeding mode can influence the outcome of catch-and-release angling (Cooke et al. 2003). Thus, these two examples suggest that fish in the same genus can differ in many ways that necessitate different catch-and-release considerations, and thus different catch-and-release guidelines.

Finally, within species, some researchers have revealed that fish respond differently to stressors at different life-history stages. Brobbel et al. (1995) compared the physiological response to angling in Atlantic salmon at two different stages of migration (kelts and bright salmon). This study demonstrated large differences in the degree of physiological disturbance that arose from angling in these two migratory stages, as well as differences in angling-induced mortality. In addition, substantial intraspecific variation can exist among stocks/populations with respect to exercise physiology (Nelson et al. 1994), environmental tolerances (Beitinger et al. 2000), and condition, that could all result in variable responses to catch-and-release angling. Mortality (Meals and Miranda 1994; Thorstad et al. 2003) and physiological disturbance (Kieffer 2000) can also vary with size of individuals of the same species. In addition, gender may also play an important role; however, there are few tests of that supposition.

These simple examples illustrate how a catch-and-release guideline that is appropriate for one species will not always be appropriate for others. And indeed, what is appropriate for an individual species in one location or at a particular life-stage, may also be inappropriate for the same species at other times. Sometimes it is anglers and outdoor media, not fisheries managers, who promote different strategies for what is believed to be of conservation benefit for some species. Anglers may reason that what works for trout or bass may also apply to carp and bonefish. The generalities that we provide represent the extent to which we can rely on deriving generic information from the catch-and-release studies conducted to date and applying it to other fish and fisheries.

Species-specific guidelines

Ecology, conservation, and indeed, many fields of science are focused on evaluating large-scale patterns among diffuse and disparate systems. In this paper, we argue that there are five patterns that are clear in the catch-and-release literature that are worthy of widespread adoption. However, there are exceptions to every generalisation including those proposed here for catch-and-release.

We submit that the ultimate goal for catch-and-release research is to develop and refine general guidelines for the successful release of all fish, and then develop a suite of specific guidelines for individual species or types of catch-and-release activities (e.g., tournaments, deep water fishes). Included in these guidelines should be species-specific considerations with respect to different life-stages, populations, sizes or genders. Although there has been a growing movement to manage and conserve fisheries at the stock/population level, for the purpose of catch-and-release angling guidelines, the species level is likely the most appropriate at this time considering the species is usually the level at which anglers can rely on gross morphological characters to identify fishes. We believe that this is not a matter of 'stamp collecting'. Instead, this level of detailed guideline is essential to minimise the negative consequences of catch-and-release.

Several recent syntheses on the well-studied species such as largemouth bass (Gilliland et al. 2001; Cooke et al. 2002b) and Atlantic salmon (Department of Fisheries and Oceans 1998) have provided this type of guidance for those species. As more species-specific information is developed, we promote the establishment of some mechanism to increase dissemination of information to anglers, guides, managers, and researchers. One example may include an online repository that could serve as a resource with all available data for a species, and then augment this with species-specific summaries that are refined as new information is available. This repository would also serve to direct future research through the identification of clear deficiencies in the repository. Alternatively, outdoor media, government, and conservation organisations could develop more educational materials tailored towards anglers.

Conclusions

Catch-and-release angling is a valuable tool for conserving fisheries resources, but only if done correctly. We advocate broader dissemination of the five generalisations of conservation-based responsible catch-and-release angling strategies we outlined here to the general angling public. We also advocate species-specific or group-specific research focused on addressing issues that are specific to disparate taxa. In addition, these studies must focus on the techniques and equipment utilised by recreational anglers in local fisheries, since these regional fisheries often adopt approaches to fish capture that differ from other such fisheries. Conservation and research efforts must be intimately linked to the user groups (Cowx 2002) to monitor trends and techniques so that the science of catch-and-release angling does not lag behind the behaviour of the anglers.

As recreational catch-and-release fisheries continue to grow in popularity, and as the world's population continues to expand, fisheries will face increased catch-and-release angling pressure. As this angling pressure increases, anglers will increasingly seek out alternative fisheries, often in developing countries for which no information on the fisheries will exist (Cowx 2002). It is our hope that research efforts will be inclusive as fisheries scientists and conservationists continue to examine the effects of catch-and-release angling on fish beyond North America. This will require expanding research efforts to evaluate global recreational fisheries that are perhaps not economically beneficial to the regions where research dollars are currently generated and distributed. The many local economies and communities that depend on recreational fishing, and the integrity of the populations and ecosystems from which fish are captured are in need of conservation-based catch-and-release guidelines to ensure the sustainability of this activity. It is our hope that catch-and-release research will focus not only on minimising sub-lethal and fitness-related disturbances, but also on facilitating or enhancing recovery. Only when constituents are provided with access to reliable information on how to properly execute catch-and-release angling while minimising mortality and sub-lethal effects, can we hope to generate sustainable recreational fisheries.

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