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# Catch-and-release science and its application to conservation and management of recreational fisheries

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**Abstract** Catch-and-release angling is a well-established practice in recreational angler behaviour and fisheries management. Accompanying this is a growing body of catch-and-release research that can be applied to reduce injury, mortality and sublethal alterations in behaviour and physiology. Here, the status of catch-and-release research from a symposium on the topic is summarised. Several general themes emerged including the need to: (1) better connect sublethal assessments to population-level processes; (2) enhance understanding of the variation in fish, fishing practices and gear and their role in catch and release; (3) better understand animal welfare issues related to catch and release; (4) increase the exchange of information on fishing-induced stress, injury and mortality between the recreational and commercial fishing sectors; and (5) improve procedures for measuring and understanding the effect of catch-and-release angling. Through design of better catch-and-release studies, strategies could be developed to further minimise stress, injury and mortality arising from catch-and-release angling. These strategies, when integrated with other fish population and fishery characteristics, can be used by anglers and managers to sustain or enhance recreational fishing resources.

KEYWORDS: fisheries management, fishing mortality, hooking mortality, recreational angling, sublethal stress.

## Introduction

Recreational fishing is a socially and economically important use of fisheries resources in most parts of the world. Participation in recreational fishing has grown as a result of population growth in developed countries, where it has a long history, and tourism in developing countries. The increased fishing effort, and possibly increased efficiency of contemporary anglers, is conducive to high exploitation, particularly in freshwater and coastal marine systems (Post, Sullivan, Cox, Lester, Walters, Parkinson, Paul, Jackson & Shuter 2002; Coleman, Figueira, Ueland & Crowder 2004; Allan, Abell, Hogan, Revenga, Taylor, Welcomme & Winemiller 2005; Arlinghaus & Cooke 2005). Harvest rates exceeding sustainable levels affect target species abundance and size structure (growth overfishing) and, with continued or extreme overfishing, can affect recruitment (recruitment overfishing). Overexploitation of sportfishes can affect biodiversity and, through trophic interactions, entire ecosystems (Cooke & Cowx 2006).

While recreational fishing is primarily considered a leisure activity, captured fish historically have been harvested for domestic consumption; but there is a growing tendency among some recreational anglers to release the fish caught (Cowx 2002). This dichotomy of purposes on the part of the recreational angler has created management dilemmas and opportunities. The management dilemmas are partly grounded on the motivations for fishing, namely to catch fish for recreation or to obtain fish for eating (e.g. Fedler & Ditton 1994; Schramm & Gerard 2004). The management opportunities are largely tied to 'quality' aspects of the fishery: the species caught (preferred species), some measure of fishing quality (e.g. fish size, number

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of fish caught, number of strikes and angling method) and the fishing environment (Schramm, Gerard & Gill 2003). In a commercial fishery, a caught fish has easily quantified value. This is true of recreational fisheries, too. However, in a recreational fishery, fish existence – knowing that fish are available to be caught (Schramm *et al.* 2003) – also has value. Some recreational anglers are willing to forego harvest to improve the quality of the fishery or ensure fish existence. It is this importance of catch quality and the anticipation that fish will be available, as well as a growing conservation ethic, that have fuelled interest in catch and release (Quinn 1996; Policansky 2002).

Extensive fisheries management activities and research have evaluated methods for controlling exploitation. For open-access fisheries, various restrictions on harvest have been used with varying success. Most of these management strategies involve the live release of fish, either because the fish is not of a suitable or legal size for harvest, because the angler continues to fish and release fish after the legal bag limit has been achieved, or because the fishery is designated a catch-and-release-only (no harvest) fishery. Furthermore, over the past three decades, substantial angler support has developed for voluntary catch and release. Intuitively, anglers and managers expect catch and release to increase the numbers of fish, specifically the numbers of larger fish; consistent with this, it is estimated that ~60% of all fish captured by anglers (many of which could have been legally harvested) are released (Cooke & Cowx 2004). With the exception of the few fish that are lethally injured by capture, the released fish swims away to rejoin the population and be caught again; or so anglers, and maybe some managers, presume. Even if some fish do not survive after release, fishing mortality is greatly reduced compared with intentionally harvesting the fish. Successful managers wisely base decisions on scientifically valid information rather than intuition. As appealing as catch and release appears as a fisheries conservation and management strategy and as prevalent as release-based harvest restrictions are, relatively few well-designed studies that isolated and measured the effects of catch-and-release fishing on target fishes or the ecosystems that support them have been conducted.

Catch-and-release practices and programmes have been discussed in three symposia on the subject since 1977 (Barnhart & Roelofs 1977, 1989; Lucy & Studholme 2002), but only a few papers in each of these symposia actually measured the effects of catch and release on populations or fisheries. While these symposia advanced awareness of the practice of catch and release, little effort was channelled towards improving the science of catch and release or effectively incorporating catch and release into management. The successes and failures of numerous restrictive harvest management strategies that involve catch and release are chronicled in various fisheries management journals (e.g. *Canadian Journal of Fisheries and Aquatic Sciences*, *Fisheries Management and Ecology*, *North American Journal of Fisheries Management* and *Fisheries Research*) and increasingly in conservation science journals (e.g. *Aquatic Conservation* and *Biological Conservation*). Additional evaluations are addressed in unpublished fisheries management agency reports. In addition to unanswered questions about the effects of catch and release on fish populations and their habitats, effective and accurate procedures for comprehensively measuring and understanding the effects of catch and release, hereafter called catch-and-release science, are often lacking and may be bottlenecks to advancing the effective use of catch and release for fisheries conservation and management.

Building on the three previous symposia and more than two decades of extensive use of harvest restrictions that depend on catch and release, a symposium titled 'Catch-and-Release Science and its Application to Conservation and Management' consisting of 21 invited presentations was convened at the 2005 American Fisheries Society annual meeting in Anchorage, AK, USA. The explicit intent of the symposium was to increase knowledge about the effects of catch and release and advance catch-and-release science. Some of the papers presented at that symposium are published in this special issue of *Fisheries Management and Ecology*. Although contributions on different taxa and problems were presented, the focus was on identifying generalised patterns relevant to conservation and management. The goal was to elevate the importance of catch-and-release angling and science among global conservation and fisheries management communities. This paper summarises the key advances that emerged from this symposium. Furthermore directions for future catch-and-release research are provided. The paper is organised around several prominent themes that emerged during the symposium and that are also evident in contemporary scientific catch-and-release literature.

## Sublethal effects of catch and release

Extensive research has focused on the sublethal physiological effects of catch-and-release angling (Cooke, Schreer, Dunmall & Philipp 2002; Cooke & Suski 2005; Siepker, Ostrand, Cooke, Wahl & Philipp 2007). However, the fisheries management community and anglers alike sometimes have challenged the utility of this type of research. Most concerns can be grouped into two primary questions: (1) how relevant are physiological data from captive fish in a laboratory setting to wild fish; and (2) how does information on individual physiology relate to fish populations, the fundamental unit for fisheries management or angling quality? Although much physiology research is restricted to laboratory settings, there is a growing body of field measurement of sublethal effects of catch and release (Siepker *et al.* 2007; Skomal 2007). To this end, catch-and-release research has been used as an example of how physiological information can be used to guide conservation and management activities (Wikelski & Cooke 2006; Young, Bornik, Marcotte, Charlie, Wagner, Hinch & Cooke 2006). Researchers have recognised for some time that laboratory settings are not always relevant to catch and release, and novel approaches for assessing sublethal effects in the wild are being used and evaluated. Skomal (2007) argued that blood samples collected from fish angled in the wild can provide meaningful measures of stress and have the potential to provide information on the physiological correlates of mortality after release. Other studies have used biotelemetry techniques to assess behavioural (e.g. swimming activity; Cooke & Philipp 2004) or physiological responses (e.g. heart rate; Anderson, Booth, Beddow, McKinley, Finstad, Økland & Scruton 1998) to catch-and-release angling in field settings. However, controlled laboratory experiments are still useful, especially when complemented by field data. For example, recent controlled studies on largemouth bass, *Micropterus salmoides* Lacepède, responses to conditions imposed by tournament angling (summarised in Siepker *et al.* 2007) were critical to identify the factors within the angling process that were most stressful. These data can then be used to focus educational and management efforts.

The second issue deals with the management utility of information from sublethal-indicator studies, and particularly those addressing physiological aspects. Mortality affects demographic characteristics of fish populations, and fisheries managers affect populations by altering mortality. Thus, mortality estimates from catch-and-release practices are readily integrated into fishery management. Conversely, catch-and-release effects that do not affect mortality are of lesser concern to fishery managers charged with sustaining quality fishing opportunities. On the other hand, some scientists contend that physiology and other sublethal indicators are highly relevant to fish populations and will become increasingly important as post-release mortality studies fail to provide mechanistic information on the factors that lead to mortality (Siepker *et al.* 2007; Skomal 2007). In the field of ecology, there is wide recognition that organismal physiology plays a role in population demographics (Ricklefs & Wikelski 2002; Young *et al.* 2006). Studies on sublethal stress are key to identifying the factors that can lead to mortality. Efforts focused on minimising stress will benefit individual fish and, in turn, fish populations. A major need is studies that link levels of physiological alterations to mortality and other variables that affect populations.

There is also a need to incorporate into catch-and-release science sublethal assessments that include behaviour (e.g. Hanson, Cooke, Suski & Philipp 2007), growth (Meka & Margraf 2007; Pope, Wilde & Knabe 2007) and fitness (e.g. Hanson *et al.* 2007). Even if a fish survives, the catch-and-release angling experience, there can be effects that are relevant to the population. This has been demonstrated for black bass, *Micropterus* spp., where the male provides extended parental care to developing offspring, making the adult fish highly vulnerable to angling (Siepker *et al.* 2007). Hanson *et al.* (2007) found that removing the male from the nest can result in nest abandonment and total mortality of the offspring. Activities that lead to releasing fish farther from the nest provide predators with more time to consume offspring. Although catch and release can cause loss of reproductive output for individual fish, the potential for compensatory mortality complicates predicting the effects of loss of individual fish reproductive output on the population. Population-level tests have not been conducted.

In addition, altered behaviour or release into an inappropriate environment may make released fish more vulnerable to predation. For example, a caught-and-released bonefish, *Albula vulpes* (Linnaeus), was selectively predated by lemon sharks, *Negaprion brevirostris* (Poey) (Danylchuk, Danylchuk, Cooke, Goldberg, Koppelman & Philipp 2007). The released bonefish swam directly back to an aggregation of uncaught bonefish and was the only fish attacked by the sharks.

Catch-and-release angling may affect fish feeding, which in turn affects growth and, thus, population size structure or reproductive potential; but results are inconsistent. Bioenergetic models indicate that reduced feeding ability caused by either chronic injury or delays in feeding after angling can negatively affect growth of individual rainbow trout, *Onchorhynchus mykiss* (Walbaum) (Meka & Margraf 2007). Conversely, Pope *et al.* (2007) found no change in measured growth of rainbow trout experimentally hooked in the mouth. Arlinghaus & Hallerman (2007) reported that zander, *Sander lucioperca* (Linnaeus), growth did not vary among fish exposed to a gradient of air-exposure durations (between 0 and 240 s) after simulated angling. Such disparate findings indicate the need for additional research to investigate the multiplicity of factors that may affect feeding and growth.

## Variation in fish, gear and angling practices and its implications for catch and release

Another theme that emerged was variation in both fish and fishing techniques and their implications for catch and release. This variation makes it difficult to develop simple catch-and-release guidelines. There have been attempts to develop generalisations for catch and release that should be applicable to most species and environments (see Cooke & Suski 2005). Simple, generic guidelines are likely best for generalist anglers as they can be applied across a range of species. As anglers become more specialised (e.g. carp, *Cyprinus carpio* Linnaeus, angling, Arlinghaus 2007; or black bass tournament angling, Siepker *et al.* 2007), they are more likely to adopt specialised catch-and-release practices that are needed for their specific fishing practices. It is these anglers that provide validation for catch-and-release practices determined by sound research to minimise stress or maximise survival of fish. At times, these anglers may push the frontiers in catch and release. Specialised carp anglers, for example, have developed unhooking mats to support large carp during the period when the hook is being removed and the fish photographed (Arlinghaus 2007).

Catch-and-release researchers must be aware of the utility of the end result. For example, research developing procedures for reducing stress or mortality of released fish would accomplish little if it recommended procedures that anglers could not implement or that were so complicated that anglers were unwilling to implement them. Of equal or greater importance is how much reduction of mortality or injury is required to support a change in regulations. In some fisheries for long-lived, slowly growing species, even 5% mortality can have serious population implications (Schroeder & Love 2002); and reduction of mortality from 5% to 3% may be critical from a conservation or management perspective. However, in other fisheries, even a reduction from, say, 15% to 10% may not be sufficient to warrant a change in regulations, as was noted with some barbless-hook salmonid fisheries (Taylor & White 1992). From a synthesis of published studies, Siepker *et al.* (2007) concluded negligible differences in the levels of injury and mortality for black bass when using circle hooks and J hooks, as well as between offset and non-offset circle hooks. Conversely, substantial reductions in injury and mortality were found through the use of circle hooks in other species (Cooke & Suski 2004; Prince, Snodgrass, Orbesen, Hoolihan, Serafy & Schratwieser 2007).

Angler practices also vary, and focusing on angler gear alone can be ineffective at reducing injury and mortality. Schisler, Bergersen & Schisler (1996) observed greater mortality among rainbow trout caught on artificial baits (slip-rigged artificial eggs) that were actively fished than among fish caught with the same bait fished passively. Similarly, Schill (1996) found that the frequency of deep hooking was greater among rainbow trout caught on a slack line than a tight line. Angler experience can also influence injury and mortality rates (Dunmall, Cooke, Schreer & McKinley 2001). Consequently, researchers and managers must communicate with anglers to stay at the leading edge of trends in angling gear and practices.

## Animal welfare and catch and release

During a facilitated discussion at the symposium, some participants recommended that greater integration of welfare considerations into recreational fisheries should promote innovative solutions to minimise stress attributable to angling, which in turn could enhance survival. Proactive approaches by researchers, anglers and fishery managers, including developing, testing and implementing innovations, such as circle hooks (Cooke & Suski 2004; Prince *et al.* 2007) that have the potential to maintain the welfare status of fish, may be the most productive way to bring more science to the debate about fish welfare and recreational fishing (Cooke & Sneddon 2006).

There is also opportunity to learn from the German experience. Arlinghaus (2007) described the status of catch-and-release angling in Germany in the context of animal welfare and existing policy and public attitude. Although voluntary catch and release was originally banned because of animal welfare concerns, today it has moved to more of a social conflict among different recreational angling groups, such as anglers against catch and release pitted against specialised carp anglers favouring catch and release.

Clearly, issues associated with animal welfare and catch and release include complex political, ethical and social dimensions that will need to be resolved to ensure that catch and release can be used as a fishery management and conservation tool. These issues extend beyond the traditional realm (and usually the training) of fishery managers and scientists and highlight the importance of adopting an interdisciplinary approach to catch and release, particularly as it relates to fish welfare.

## Exchanging knowledge with the commercial fishing sector

There is considerable opportunity to share information between the commercial and recreational fishing sectors. Cooke & Cowx (2006) concluded that these two sectors, although fundamentally different, have similar effects on fish, fisheries and the environment. The linkage to recreational catch-and-release fisheries is most apparent for the survival of commercial fishery bycatch. Ruderhausen, Buckel & Williams (2007) suggested that barotrauma issues surrounding survival of bycatch in a commercial fishery were identical to those in a recreational catch-and-release fishery. In that study, marine fish captured from deep water experienced substantial signs of rapid decompression (barotraumas), similar to that observed in freshwater recreational fisheries for black bass (Siepker *et al.* 2007). Another issue common to both fisheries sectors is air exposure as a stressor. Brief air exposure can result in physiological (Siepker *et al.* 2007) and behavioural alterations (Hanson *et al.* 2007), as well as mortality (Arlinghaus & Hallerman 2007). There is a need to identify air exposure thresholds for different species and for different conditions for both fisheries sectors (see Arlinghaus & Hallerman 2007).

## Designing better catch-and-release studies

Past studies on the effects of catch and release have used one of three broad approaches: changes in mortality, changes in physiological parameters or changes in behaviour. Measuring changes in post-release survival directly provides information needed by managers, but these measures are difficult to obtain, lack precision and suffer from a lack of suitable reference (Pollock & Pine 2007). Whether fish are confined or tagged and released, additional stress is imposed; at best, even the most carefully designed and conducted studies of post-release mortality provide conservative estimates of survival. Physiological parameters can be measured accurately and precisely but have not yet been equated to mortality. Further, the physiological measures used to date are changes associated with angling activity and lack appropriate reference comparisons, such as the physiological changes that result from capturing prey, escaping predation or guarding a territory. Behavioural studies, such as investigation of altered parental care leading to reduced offspring survival per nest (Hanson *et al.* 2007; Siepker *et al.* 2007) or increased vulnerability to predation (Danylchuk *et al.* 2007), may not be constrained by the lack of adequate reference conditions; but measuring effects is limited by environmental conditions (e.g. water clarity and water depth) and behaviour of the fish (e.g. extent of movement after release and spawning behaviour). Further, the effect measured is system specific; for example, loss of eggs in an unguarded black bass nest depends on the abundance of egg predators, or predation on adult fish after release depends on the species and abundance of predators present.

The papers in this issue reflect all three methods of evaluating the effects of catch and release – mortality, physiological change and behavioural change. Although solutions to the shortcomings of the three methods for evaluating catch and release were not proposed, the limitations of each method were made apparent. It appears that better ways to measure post-release survival will contribute to more rapid progress in catch-and-release science. Pairing physiological measures with post-release behaviour, as suggested by Skomal (2007), may advance catch-and-release science; and quantitative linkages between sublethal stress measures and mortality should be a high research priority.

Comparative studies that estimate differences in effect (i.e. relative effect) may not quantify mortality or stress, but may still provide important information for anglers and managers. For example, hook-type comparative studies, such as Prince *et al.* (2007) and studies reviewed in Siepker *et al.* (2007) provide management and angling guidance for improving survival. Nevertheless, such studies must also be integrated with information about population status to determine whether fishery agency-supported gear recommendations or regulations are needed. Meta-analyses can reveal significant factors and trends not apparent in individual studies, as demonstrated by Bartholomew & Bohnsack (2005); but data included in meta-analyses should be used carefully. Empirical studies must report sufficient information on sample sizes, variance and experimental design to enable use of information in meta-analyses.

A second issue in measuring the effects of catch and release should be *a priori* concern about the utility of the information to anglers and managers, i.e. does a catch-and-release practice make enough of a difference that anglers will realise better catches and managers will have sufficient data to decide if regulations or major educational efforts are necessary to effect the population (note that this decision must be tempered with individual welfare status as discussed above). The potential application of the results of a catch-and-release study should be fully considered in study design, selection of variables and measurement precision.

The potential benefits of catch and release can only be fairly evaluated when good science produces accurate and precise data about catch-and-release effects. However, decisions about the need to implement catch and release and determination of the effects of catch-and-release practices also require accurate and precise information about fish populations (e.g. population size, recruitment and size structure) and fisheries (e.g. catch and harvest rates, bycatch and discard rates). The true evaluation of catch-and-release benefits, whether voluntary or mandatory, rests with fish population and fishery changes. Thus, effective management with catch and release will depend on integration of the best catch-and-release science with the best fishery science.

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