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Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters

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The importance of recreational fisheries to local and national economies, and as a generator of immense social welfare throughout the developed world, is well established. Development in the sector and its interaction with non-fishery-related nature conservation objectives for aquatic biodiversity, however, have the potential to generate conflict. This article reviews the intersection between recreational fisheries and nature conservation goals for aquatic biodiversity with specific reference to inland waters in industrialized countries, and the principal management activities and constraints that can lead to conflicts. A SWOT (strengths, weaknesses, opportunities and threats) analysis was used to review the issues facing sectoral development and identify options for future advancement of recreational fisheries to ameliorate potential conflicts with nature conservation goals. It is concluded that reconciliation of recreational fisheries and modern conservation perspectives is both possible and desirable, because many conservation problems also benefit fisheries quality. Angler buy-in to conservation is probable if (1) management scales are small, (2) threats to conservation originate from outside the fisheries sectors and (3) ecological awareness for the conservation problem is high. If these aspects are not present, reconciliation of recreational fisheries and nature conservation goals is less likely, risking both the aquatic biodiversity and the future of angling. To address these issues, enforcement of legislation and continued communication with angler communities is necessary, as well as development of integrated management policies that build on the instrumental values of aquatic biodiversity for recreational fisheries, while curtailing the more insidious threats to such biodiversity that originate directly from the recreational fisheries sector.

Key words: angling; biocentrism; fisheries management; sustainability; SWOT analysis.

INTRODUCTION

Recreational fisheries are activities that capture and possibly harvest aquatic animals for various reasons other than meet primary physiological (*i.e.* nutritional) needs, and where the catch is usually not traded on formal markets or otherwise sold

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(EIFAC, 2008; Arlinghaus & Cooke, 2009). Recreational fishing is popular worldwide and is pursued in both marine and inland waters, usually with rod and line using natural or artificial baits, although other methods are used according to local custom (Arlinghaus & Cooke, 2009). Recreational fisheries are an important use of fish resources throughout the temperate zones (Smith, 1986; Welcomme, 2001; Cowx & Arlinghaus, 2008), particularly in Europe, North America, Australia, South Africa and South America (Cowx, 2002*a*; Cooke & Cowx, 2006; Arlinghaus & Cooke, 2009; Hickley, 2009; Potts *et al*., 2009; Aprahamian *et al*., 2010; Ellender *et al*., 2010), with many millions of people worldwide participating in the pursuit. Generally, with increasing industrialization, the importance of commercial fishing decreases, and inland water bodies are increasingly or exclusively used by recreational fisheries (Fig. 1). This trend continues, but management objectives increasingly rely on non-fishery-related conservation objectives when anthropogenic changes become visible within a society (Fig. 1). Arlinghaus & Cooke (2009) estimated that globally 10·6% of the population participates in recreational fisheries in the industrialized world. Similarly, in many transitional economies in Africa, Asia and Latin America, there appears to be a shift from small-scale commercial and subsistence fisheries towards recreational fisheries (Ditton, 2008; Potts *et al*., 2009; Ellender *et al*., 2010), especially as the economy develops to accommodate more wealthy nationals with leisure time or an increasing tourism trade (FAO, 2009). It should be noted, however, that while the economic potential of recreational fisheries is considerable throughout the world (Weithman, 1999; Arlinghaus *et al*., 2002), it is sometimes

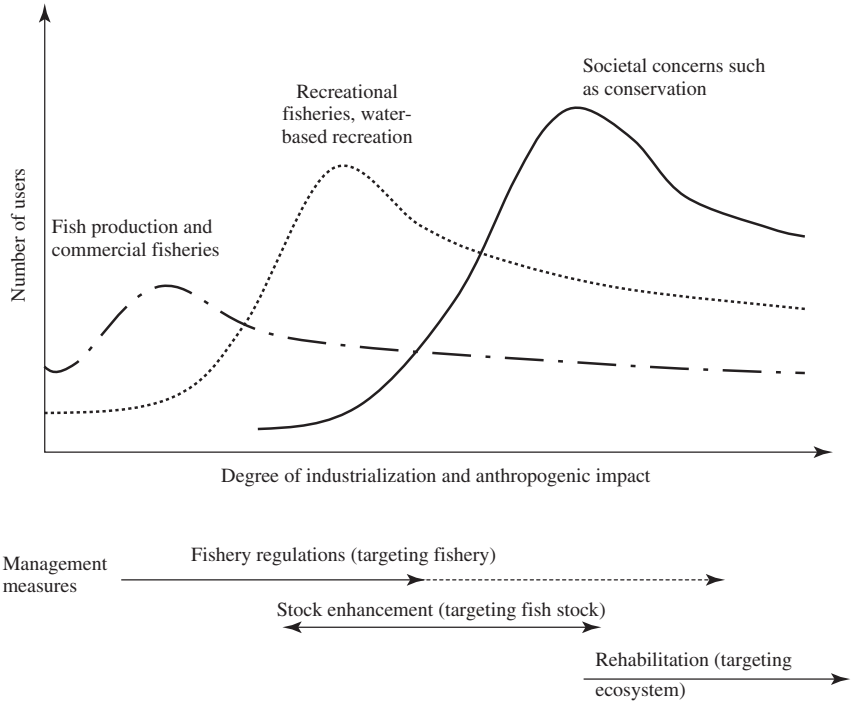

FIG. 1. Schematic presentation of the life cycle of inland fisheries. Text inside the figure indicates the predominant use or concern of inland water bodies (modified from Cowx & Arlinghaus, 2008).

unrecognized or underestimated by political decision makers (Cowx, 1998; Cooke & Cowx, 2004, 2006; Arlinghaus, 2006*a*; Hickley, 2009).

Despite the socio-economic importance of recreational fisheries in many regions of the world, there is concern that activities associated with the practice are in conflict with non-fishery-related aquatic biodiversity conservation objectives (Post *et al*., 2002; Coleman *et al*., 2004; Cooke & Cowx, 2004, 2006), such as those advocated under the Millennium Ecosystem Assessment (2005) and the numerous conventions and directives encouraged or enacted through the Convention for Biodiversity (CBD). It appears that many of these conflicts arise from divergent perspectives about intrinsic *v*. instrumental values of biodiversity in the context of conservation biology and fisheries, and occur when recreational fishing exploits already threatened fish resources and aquatic ecosystems. These threats to aquatic biodiversity generally stem from sources external to the recreational fisheries sector, such as habitat degradation and loss, resulting from river engineering, pollution and nutrient inputs and damming (Arlinghaus *et al*., 2002; Cowx, 2002*b*). Justus *et al*. (2009) argued that effective decision-making in the context of conservation in general must build on the instrumental value of biodiversity, which facilitates buying into conservation by stakeholders. Accordingly, for the purpose of this article, nature conservation in the context of aquatic biodiversity and recreational fisheries is defined as the conservation of the structure and diversity at all biological levels of an aquatic ecosystem, including its surrounding terrestrial ecosystem at a state that existed without recreational fisheries exploitation and management. Biodiversity is defined as 'the variability among living organisms from all sources, including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (Justus *et al*., 2009). This perspective values larger biological entities, such as populations, equally with supporting habitats and the individuals making up these populations (Paterson, 2006; Arlinghaus *et al*., 2007*a*). This represents a minimal standard for conservation because recreational fisheries management can also result in actions that increase desirable biological entities, such as a fish population, that are under threat by non-fishing-related anthropogenic activities such as habitat change. Thus, the intersection of recreational fisheries and conservation is not necessarily negative but is positive in some situations (Granek *et al*., 2008).

Taking such a perspective on the interaction between recreational fisheries and conservation of aquatic biodiversity is relevant because recreational fisheries exploitation and management can, in addition to non-fishing-related threats, directly affect fish populations and wildlife negatively (Post *et al*., 2002; Cooke & Cowx, 2006; Lewin *et al*., 2006). Globally, marine and particularly freshwater fish species are the most threatened group of vertebrates worldwide (Warren & Burr, 1994; Vincent & Hall, 1996; Ricciardi & Rasmussen, 1999; Powles *et al*., 2000), with >35% of the evaluated species considered vulnerable or threatened (IUCN, 2009). Aquatic ecosystems also represent some of the most altered habitats on the planet (Brönmark & Hansson, 2002; Kennish, 2002; Malmqvist & Rundle, 2002), and in this context, non-fishing-related anthropogenic interactions are probably the most important drivers of global loss of fish biodiversity, particularly in fresh waters (Richter *et al*., 1997; Arlinghaus *et al*., 2002; Cowx, 2002*b*). Nevertheless, there are also issues for conservation that originate from the recreational fishing sector, *e.g.* those stemming from illegal release of non-native fishes (Cambray, 2003; Johnson *et al*., 2009).

To highlight important intersections of recreational fisheries and general nature conservation goals for aquatic biodiversity, this article develops a narrative SWOT analysis (strengths, weaknesses, opportunities and threats) and identifies options for the future integration of recreational fisheries and modern conservation goals to align the benefits from this fisheries sector with generic conservation principles and ideas. SWOT analysis is increasingly being applied to problems in natural resources conservation (Paliwal, 2006; Verfaillie *et al*., 2009), as it provides an opportunity to reconcile different perspectives; it takes reasonably few financial resources to execute and could thus be a suitable framework for local and regional application. This article specifically examines the relationships between recreational fisheries and conservation of aquatic diversity and does not address the interactions between recreational fisheries and other fisheries sectors, which are reviewed elsewhere (Cooke & Cowx, 2004, 2006; Lewin *et al*., 2006).

SWOT ANALYSIS

SWOT analysis is used to identify and analyse the strengths and weaknesses of a sector, in this case recreational fisheries, or organization, as well as the opportunities and threats revealed by the information gathered on the external environment (externalities). It is used to develop a plan that takes into consideration many different internal (strengths and weaknesses of the sector) and external (opportunities for the sector and threats or obstacles to performance) factors, and maximizes the potential of the strengths and opportunities while minimizing the effects of the weaknesses and threats, and is thus ideal for examining the interrelationships between recreational fisheries and conservation of aquatic diversity. The process is a simple, qualitative analysis that encourages the development of opportunities to build on strengths of the sector and overcome weaknesses while at the same time utilizing sectoral strengths to minimize vulnerability to external threats. A summary of the key strengths, weaknesses, opportunities and threats with respect to the interrelationships between recreational fisheries and conservation of aquatic diversity is given in Table I and elucidated in detail below.

STRENGTHS

Economic, social and ecological benefits generated through recreational fisheries have been comprehensively reviewed by Weithman (1999) and Arlinghaus *et al*. (2002). They encompass classical economic benefits to angler-dependent industries as well as the creation of social welfare to anglers and other social and psychological benefits. These benefits must be recognized as a strength because of the financial contributions towards conservation efforts spilling out from activities to enhance recreational fisheries, together with the widespread aquatic stewardship associated with such behaviour (Knuth & Siemer, 2007). It is widely accepted by the international community that there is a need to protect the environment and aquatic biodiversity, including fishes (Fig. 1). This international agenda, which has filtered into the political arena, is generally strongly supported by recreational fisheries, where anglers are often considered key guardians of the environment and intensively involved directly and indirectly with actions to protect fish stocks and species

TABLE I. Key strengths, weaknesses, opportunities and threats with respect to the interrelationships between recreational fisheries and conservation of aquatic diversity

Strengths	Weaknesses
• High social and economic value of recreational fisheries. • Anglers act as guardians of the environment. • Expansive network of dedicated persons lobbying or otherwise directly working towards conservation goals. • Investment from angling revenues towards conservation programmes.	• Potential for lack of understanding of the ecological processes driving fish population dynamics. • Potentially naive awareness of the complex issues and problems facing aquatic biodiversity. • Occasional misconception that fisheries can only be improved by intensive stocking. • Fishes and fisheries often considered of marginal importance because the value of the resource is usually ill defined. • Recreational fisheries are often given low priority in any consultation process and tend to operate in an isolated environment. • Intra-sectoral and inter-sectoral conflict surrounding aquatic ecosystems make it difficult to come to consensus on issues related to conservation.
Opportunities	**Threats**
• Willingness of anglers and general public to support environmental and conservation campaigns through environmental education and extension programmes. • Lobbying of potentially damaging ecosystem development projects. • Reduce burden on fish stocks by shifting exploitation of fish from intensive commercial to recreational fishing in inland and coastal waters. • Adopt ecosystem approach to fisheries management to encapsulate recreational fisheries and conservation goals.	• Main external threats to biodiversity are species stocking, introductions, translocations and invasions, impoundment of running water, water quality deterioration, habitat alteration and fragmentation. • Local overexploitation of fish stocks. • Recreational angling practices affecting the structure and function of fish populations and potentially entire aquatic ecosystems. • Recreational fishing implicated with disturbance to wildlife and the environment. • Animal welfare concerns that holding of fishes at high densities, coupled with the hooking, playing and handling of the captured fishes, can cause injury and distress.

diversity (Bate, 2001; Kearney, 2002; Granek *et al*., 2008). Recreational fishing is underpinned by an expansive network of dedicated persons lobbying or otherwise directly working towards conservation goals (Granek *et al*., 2008), and this strength should be enhanced and supported where possible. In countries with public fishing rights, angler licence revenue is often invested directly in conservation programmes, and in some countries with private fishing rights, angling clubs and associations as leaseholders of fisheries rights are responsible by law to manage fish populations and the supporting habitats with a view to preserving native biodiversity, *e.g.* in Germany (Arlinghaus, 2006*b*). Such work is done with little or no government support and is self-financed and self-organized. To capitalize on the potentially enormous benefits this creates for aquatic biodiversity, efforts should be made by policy makers and others to encourage recreational fishing as long as development of the sector is oriented towards maintaining viable fisheries on native species, as it is usually the case in most industrialized countries.

The value of recreational fishing for conservation of aquatic systems in general has a simple economic root: anglers have a vested interest in preserving or enhancing the resources they depend on. There is ample evidence that either directly, *e.g* through supportive stocking of native fishes, or indirectly through habitat management and other fisheries management actions, usually financed by angling license money, they work proactively to conserve and, if possible, enhance aquatic biodiversity (Granek *et al*., 2008). There is also evidence that anglers are instrumental in shaping pro-environmental legislation and combating pollution incidences through legal action (Bate, 2001; Kirchhofer, 2002). In addition, where fish resources are reserved for recreational purposes or exclusively managed by angling clubs and associations (as it is typical in much of central Europe and the U.K.; Arlinghaus, 2006*b*), it is common for the fish assemblages to remain reasonably pristine, despite a tendency to encourage populations of the preferred species by stocking and elimination of competitors (Cowx, 1999; Baer *et al*., 2007; Baer & Brinker, 2010). There are also other benefits of recreational fisheries for aquatic ecosystems because the recreational fishing sector is one of the most powerful lobbies for the conservation or rehabilitation of damaged aquatic ecosystems in terms of habitat improvement schemes, improvement of lateral and longitudinal connectivity of rivers and biomanipulation (Kearney, 2002; Mehner *et al*., 2004; Arlinghaus *et al*., 2010).

WEAKNESSES

When reviewing the weaknesses surrounding the relationships between recreational fisheries and conservation, it is evident that there is occasionally lack of understanding of the ecological processes driving fish population dynamics among some angler communities and selected fisheries managers, particularly under private fishing rights regimes where managers are usually self-educated, avid anglers (Arlinghaus, 2006*b*). This may foster the misconception that fisheries can only be improved by intensive stocking (Cowx, 1999) and ultimately contributes to the often unrealistic expectations among anglers about the natural limits of fisheries or both (North, 2002; Arlinghaus, 2004). Pressure on managers by local anglers may also create incentives to establish and translocate non-native fishes, some of which may become invasive (Gozlan *et al*., 2010). As a result, recreational fisheries managers in some countries tend consistently to manage stocks through stocking rather than to

enhance the environment. This can lead to disruption of ecosystem functioning and, potentially, affect several ecological services generated by fish stocks (Holmlund & Hammer, 2004; Lewin *et al*., 2008). This trend needs reversing towards maintenance of angling experiences within limits set by natural productivity of native fish stocks and a change in the deeply entrenched belief among some anglers and managers that good fishing happens only because fishes are stocked (Schramm & Edwards, 1994). Irrespectively, different water bodies (*e.g.* natural waters *v*. artificial waters) necessitate different judgement criteria in terms of the acceptance of stocking policies (Cowx, 1994; Hickley & Chare, 2004).

It should be recognized that recreational fisheries in a multiple-user inland environment are fraught with social dilemmas. Fishes and fisheries, particularly in the inland environment, are often considered of marginal importance because the value of the resource is usually ill defined and poorly represented from an economic and social perspective (Cowx, 2002*a*, *b*; Cowx & Gerdeaux, 2004). Moreover, inland fisheries are typically small scale and, mistakenly (Allan *et al*., 2005), not considered to represent major food opportunities in many areas of the world, in contrast to marine fisheries. This reduces exposure of the undoubtedly immense cumulative economic importance of inland fisheries for recreational purposes and reduces investment into research and monitoring, and ultimately conservation of aquatic systems. Consequently, many recreational fisheries are traditionally managed based on the quality of the fishing experience, and few are managed from an economic perspective (Cowx, 2002*a*) taking a broader ecosystem approach into account (Arlinghaus & Cowx, 2008); an issue borne out by the paucity of information on the economic value of such fisheries (Kennedy & Crozier, 1997; Peirson *et al*., 2001). This problem spills over into recreational fisheries because the value of the resource has rarely been assessed (Cowx *et al*., 2004). Consequently, recreational fisheries are often given low priority in any consultation process, and it is then difficult to argue for protection of the ecosystem from non-fishing-related developments (Arlinghaus, 2006*b*). This has considerable effect on conservation and aquatic biodiversity unrelated to recreational fishing, because the marginal recognition given to recreational fisheries means they operate in an isolated environment and, like other stakeholders, often neglect their own interaction with the environment as they strive to develop. Thus, recreational fisheries and nature conservationists should work in harmony towards protection and enhancement of ecosystem functioning and aquatic biodiversity by respecting each other's interests in the ecosystem, which can fundamentally differ due to divergent values. Accounting for the economic importance alone, however, will not solve the issue of potentially over-optimistic catch expectations by many anglers that result in the excessive focus on stocking as a panacea of contemporary recreational fisheries management. Education programmes and involvement of experts as well as increasing involvement from the public sector, which is common in some countries such as the U.S.A., are needed to align future stocking practices with conservation goals. It is not argued that all stocking should be curtailed, as there are fishery-specific issues to be considered (Cowx, 1994, 1999), but more consideration of the objectives and risks of stocking is needed if the sector is to move forward in terms of not compromising aquatic biodiversity further (Cowx, 1994, 1999; Arlinghaus *et al*., 2002).

Although the enthusiastic network of persons with self-interest in conserving fishes and aquatic ecosystems is considered a strength of recreational fisheries, it may equally be a weakness. This contradiction arises because the recreational fisheries

fraternity, particularly those operating in fresh waters, frequently work in isolation of other resource practitioners and nature conservation bodies. Similarly, other resource users or lobby groups often disregard the needs and interests of the recreational fisheries sector when deciding on aquatic ecosystem development or conservation action (Arlinghaus, 2005). Inevitably, this leads to conflict, which tends to favour the strongest economic argument or the most powerful lobby group, often to the detriment of recreational fisheries and biodiversity (Cowx, 2002*b*).

Some of the blame must fall on recreational fishing and conservation practitioners because of long-term lack of cooperation, partly because they are responding to different motivations, constituencies and reward systems (Meffe, 2002). As Meffe (2002) pointed out, if each sector is to expand, they must engage and work effectively with each other as a unit rather than blaming each other for inappropriate action. This is highlighted by the ongoing debate over the effects of fish-eating birds and aquatic mammals such as otters on fish stocks in some areas of the world (Cowx, 2003). The levels of intra-sectoral and inter-sectoral conflict surrounding aquatic ecosystems are divisive and generate issues that extend into the public arena, making it difficult, if not impossible, to come to consensus on issues related to conservation (Arlinghaus, 2005). Part of the reason is that the recreational fisheries sector has traditionally claimed to be the sole stakeholder group with a valid claim for conservation of aquatic ecosystems. While this has been true in the past, today the world has become complex with various groupings and stakeholders being advocates of conservation action (Fig. 1). This can create enduring conflict, and some particular cases are worth mentioning in this context. For example, in many areas of the world, public agencies and non-government organizations (NGO) dealing with conservation have developed a perspective where humans are generally considered a non-natural disturbance to be avoided (Paterson, 2006; Arlinghaus *et al*., 2007*a*). This culminates in the designation of conservation areas where human activities, including fishing, are excluded leading to pervasive conflict and preventing a constructive dialogue on other conservation issues (Arlinghaus, 2005, 2006*b*). Another example concerns the current conflict surrounding conservation of fish-eating birds, particularly cormorants *Phalacrocorax* spp. (Suter, 1995; Cowx, 2003; Rudstam *et al*., 2004). While the recreational fisheries sector is concerned with the conservation of aquatic systems, which happens to include protecting fishes from excessive cormorant predation, many conservation practitioners do not welcome any constraints on cormorants. The resulting conflict is enduring, complex and intensive, with potential spill-over effects hampering future collaboration.

OPPORTUNITIES

As mentioned above, one of the factors common to successful conservation projects is the involvement of people and inclusion of their attitudes, wishes, concerns, believes and preferences into decision-making (Meffe, 2002). The general public are excellent ambassadors to promote conservation causes (Cambray & Pister, 2002), and anglers are equally valuable in efforts to guard and protect the aquatic environment as they are large in number, widely dispersed and have a vested interest in ensuring their fisheries, and hence environments are not degraded (Granek *et al*., 2008). The biggest problem, however, is that the general populace, and in some

cases also anglers and their political representatives, have a rather naive awareness of the complex issues and problems facing aquatic biodiversity. Consequently, greater opportunity should be made of their willingness to support environmental and conservation campaigns by promoting environmental education and extension programmes (Knuth & Siemer, 2007). For example, projects are needed that exemplify the potentially negative effects of stocking to increase ecological awareness and understanding within angler communities. This knowledge will then rapidly spread in the social network of anglers and managers and may help shift the entrenched mindset of managing fisheries through potentially ecologically damaging stocking practices.

Similarly, fishing clubs and organizations should be continually encouraged to promote protection of fisheries and front environmental lobbying of potentially damaging ecosystem development projects, such as hydropower schemes. This can also happen in urban environments traditionally not regarded as important for biodiversity but may offer outstanding benefits to aquatic conservation. In this context, recreational fishing is an excellent driver, *e.g.* to support urban regeneration through enhancement of modified waters (Hickley, 2009). This has major social and ecological benefits, including increasing employment opportunities, providing focal points to improve social cohesion, developing life skills and most importantly, creating aquatic environments in an urban landscape to arrest the decline in biodiversity and provide new habitats for colonization (Hickley, 2009). Given the economic benefits discussed earlier, decision-makers might also be better-off and probably create more social welfare and reduce burden on fish stocks by shifting exploitation of fishes from intensive commercial to recreational fishing in inland and coastal waters, but this type of economic thinking is only slowly becoming appreciated in European countries.

As mentioned previously, anthropogenic activities, such as agriculture, damming, deforestation, navigation, wetland reclamation, urbanization, water abstraction and transfer and waste disposal, have altered aquatic ecosystems profoundly, probably more than terrestrial ecosystems, particularly in fresh waters (Cowx & Welcomme, 1998; Cowx, 2002*a*). Consequently, in most areas of the world, the principal effects on inland fisheries and biodiversity originate from outside the fishery (Arlinghaus *et al*., 2002). The need for concerted effort to prevent and reduce modification of inland aquatic ecosystems, as well as conservation of fishes and fisheries as renewable common-pool resources or entities in their own right, are the greatest challenges facing sustainable development of aquatic resources (FAO, 1999). An emerging approach to help address the multi-facetted problems facing aquatic ecosystems is the ecosystem approach to fisheries management (FAO, 2003). This approach may also help resolve the conflicts between recreational fisheries and conservation (Arlinghaus & Cowx, 2008). There is no doubt that an integrated, ecosystem-orientated strategy is the way forward, but mechanism for raising the profile of recreational fisheries and biodiversity in the political and economic arenas is needed to achieve this goal.

THREATS

As mentioned throughout this article, aquatic biodiversity is threatened by a wide array of factors, but anthropogenic disturbance seems to underlie the decline and extirpation of many aquatic species. The main perturbations can be broken down into

five key problems, namely species stocking, introductions, translocations and invasions, impoundment of running water (dams and weirs, water abstraction and water transfer schemes), water quality deterioration (pollution, eutrophication, acidification and climate change), habitat alteration and fragmentation (dredging, channelization and land-use change, and mineral extraction) and overexploitation (Richter *et al*., 1997; Cowx, 2002*a*, *b*). These problems seem to be universal. Although many of the issues are being addressed in developed countries through environmental legislation, the rate of progress in reversing the effects is slow. Of these key threats, water resource development schemes are a particular problem because the economic value of such schemes outweighs the presumed fisheries, biodiversity and conservation values of the aquatic ecosystem. Furthermore, the cost of implementing rehabilitation programmes or seeking alternative solutions to the demands on water resources, which underlies many of the issues, is prohibitive in many cases. At best, only a *status quo* is being achieved with respect to habitat quality, and at worst, as is still commonly found throughout the developing world where financial resources are limited, progressive deterioration is rife. Recreational fisheries could play a key role in reversing some of these problems, but the outlook is not positive, given the presumed low social priority of inland fisheries in general. Notwithstanding, the recreational fisheries sector is a large and powerful lobby that demands good environmental quality to maintain the fisheries and thus complements the aspirations of the conservation sector (Kearney, 2002). This institutional capability can be used, in conjunction with legislation, to influence decision-making about remedial actions that will benefit both fisheries and aquatic biodiversity interests. It is critical that conservation bodies engage with the fisheries sector to have a common thrust to their arguments.

Other threatening interactions between recreational fisheries and aquatic conservation interests relate more to fisheries practices. A particularly important pathway by which recreational angling affects the structure and function of fish populations, and potentially entire aquatic ecosystems, is the practice of fish stocking and the introduction or transfer of alien species, non-native genotypes or pathogens (Cowx, 1994, 1999; Lewin *et al*., 2008; Johnson *et al*., 2009; Gozlan *et al*., 2010). Fish-stock enhancement, *i.e.* the stocking, transfer or introduction of fish species, is frequently used in recreational fisheries in the belief that it will improve the quantity or quality of stocks and catches, enhance the angling experience and have long-term beneficial effects on fish stocks (Cowx, 1994, 1999; Arlinghaus, 2006*b*). Most industrialized countries have reported stocking to some degree, as more conventional approaches to fisheries and ecosystem management are perceived to have failed to control decline in fish stocks. Information on quantities of fish stocked is difficult to access, but it is estimated that, for example, in excess of 20 billion Atlantic salmon *Salmo salar* L. of various juvenile life stages, mainly eggs and fry, are stocked annually in western European rivers (Cowx & Godkin, 1999). In Europe, high levels of stocking are also common for rainbow trout *Oncorhynchus mykiss* (Walbaum), coregonids, European eel *Anguilla anguilla* (L.), common carp *Cyprinus carpio* L. and various cyprinids to support recreational and commercial inland fisheries. Some introductions and stocking programmes are carried out illegally because recreational angling demand is high and commercial benefits override the small financial penalties incurred (Cambray, 2003; Hickley & Chare, 2004; Johnson *et al*., 2009). Other introductions occur indirectly through angler activities, for example, the introduction

of non-native invertebrates as bait, such as worms to terrestrial ecosystems (Hendrix *et al*., 2008), aquatic zooplankton through attachment to fishing lines (Jacobs & MacIssac, 2007) or fishes when released from bait buckets (Johnson *et al*., 2009).

While positive benefits can accrue from stock enhancement activities in terms of increased diversity of target fish species, improved catch rates and contributions to local social and economic well-being (Baer *et al*., 2007), negative interactions with indigenous fish communities and other fauna are common and they may be largely irreversible (Araki *et al*., 2007; Gozlan *et al*., 2010), such as the introduction of new diseases (Hewlett *et al*., 2009). These can have direct implications for conservation of biodiversity, especially endemic species that often have little resilience to a new species or proliferation of a targeted species above the normal levels of abundance creating predation pressure on native fishes or other forms of competition (van Zyll de Jong *et al*., 2004; Eby *et al*., 2006). Stocking can also lead to loss of genetic integrity of locally adapted species, especially where the stocking material originates from different catchments (Almodóvar & Nicola, 2004; Hickley & Chare, 2004; Van Zyll de Jong *et al*., 2004). Species-poor fish communities and those with a high degree of local adaptation appear more vulnerable to stock enhancement and invasion by non-native species or genotypes (Cowx & Gerdeaux, 2004).

Despite the negative aspects, introductions and stocking made for recreational purposes can also be beneficial to conservation initiatives because, in some cases, stocked species now support sustainable fisheries of conservation species with no detectable detrimental effects (Hickley & Chare, 2004). Consequently, fish introductions and stocking should not be systematically assumed to be deleterious. Unfortunately, there is often insufficient information on effects of introductions and stocking programmes. Consequently, managers have a dual role to maintain, improve and develop fishing at the same time as having to protect the environment and native aquatic biodiversity. Such a situation can lead to conflict as is currently the case in U.S.A., where there is a discussion whether angler licence revenue can be invested in non-targeted fish species or should be used exclusively for fish species of immediate recreational importance (B. Johnson, pers. comm.). Nevertheless, the threats posed by fish-stock enhancement programmes, especially introductions of non-native genotypes, are particularly insidious because recovery management tools to overcome any adverse effects are generally not available or difficult to accomplish (Gozlan *et al*., 2010). As a result, a precautionary approach should be adopted with regard to the stock enhancement programmes to avoid possible adverse impacts that could compromise aquatic biodiversity (Cowx, 1994).

Recreational fishing is often regarded as more benign to aquatic ecosystems than commercial fishing (Cooke & Cowx, 2006). Recreational exploitation of fishes, however, can have direct effects on fishes and fish populations (Cooke & Cowx, 2006; Lewin *et al*., 2006) and indeed entire aquatic ecosystems (Roth *et al*., 2007). Intensive recreational fishing can induce large-scale, sometimes irreversible, changes in fish communities and aquatic ecosystems. For example, recreational fishing can reduce the population size of target fish species (Post *et al*., 2002) and lower the average size and age of fishes in exploited populations (Goedde & Coble, 1981; Olson & Cunningham, 1989; Beard & Kampa, 1999). Selective recreational fishing exploitation and elevated mortality can thus induce ecological changes in the fish stocks (Cooke & Cowx, 2006; Lewin *et al*., 2006; Arlinghaus *et al*., 2009*a*) as well as alter ecosystem structure and functioning through removal of keystone

species or change in population size structure (Post *et al*., 2002; Roth *et al*., 2007). There is also growing evidence that recreational fishing induces evolutionary changes caused by elevated and selective harvest or catch-and-release angling (Cooke *et al*., 2007; Arlinghaus *et al*., 2009*b*; Philipp *et al*., 2009), which may be difficult to reverse (Conover *et al*., 2009).

Other effects of recreational angling that are relevant in an aquatic conservation and biodiversity context relate to changes to the environment and wildlife (Cooke & Cowx, 2006; Lewin *et al*., 2006). For example, excessive ground baiting (also known as chumming) can result in excessive nutrient inputs to aquatic systems (Niesar *et al*., 2004; Arlinghaus & Niesar, 2005), and certain baits can release toxic chemicals (Rapp *et al*., 2008) that can persist in the environment, with potential deleterious ecosystem effects (Danner *et al*., 2009). In addition, lead poisoning of aquatic birds and accumulation in sediments caused by fishing sinkers have been found (Cryer *et al*., 1987), although the problem appears to be site specific (Goddard *et al*., 2008). There is also a growing literature on the influence of boating activities causing bank erosion through wave action to wildlife disturbance and pollution (Schenk *et al*., 1975; York, 1994; Wolter & Arlinghaus, 2003) or damage to sensitive habitats, such as coral reefs (Yoshikawa & Asoh, 2004). Recreational fishing has been implicated with general disturbance to wildlife, *e.g.* breeding birds, by trampling riparian and littoral vegetation to gain access to the fishery or discarded fishing gear (line in particular) entangling birds and other wildlife (Laist, 1997). While this may be the case in some situations, recreational fisheries are not necessarily negative for aquatic habitat structure, as anglers prefer undisturbed, tranquil conditions and work for their preservation or creation through local action. Furthermore, through the sheer demand for recreational fishing, many water bodies are created or enhanced, which can benefit biodiversity conservation goals because a mosaic of different habitats and water bodies is created or preserved.

Finally, recreational fishing also affects the welfare and well-being of individual fishes where they are not harvested. There is, for example, concern that the holding of fishes at high density in keepnets or other enclosures, coupled with the hooking, playing and handling of the captured fishes, can cause injury and distress (Huntingford *et al*., 2006). To shed light on this issue, there has been a plethora of studies on catch-and-release mortality and sublethal alterations (*e.g*. physiology and behaviour) in recreational fisheries (Bartholomew & Bohnsack, 2005; Cooke & Suski, 2005; Arlinghaus *et al*., 2007*a*; Cooke & Schramm, 2007). In general, these studies suggest that if the fish is appropriately handled and injury and stress are minor, recovery is rapid and no long-term effect is measurable (Cooke & Suski, 2005; Arlinghaus *et al*., 2009*b*; Sumpton *et al*., 2010). Similarly, studies on holding fishes in keepnets suggest that the fishes are not unduly stressed until the density at which they are held is high (Pottinger, 1997; Raat *et al*., 1997) or the type of keepnet or other holding facilities is inappropriate (Cooke & Hogle, 2000; Gallardo *et al*., 2010). In most countries, however, anglers are generally aware of animal welfare issues and do everything possible to minimize the effect of the activity on fisheries and wildlife (Berg & Rösch, 1998). Nevertheless, there is a growing threat from animal rights campaigners to ban recreational angling because it is considered an immoral act inducing pain and suffering in individual fish (Arlinghaus *et al*., 2007*b*, 2009*c*).

OPTIONS FOR THE FUTURE

One of the major problems fuelling the discourse between recreational fisheries and conservation is the widespread lack of ecological knowledge about aquatic species abundance, distribution and population development, and the factors constraining sustainability of the resources. This issue is not unique to recreational fisheries but is generally true for many societies due to lack of applied research and monitoring. Consequently, further efforts need to focus on the underlying problems and how they can be overcome by better governance and management practices rather than implicating recreational fisheries as a threat to conservation *per se*. Recreational fisheries have a vested interest in preserving and increasing fish populations, but little is known about the efficacy and true consequences of the most commonly used recreational fishery management practices, namely rehabilitation programmes, stock enhancement and various harvest regulations. Research should therefore focus on development of low-risk habitat rehabilitation measures and sustainable stock-enhancement strategies as well as optimal regulatory policies and best catch-and-release practices. In view of the critical status of many fisheries, there is a pressing need to take action now and not fall back on the old adage that more research is required to ensure the decisions being made are appropriate. Therefore, some rule-of-thumb management might be needed based on sharing of experiences from more intensively studied systems.

In this context, increasing pressures on aquatic resources dictate that recreational fisheries and non-fisheries defined conservation of biodiversity can no longer be treated in isolation and an integrated approach to aquatic resource management is required (Cowx, 1998; Collares-Pereira & Cowx, 2004; Arlinghaus & Cowx, 2008). Fishing opportunities are constantly being eroded not only by exploitation of fishes directly but also through alteration of aquatic habitat. These activities can lead to the declines in biodiversity such as those that are the subject of the Millennium Ecosystem Development Goals and the CBD. Demands for sustainability of natural resources and the need to arrest the continued alteration of ecosystem functioning and the services they deliver have thus put emphasis on the need to manage exploited resources in a proactive and integrated manner involving all stakeholders and acknowledging the uncertainty inherent in all ecosystem management practices (Carpenter *et al*., 2009; Chapin *et al*., 2009). To this end, traditional conflicts between the recreational fisheries sector and conservation goals, as well as those of other stakeholders, must be resolved by proactively involving all stakeholders in the management process. This can be only achieved through integrated aquatic resource planning and management, enacted through strategies such as the ecosystem approach (Cowx, 1998; Link 2002; Arlinghaus & Cowx, 2008). Catchment management plans, at both the national and multi-national scale, will support this process, but the profiles of recreational fisheries and conservation need to be raised and be better integrated into the planning process. Only through a collaborative approach acknowledging the value of all sectors and the legitimate interest of various stakeholders can effective conservation policies and the preservation of fishes and fisheries be jointly accomplished. It should, however, also be recognized that mechanisms to influence key political players need to be developed if this route is chosen (Granek *et al*., 2008).

To achieve this end, applied scientists are advised to expand their range of activities from objective monitoring and reporting the status of fisheries and biodiversity to more influential and preventative work in partnership with stakeholders. Such an approach with a transdisciplinary focus (*i.e.* where practitioners and scientist work together on common questions and towards common goals) is currently not widely developed but urgently needed (Carpenter *et al.*, 2009; Chapin *et al.*, 2009). In this context, scientists must use the best available data to engage with, and educate, other stakeholders and the wider public. They need to be involved in accurate environmental impact assessments and rehabilitation programmes to argue the case for recreational fisheries and nature conservation in a co-ordinated way. The strategy to be pursued is a greater use and fostering of the environmental stewardship principle to respond to and shape social–ecological systems under conditions of uncertainty and change. This will help sustain the supply and opportunities for use of ecosystem services generated by fishes and aquatic ecosystems (Chapin *et al.*, 2009). In this context, and for many regions of the world, there is a need to elaborate fiscal measures, such as the polluter-pays principle, and enforce already well-developed legislation through the appropriate channels and institutions. This will only be achieved through objective valuation of recreational fisheries resources and biodiversity, an issue that is acting against the fisheries and conservation lobbies at higher political levels. Until this is undertaken, recreational fisheries and biodiversity will continue to be given low priority in any consultation process, and it will remain difficult to attract investments for aquatic conservation measures that also benefit fisheries.

Future action, however, can and must happen within the recreational fisheries sector as well. This entails a thorough analysis and possible adaptation of traditional practices such as the reliance on stocking as well as full compliance with the generally established bans on translocation of non-native genotypes and species across catchments (Johnson *et al.*, 2009). Also, traditional harvest regulations need to be re-analysed to test whether they comply with new knowledge about the effects of recreational fisheries exploitation on stocks (Birkeland & Dayton, 2005; Anderson *et al.*, 2008). Thereby, recreational fishers may restore their locally eroded role as key ambassadors and protectors of aquatic ecosystems by adapting the way some fisheries are managed and exploited.

CONCLUSIONS

Recreational fisheries and biodiversity represent extremely important commodities that are under threat from many sources. Sound proposals are needed that will maintain and enhance recreational fisheries while fulfilling important functions for conservation of aquatic biodiversity. These include, but are not limited to: (1) maintaining recreational fisheries and biodiversity in the face of other aquatic resource developments; (2) investment in the sector, *e.g.* human capital, to promote recreational fisheries and conservation interests jointly using a proactive integrated approach; (3) identifying mechanisms by which the dependence on operations to enhance stocks do not conflict with environmental issues, including mechanisms to enhance fisheries other than through stocking; (4) reconsidering the use of some traditional management tools, such as harvest regulations, in the light of new scientific information to support and promote best practices.

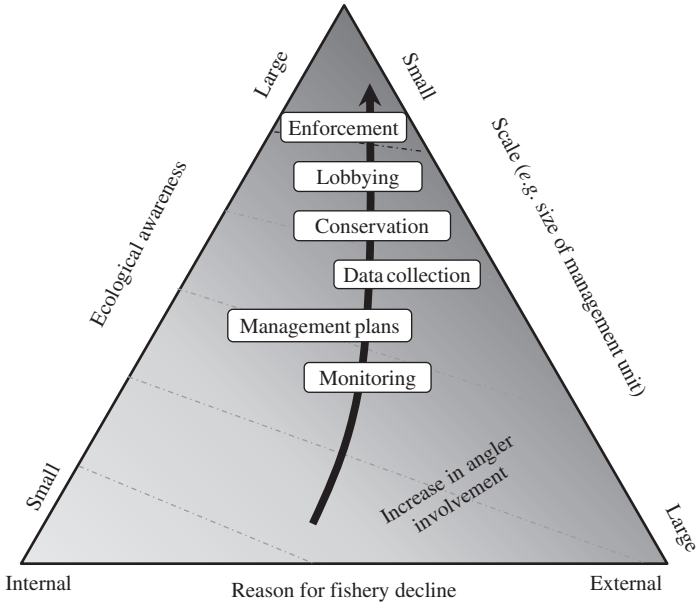

FIG. 2. Synthesis of global case studies of factors influencing involvement of anglers in conservation projects. The contributions of anglers within these projects are given inside the panel in text boxes (modified from Granek *et al*., 2008).

In this context and repeatedly stressed throughout this article, recreational fishing and modern conservation principles do not represent opposite viewpoints. Recreational fishing and conservation share similar ideas, not least because recreational fishing depends on conservation of the resource base. In addition, many angler populations are well prepared to engage in conservation projects because they care for fishes and aquatic ecosystems. Buying into non-fishery defined conservation by recreational anglers is highly likely to be accomplished if three aspects align (Fig. 2): (1) small scale (*e.g*. few water bodies under consideration and small number of avid local anglers within a community, facilitating strong networks and emotional ties to a particular place), (2) effects on local fish stocks external to fishing (*e.g*. habitat loss or cormorant predation) and (3) high level of ecological awareness among local and regional anglers. If these three aspects converge, involvement of anglers in general conservation programmes is likely (Granek *et al*., 2008), and the angler can, and will, support conservation programmes through actions such as monitoring, data collection, enforcement and lobbying (Fig. 2). The issue is more difficult if management scales are large, the anglers are responsible for degrading fish stock, ecological awareness about the need to act is marginal and personal behaviour is not considered important for conservation. Under these situations, strong leadership and networks among various participants, appropriate legislation and constructive and long-lasting communication with anglers are needed to bring about change and action.

In this respect, there is a need for general guidelines that are readily understandable by stakeholders and fisheries administrators alike. In particular, there is a need

to encourage uptake of codes of practice, such as that developed under the auspices of the European Inland Fisheries Advisory Commission (EIFAC) (EIFAC, 2008; Arlinghaus *et al*., 2010), to facilitate appropriate management of recreational fisheries activities, thereby contributing towards mitigation of the adverse effects identified previously. Widespread adoption of this voluntary code by management agencies and angling bodies could help harmonize the relationships between recreational fisheries and conservation stakeholders and provide a united front to tackle environmentally damaging development projects. This initiative should be supported by specific protocols that target the potentially most damaging recreational fisheries practices, specifically some fish-stock enhancement and habitat-modification practices, to improve access and the angling experience. It is therefore recommended that existing guidelines for stocking and introductions be updated and incorporated into national and local level policy. As proposed by Cowx & Gerdeaux (2004), it is also recommended that risk-assessment based approaches be adopted for all fisheries management activities and the strength of legislation and regulation should relate to the potential risk of the management interventions. By taking this and other actions, reconciliation of recreational fisheries and modern conservation concerns is possible, not least because the recreational fisheries sector represents a powerful source of action, lobbying and engagement for conservation of aquatic biodiversity worldwide.

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