CHAPTER 4.4

Recreational fisheries in inland waters

Steven J. Cooke[1], Robert Arlinghaus[2,3], Brett M. Johnson[4] and Ian G. Cowx[5]

[1] Fish Ecology and Conservation Physiology Laboratory, Institute of Environmental Science and Department of Biology, Carleton University, Ottawa, Canada

[2] Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

[3] Faculty of Life Sciences, Humboldt-Universität zu Berlin, Berlin, Germany

[4] Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, USA

[5] Hull International Fisheries Institute, Department of Biological Sciences, The University of Hull, Kingston-upon-Hull, UK

Abstract: Recreational fisheries represent the dominant fisheries sector targeting wild freshwater fishes in all industrialized nations and are becoming increasingly popular in some emerging economies. The socio-economic benefits of recreational fisheries are numerous and substantial. Recreational fisheries through their practices (*e.g.* overharvest, habitat change, release mortality, stocking and dispersal of non-native fishes), however, have been implicated in negative effects on populations and ecosystems. In inland waters, fish populations also face a variety of threats that are external to the recreational fisheries sector such that recreational fisheries often operate on top of already imperilled resources. This chapter characterizes the scope and magnitude of inland recreational fisheries globally, explores recreational fisheries as a coupled social–ecological system, reviews management strategies, identifies the main issues faced by inland recreational fisheries and discusses the future of recreational fishing in inland waters with an emphasis on research and information needs to ensure their long-term sustainability.

Keywords: angling, catch and release, exploitation, fisheries management, fresh water, inland, recreational fishing, sustainability

Introduction

A bowfisher takes aim at a common carp *Cyprinus carpio* in a slow-moving river in West Virginia. A family enjoys a sunny day on the Laurentian Great Lakes as they troll for native lake trout *Salvelinus namaycush* aboard a charter boat hoping to capture food for a shore lunch. Match anglers stand shoulder to shoulder as they target cyprinids in a competitive angling event in a small stillwater fishery in England, releasing all fishes. Tourists travel to remote regions of Mongolia in an attempt to hook up on a (endangered) taimen *Hucho taimen* and let it go to be caught another day. In Patagonia, a fly angler strips her line in a montane stream as an introduced rainbow trout *Oncorhynchus mykiss* inhales the fly. Anglers on the Zambezi River in Zimbabwe try to catch the largest tigerfish *Hydrocynus vittatus* of the day as part of a competitive live-release angling event. In Norway, an auger bores through the ice providing an angler access to fishes in the winter.

As these examples show, recreational fishery types are varied; they can be wild, supplemented, cultured or some combination (Cowx, 2002*a*; see Table 4.4.1). All of the individuals described earlier are participating in recreational fishing in inland waters of one form or another (see Figs 4.4.1, 4.4.2 and 4.4.3 for examples), which emphasizes the challenges in arriving at an inclusive definition. The discipline of leisure research defines recreational fishing as a goal-directed behaviour in which participants seek to meet multiple satisfactions (*i.e.* psychological and physiological needs such as affiliation, achievement and adoration; Hendee, 1974). Most abstractly, recreational fishing is fishing of aquatic animals (mainly fishes) that do not constitute the individual's primary resource to meet basic nutritional needs. Fishes are not generally sold or otherwise traded on export, domestic or black markets (Arlinghaus & Cooke, 2009; FAO, 2012). Therefore, the lack of individual desire to generate essential survival resources and the lack of market of the fish products are a characteristic of most recreational fisheries worldwide, although it is worth noting that there is a fine line between subsistence and recreational fisheries in some locales. If these occur in fresh water (*i.e.* inland), the activity is freshwater recreational fisheries, the focus of this chapter.

Freshwater Fisheries Ecology, First Edition. Edited by John F. Craig.

Table 4.4.1 Characteristics of different types of recreational fisheries with relevant examples. Note that a single waterbody may have different types of fisheries in operation. For example, a wild endemic lake fishery for *Micropterus dolomieu* could also have a cultured put-grow-and-take fishery for *Salvelinus namaycush* in the same system. The fishery types described here where stocking is involved tend to be focused on developed countries where there are active management programmes and capacity (both technical and financial) to stock

Type of recreational fishery	Characteristics	Examples
Wild endemic	Wild endemic fisheries rely entirely on natural reproduction and feeding of endemic fishes with productivity limited by the environment and reproductive potential of the target stock	*Micropterus salmoides* in Wisconsin; *Perca flavescens* in Lake Erie
Wild introduced	Same as wild endemic but at some point in the past, humans have introduced fishes that have since become naturalised and reproduce on their own with no recent stocking Quite common and in some cases, stakeholders may assume that the introduced species are endemic given the lack of contemporary stocking especially for introductions that occurred decades ago	*Salvelinus fontinalis* of eastern North America introduced into streams in the Rocky Mountains of Alberta, Canada *Micropterus dolomieu* introduced into lake of Algonquin Park, Ontario, Canada
Wild endemic – supplemented	Wild endemic populations as above, however, the productivity of the system or reproductive rates are insufficient given the level of fishing such that additional individuals of the endemic species are stocked to enhance fishing opportunities Often but not always with a target of rebuilding populations such that stocking can cease but in some cases a proportion of the population is presumed to be just for harvest	*Maccullochella peelii* in rivers of NSW, Australia; *Sander vitreus* in lakes of central ON, Canada; *Sander lucioperca* and *Esox lucius* in German lakes
Wild introduced – supplemented	Wild introduced as above but with stock enhancement to improve or maintain the population and associated fishing opportunities Often but not always with a target of rebuilding populations such that stocking can cease but in some cases a proportion of the population is presumed to be just for harvest	*Oncorhynchus* spp. stocking programme on the Laurentian Great Lakes where there is some natural reproduction but not sufficient to support the recreational fishery
Cultured (put and take)	Often referred to as put-and-take fisheries where the assumption is that the fishes will not or cannot reproduce or potentially even grow or survive long term such that the fishes that are stocked are of adequate size to be harvested Common in urban environments or high-use areas where there is public demand for and socio-economic benefit of having such fisheries even though they are extremely expensive (fishes have to be grown to catchable size in culture facilities)	Adult *Oncorhynchus mykiss* and *Salmo trutta* in small ponds throughout much of North America (*e.g.* Maryland); adult *O. mykiss* in small lakes in Alberta, Canada, where winterkill makes establishing other types of fisheries impossible; adult *S. trutta* and *O. mykiss* stocked into ponds during holiday periods close to urban and regional centres in Victoria, Australia
Cultured (put, grow and take)	Often referred to as put-grow-and-take fisheries where the assumption is that the fishes will not or cannot reproduce but do have the potential to grow Less expensive than put and take (on a per fish basis because fishes usually stocked as fry) but the stocked fishes are subject to the same natural laws (*i.e.* predation, starvation and disease) such that mortality can be high so few fishes grow to catchable size	A variety of *O. mykiss* and *S. trutta* ponds and lakes in North America and Australia

Adapted from Cowx (2002*a*).

Fishing with rod and reel is the most common recreational fishing technique, which is why recreational fishing is often used synonymously with angling (Arlinghaus *et al.*, 2007*a*). In some countries, however, recreational fishers use gear such as spear, bow and arrow, rifle, traps or gillnets (Arlinghaus & Cooke, 2009). In many countries, fishes are taken home for personal consumption, but a variable proportion are released (termed catch and release) either due to conservation ethic of the angler, because of culinary dislike of the captured fishes, because of too many or few or fishes of an undesirable size, or to be compliant with harvest regulations (Arlinghaus *et al.*, 2007*a*).

Recreational fisheries represent the dominant fisheries sector in terms of participation (but not always catch or harvest) targeting wild freshwater fishes, particularly in industrialised nations (Arlinghaus *et al.*, 2002). In some developing countries and emerging economies, there is also a growing interest in recreational fisheries (*e.g.* Argentina, Brazil, China and India) (FAO, 2010, 2012). The socio-economic benefits of recreational fisheries are numerous and substantial (Arlinghaus *et al.*, 2002; Parkkila *et al.*, 2010). Recreational fisheries through practices such as intensive harvest, hooking mortality and illegal introductions of non-native fishes, however, have been implicated in affecting fish populations and indeed entire ecosystems (Post *et al.*, 2002; Cooke & Cowx, 2006; Lewin *et al.*, 2006; Altieri *et al.*, 2012). Freshwater fish populations also face a variety of threats that are external to the recreational fisheries sector (Arlinghaus *et al.*, 2002; Cowx *et al.*, 2010), resulting in recreational fisheries often targeting already altered fish populations due to anthropogenic habitat modification for agriculture, hydropower, water extraction and flood control. Given the growing importance

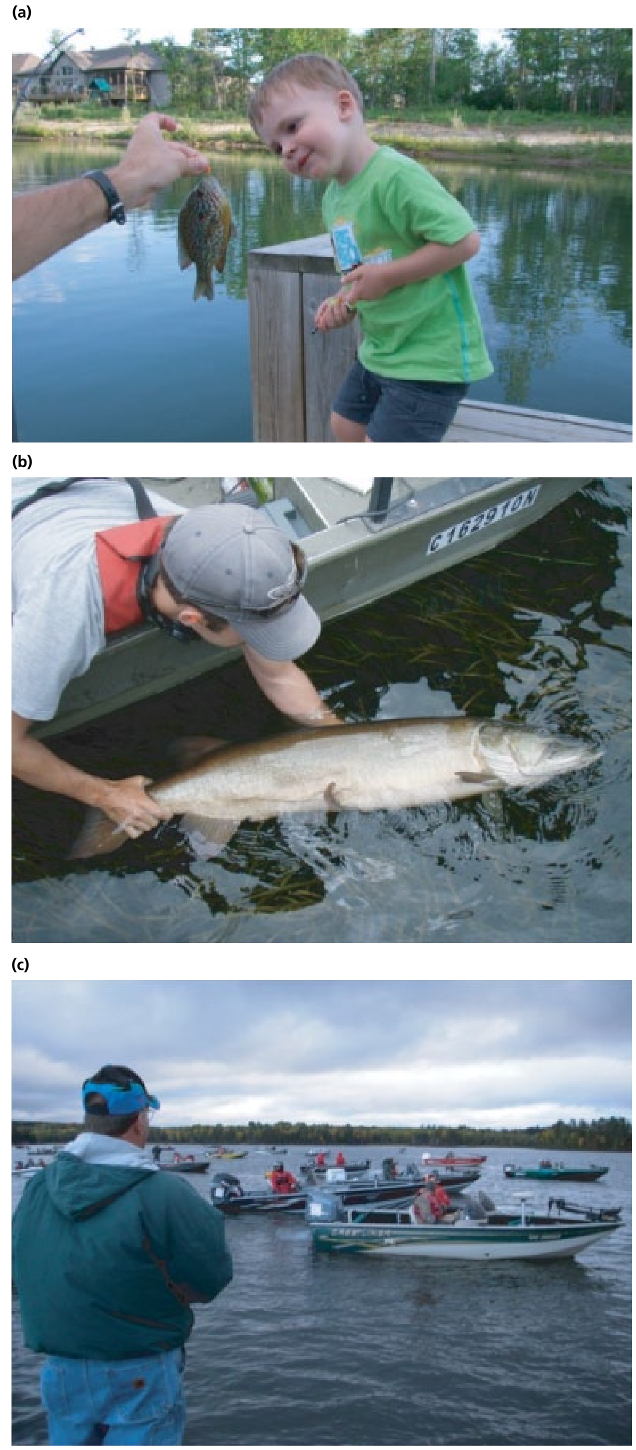

Figure 4.4.1 (a) A child fishes with his father for sunfish *Lepomis gibbosus* in a small lake in eastern ON, Canada, emphasizing one of the socio-economic benefits of inland recreational fisheries (time with the family) (Photograph by Andrea Cooke). (b) A trophy muskellunge *Esox masquinongy* captured by a specialized musky angler on a river in eastern ON, Canada, where release rates approach 100% (Photograph by Sean Landsman). (c) A black bass *Micropterus* spp. fishing tournament in northern ON, Canada, where anglers compete for the largest mass for the daily bag limit. Fish are retained in aerated live wells aboard the boat until weighing at a central weigh-in station at the end of the day when fish are released (Photograph by Steven Cooke).

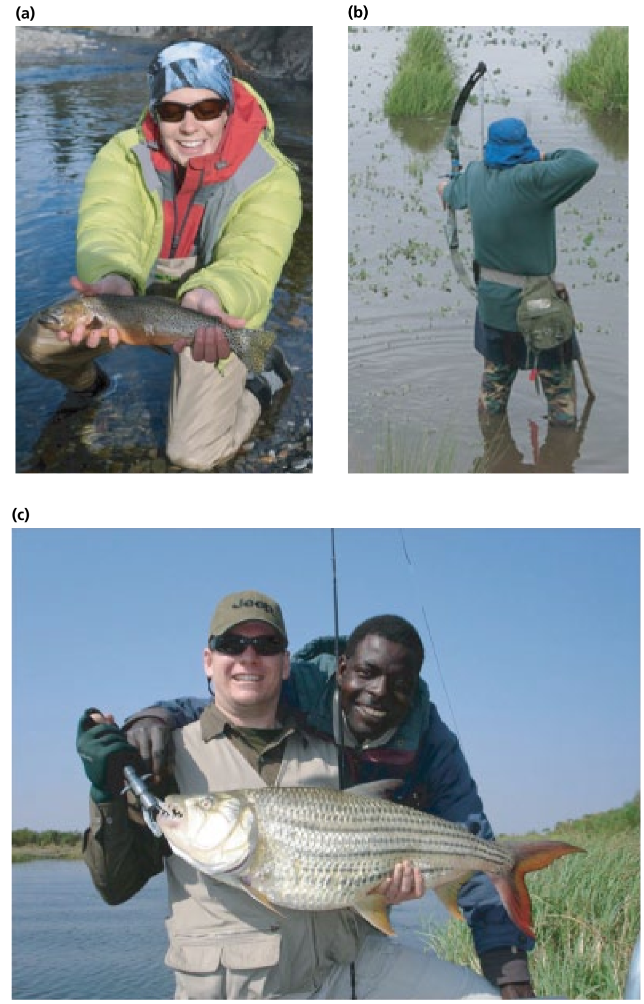

Figure 4.4.2 (a) A female angler captures a native salmonid in a small stream in AB, Canada, with fly fishing gear (Photograph by Mark Taylor). (b) A bowfisher takes aim at an invasive koi carp *Cyprinus carpio* in the Whangamarino wetlands, Waikato, New Zealand (Photograph by Dave Gousmett). (c) A tourist poses with his guide at a lodge on the Zambezi River in Zambia, Africa, while holding a tigerfish *Hydrocynus vittatus* caught on rod and reel (Photograph by Garreth Coombes).

(and recognition) of the recreational sector in inland waters and the fact that the management of recreational fisheries is embedded within a complex suite of non-fishing influences and competing uses, we focus this chapter on recreational fisheries and outline a road map of its characteristics and major management approaches. Our work complements earlier syntheses on the very same topic (Cowx, 2002*b*; Arlinghaus & Cooke, 2009), but in contrast to earlier papers, we will focus exclusively on fresh water.

The objectives of this chapter are to (1) characterize the scope and magnitude of inland recreational fisheries globally, covering participation rates, capture and harvest, effort and socio-economic benefits; (2) consider the natural and human ecology of inland fisheries with a focus on their interconnectedness (*i.e.* coupled social–ecological systems); (3) review management approaches for inland recreational fisheries;

Figure 4.4.3 (a) An angler uses an ice auger to drill a hole through the ice in preparation for ice fishing in ON, Canada (Photograph by Greg Bulte). (b) An angler tends several tip-up rigs used to fish passively in the winter on the St Lawrence River, Canada (Photograph by Greg Bulte). (c) An angler jigs a minnow bait under the ice while fishing for pike *Esox lucius* in the Northwest Territories of Canada (Photograph by Karen Murchie).

(4) consider the future of inland recreational fisheries in the context of threats and opportunities; (5) identify information needs for long-term sustainability of inland recreational fishes and fisheries. Our approach is inherently global, although the literature and scientific knowledge are biased towards recreational fisheries in developed regions including North America, Europe and Australia. We attempt to highlight differences and unique challenges associated with recreational fisheries development in developing countries and emerging economies. We include recreational fisheries that target anadromous and catadromous fishes but only discuss the freshwater phase. Recreational fisheries are also popular in nearshore marine waters (Coleman *et al*., 2004), although are often overshadowed by the commercial sector. We use the words inland and fresh water interchangeably, although technically inland refers to waters upstream of any tidal influence. Where relevant, we draw comparisons between the recreational sector in marine and inland waters.

Characteristics of the inland recreational fisheries sector

There are a number of challenges in characterizing the global inland recreational fisheries sector in terms of participation, catch and harvest and economic value, particularly with respect to regional and temporal trends. The challenge mainly emerges from inconsistent national surveys and the lack of comprehensive data on which to base a global assessment (Worm *et al*., 2009). An understanding of these limitations is a necessary prerequisite to presenting and interpreting quantitative information on trends in inland recreational fisheries. Quite simply, most jurisdictions fail to monitor basic characteristics of the sector, and when they do so, it is rarely done annually and often without the methodological rigour for valid extrapolations (*e.g.* random sample with non-response bias corrections). Some jurisdictions use licence sales to estimate participation rates (which usually underestimate participation; Arlinghaus, 2008), while a few jurisdictions such as the United States and Canada do regular off-site surveys of high quality using some form of randomized probability sampling. The Food and Agriculture Organization (FAO) of the United Nations solicits information on annual catch and value, but only recently has the recreational sector (in either realm) begun to be routinely reported by member countries, and if done, there is the issue of valid catch information at the national scale, which again depends on proper surveys that are highly challenging to implement. Most available estimates therefore probably represent dramatic underestimates. Given the above, the numbers and trends presented here are drawn from those jurisdictions and data sets where such information exists, if accessible and when judged methodologically reliable.

Participation, motivation and diversity

The prevalence of recreational fisheries is not confined to fresh waters as recreational fishing is present in 76% of the world's exclusive economic zones (Mora *et al*., 2009). Participation rates at national or regional scales are typically generated without reference to whether fishing is targeted towards inland or marine systems, which makes it difficult to determine what proportion of global recreational fishing activity is actually focused on fresh waters. On average across countries with reliable statistics, the participation rate in all recreational fishing by the total population in a given country is $10.6 \pm 6.1\,\%$ (mean ± S.D.) (Arlinghaus & Cooke, 2009). In light of this estimate, *c.* 140 million recreational fishers are present in three of the most industrialized continents alone, North America, Europe and Oceania, many of which fish both in fresh and marine waters. Extrapolating to the globe is more difficult due to the paucity of information on participation rates in recreational fishing in less developed and low-income countries, but global estimates range from 220 million (World Bank, 2012) to a maximum of 700 million recreational fishers globally (Cooke & Cowx, 2004). Hotspots of recreational fishing participation are found in relatively sparsely populated, but freshwater- or coastline-rich industrialised countries, such as the Scandinavian countries, Australia and North America. In each of these countries, >10% of the adult population engages in recreational fishing, with record values of close to 40% reported from Norway. It is important to be reminded that the reported low levels of participation from selected countries, *e.g.* in Southern Europe (Hickley & Tompkins, 1998), are likely to be the result of weak data rather than low participation overall. Indeed, recreational fishing participation is often reported to be low in many Eastern European countries (Arlinghaus & Cooke, 2009), although it is well known that a substantial number of people participate in this type of fishing, maybe more than in Western and Central European countries. The difficulty here arises because of the grey area between recreational fisheries as defined previously and recreational fisheries that err towards subsistence fishing, and this problem is exacerbated in low-income countries where families fish to supplement their diet.

The reasons for variation in participation rates among jurisdictions and population segments are only beginning to be understood. Arlinghaus (2006) reviewed existing studies relating demographics on the probability of becoming a recreational fisher and tested a range of these factors in a German sample. He found that the probability of being an angler was significantly higher for males with full-time working status, living in rural areas and near the coast. Educational level and household size were negatively related to angling participation probability, while increasing net monthly household income increased the odds of engaging in recreational fishing, probably due to the resources available in the household. A more recent cross-country participation regression model confirmed many of these predicators to explain variance in angling participation across countries suggesting a peak in participation with industrialisation, after which interest in angling continues but not at the same level (*i.e.* it declines; R. Arlinghaus, R. Tillner and M. Borck, Unpublished data). Considering that in absolute terms many of the proponents of angling and hunting are now from urban rather than rural environments (Franklin, 1998), despite lower participation rates in more urbanised societies, there is interest in enhancing opportunities for urban fishing in an attempt to reverse the decline (Hickley *et al*., 2004). Dedicated marketing can increase interest in fishing in a given society, which can therefore provide very good value per monetary investments by agencies depending on high participation to legitimate their work and maintain financial income (Aprahamian *et al.,* 2010). It is worth noting that this probably does not apply to developing countries.

Related to participation, one may ask, ‘Why do people engage in recreational fishing’? According to social–psychological expectancy theory, people participate in fishing to reach personal goals, termed preferred psychological outcomes (Manfredo *et al*., 1996). The motivations for fishing vary extensively within the angling community in line with the diversity of people engaging in the activity (Beardmore *et al*., 2011). The different experiences sought by recreational anglers can be viewed in terms of two generic sets of elements: activity specific (unique to that activity, *e.g.* desire to catch fish for eating) and activity general, which are common motives that can be realised in many outdoor recreation activities, *e.g.* achievement motives (Fisher, 1997). Activity-specific elements include the species sought, size of fish, number of fish, setting in which they are caught, disposition of the catch (*e.g.* releasing *v.* harvesting), pulling strength of the fish and method by which the fish is caught. Activity-general elements are relaxation, being with peers and friends, experiencing natural surroundings, escaping and being outdoors, among other things (Fedler & Ditton, 1994). There is a vivid debate if many of the so-called activity-specific motivations are actually components of activity-general motivations. For example, catching hard fighting fish might be a mechanism to fulfil general achievement motivations. Irrespective of this ongoing discussion, previous motivation research has revealed that recreational fishing constitutes a multifaceted outdoor experience in which people seek multiple benefits, both catch and non-catch related (Hendee, 1974; Driver & Knopf, 1976; Fedler & Ditton, 1994). The importance of the catch along with non-catch motivations has been shown to vary among angler segments (Bryan, 1977). A German study has shown that irrespective of catch motivation, most anglers value catching fish and depend on it to achieve a satisfactory experience, *inter alia* because non-catch experience components are more easily satisfied and under direct control by the angler (Arlinghaus, 2006).

Economists would take a similar view and state that recreational fishers go fishing because they receive utility from the experience (Anderson, 1994). Utility is a common currency that also unites commercial fisheries; it is the component of utility that differ in recreational fisheries encompassing both activity-general (*e.g.* relaxation and enjoyment of nature) and activity-specific motivations (*e.g.* experiencing a fight with a large fish; Fedler & Ditton 1994).

There has been a long tradition in attempting to understand the diversity of angler types and develop frameworks for typologies that then allow prediction of behavioural patterns and attitudes and preferences of angler. A framework to capture the diversity of anglers is recreational specialization developed by Bryan (1977) and further conceptualized by Ditton *et al.* (1992) in the context of fishing. Accordingly, anglers can be arranged in a continuum of behaviour from the general to the specific, reflected by equipment used, settings desired and behaviours revealed (*e.g.* whether anglers have a tendency to release or harvest fish) (Bryan, 1977). Although the specialization framework is well suited to capture the heterogeneity of anglers, no agreement on operationalisation of the framework has been achieved. The utility of the framework, however, should not be devalued; see, for example, the study by Johnston *et al.* (2010) that highlights the importance of the framework. The authors showed that optimal regulations were tightly dependent on which angler type it was designed for. This calls into question the pursuit of 'one-size-fits-all' policies that are prevalent in many jurisdictions (Daedlow *et al.*, 2011). In terms of participation, the general trend is for the more committed (specialized) anglers to take more trips per year, benefit more from the experience, harvest fewer fish (although see Dorow *et al.* (2010) for a study where more committed anglers harvest more) and be more receptive for conservation messages (Oh & Ditton, 2006) than less committed anglers.

Effort, harvest and release

Information on recreational fisheries capture and associated harvest and release is a prerequisite for conducting stock assessments common in marine fisheries. Hence, one would assume such information would be widely available. In reality, there is relatively little information on the magnitude of harvest and release by regional or national recreational fisheries. Creel surveys (Pollock *et al.*, 1994), sophisticated complementary surveys (Lyle *et al.*, 2002; Dorow & Arlinghaus, 2011) and voluntary angler diary programmes (Cooke *et al.*, 2000) have all been used largely on specific waterbodies or for specialized fisheries (*e.g.* muskellunge *Esox masquinongy*), but scaling that information to broader spatial scales is difficult (Lyle *et al.*, 2002; Dorow & Arlinghaus, 2011). As such, estimates of global recreational fisheries harvest specific to inland waters are unavailable. On a national scale, mail surveys have been executed in Canada every 5 years and provide some of the best information on inland fisheries capture and release, although they tend suffer from recall biases and overestimate landings. Accordingly, in Canadian fresh waters, anglers caught >193 million fishes of all species and retained nearly 63 million (DFO, 2012). On average, each resident angler kept 21 fish in 2010, which equated to a release rate of *c.* 63%. Cooke and Cowx (2004) scaled the data from Canada in 2000 to the global stage (both inland and marine) and estimated that 47.10×10^9 fishes were landed on a global basis annually, of which 17.09×10^9 fishes are harvested, weighing 10.86×10^6 t. There is no simple way to estimate what proportion of that harvest is attributed to inland waters, but even if it were 25–50%, it would represent a significant component of all inland fish production (Welcomme, 2011).

Socio-economic benefits

Recreational fisheries have high socio-economic and socio-cultural importance and provide a significant number of diverse benefits to society (Weithman, 1999; Pitcher & Hollingworth, 2002; Parkkila *et al.*, 2010). To a recreational angler, a fishing trip is an experience that includes multiple dimensions as described earlier. A fishing trip has also a planning phase and a recollection phase (often inspired by photographic records and interaction with peers), as well as the event itself. Each of these phases is generally viewed positively by anglers and therefore has benefits that accrue to anglers (Pollock *et al.*, 1994). In addition, other sectors benefit from anglers by receiving angler-generated revenues, which, from the perspective of the angler, reduce the utility received by the individual that is engaged in fishing. Generally, three domains can be distinguished, where benefits are accrued in recreational fisheries, namely, economic, social and ecological benefits of recreational fisheries (Arlinghaus & Cooke, 2009; Parkkila *et al.*, 2010). All social benefits can, in principle, be expressed in monetary values and constitute the mechanistic basis of value as perceived by anglers.

Although recreational fishing does not contribute substantially to generating resources for the survival of the fisher, it does not mean that there is no economic activity associated with recreational fisheries. The spillover economic effects associated with recreational fishing create a multibillion dollar industry that supports economic activity and livelihoods for many (Arlinghaus *et al.*, 2002). Such effects are called economic impacts that are not to be confused with the concept of economic value (Edwards, 1991). Indeed, in terms of value, from the perspective of the individual fisher, the participation in recreational fishing creates utility over and above the expenditures needed to participate in fishing, and a social planner would maybe want to maximize this value for the individual. Because expenditure is reduced utility to the fisher, net willingness to pay is considered the appropriate economic measure to value the experience and the well-being created by fishing in the population of anglers. Despite the economic rigour of economic value, however, in many countries, there has been a focus on economic impact assessments (Probst & Gavrilis, 1987) to value the fishery. For example, the value of each rod caught Atlantic salmon *Salmo salar* in Ireland is >€400 (Indecon, 2003). Unfortunately, expenditure and economic impact data do not fully account for the full economic value of a recreational fishery including the non-use values (*e.g.* value to an individual of maintaining the option to use a resource the future, value to an individual knowing that a resource is available for future generations to use and value derived by an individual from knowing that a resource exists and that others have the opportunity to use it; Riechers & Fedler, 1996; Weithman, 1999; Parkkila *et al.*, 2010). For recreational fisheries conservation as well as management, it is essential to provide a thorough economic evaluation of fisheries to defend the position of the sector against aquatic resource development schemes (Cowx, 1998, 2002*a*). Nonetheless, expenditure by recreational fishers represents revenues and jobs in local economies and is certainly worth considering in particular if 'new' money is generated in a given region, creating well-being effects. For example, in Lake Texoma, the recreational fisheries in 1990 were valued at US $\$25.641 \times 10^6$ on the regional economy (Schorr *et al.*, 1995). Direct, indirect and induced impacts of these expenditures were directly associated with US $\$57.392 \times 10^6$ in total business sales, US $\$23.273 \times 10^9$ in value added and 718 jobs in the impact region. In Germany, recreational fishing is responsible for feeding a $€5.2 \times 10^9$ industry, with 52 000 jobs dependent on this expenditure (Arlinghaus, 2004).

Social impacts of recreational fishing are somewhat elusive (Vanderpool, 1987) and typically relate to quality of life and social well-being associated with fishing (Gregory, 1987). Brown and Manfredo (1987) identified four categories of social value in recreational fisheries: cultural, societal, psychological and physiological. The former two pertain more to nations and regional communities, whereas the last two relate to individuals and thus are the representation of the economic value expressed as net willingness to pay as elaborated before (Weithman, 1999; Kearney, 2002). Cultural values represent a collective feeling towards fishes and fishing. Fishing is an important societal asset and is valued by the community as a whole. Societal values are based on relationships among people as part of a family or community (*e.g.* family fishing). Psychological values are those that relate to motivation and desires associated with the use, or knowledge of the existence, of a fishery. Meeting these motivations or needs can be regarded as meeting basic benefits sought by the fisher, but complex interactions are conceivable. For example, for some anglers, catching fish is irrelevant if it is not conducted in a particular natural environment (Bryan, 1977), or alternatively, satisfaction might be only moderate if non-catch aspects of the fishing (*e.g.* camaraderie) are excellent, but catch is weak and only then be rated excellent if the catch expectations are met (Arlinghaus, 2006). Physiological values of recreational fishing relate to improvements in human health (*e.g.* reduction of stress) related to fishing (Weithman, 1999). Ulrich *et al.* (1991) reported that the level of stress people experienced decreased rapidly when exposed to more natural compared with purely urban environments.

Inland recreational fisheries as coupled social–ecological systems

For the purposes of this synthesis, we position recreational fisheries with the framework of a coupled social–ecological system (also called human–natural or ecological–economic systems; see Fig. 4.4.4). We recognize the importance of understanding the environment in which fishes live, feed, reproduce and compete, as well as the natural dynamics of aquatic systems

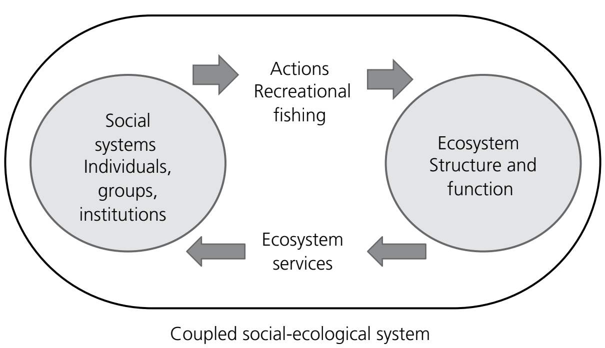

Figure 4.4.4 Conceptual diagram of elements of a social–ecological system with recreational fishing and recreational fisheries management as the assumed actions. This modifies ecosystem structure and function both directly and indirectly and provides ecosystem services, including recreational experiences, to the social system.

(Sigler & Sigler, 1990). Chapters on freshwater ecosystems and their dynamics (Moss, 2015; Petts *et al.*, 2015; Potter *et al.*, 2015) and recruitment processes (Johnston *et al.*, 2015), however, are covered elsewhere in this book. Given that in recreational fisheries it is impossible to divorce the actions of the fisher and the managers from ecological processes, it is unwise to consider the various components independently (Hunt *et al.*, 2013).

Coupled human and natural systems are integrated systems in which people interact with natural components in nonlinear ways across space and time (Liu *et al.*, 2007*a*). As a result of this interaction, emergent properties are to be expected that cannot be predicted from 'breaking the system' into pieces and studying them in isolation (van Poorten *et al.*, 2011). Recreational fisheries constitute a prime example of a coupled social–ecological system (Carpenter & Brock, 2004; Hunt *et al.*, 2013). An inherent component of such systems is their complexity given that they include both ecological and human components and their interconnections (Liu *et al.*, 2007*b*). Coupled social–ecological systems self-organize, they adapt and they show thresholds and potentials for regime shifts. Moreover, these systems are highly connected over multiple spatial contexts, and they constantly vary temporally, spatially and institutionally. Recreational fisheries have always operated as coupled social–ecological systems, and one can argue whether the economic theory of recreational fisheries considers this precisely (Anderson, 1994), but formally recognizing them as such and adapting research, monitoring, management and institutions to reflect such integration have been relatively recent (Carpenter & Brock, 2004; Cowx & van Anrooy, 2010; Hunt *et al.*, 2013).

At a most primal level, the fisher can be considered as a predator in an ecological sense (with its fitness function being multidimensional and affected by both catch and non-catch factors; Hunt, 2005) and the fish the prey (Post *et al.*, 2008). This perspective emphasizes the role of humans (fishers) in the ecosystem in a biological sense. One can integrate this perspective with optimal management of recreational fisheries by searching for regulations that optimize the experience for a population of mobile anglers as predators exploiting single fisheries (Johnston *et al.*, 2010, 2013) or landscapes of fisheries (Hunt *et al.*, 2011). In this context, it is necessary to consider the dynamic interaction between fishes and fishers explicitly (Johnson & Carpenter, 1994; Post *et al.*, 2008; Hunt *et al.*, 2011) and perceive angler behaviour as an important factor of the dynamic system (Post, 2013).

To represent the dynamic interaction of angler and their prey, a behavioural model is needed. One can refer to expectancy theory mentioned previously or derive such a model from random utility theory borrowed from economics (Johnston *et al.*, 2010). Put simply, angler desire well-being from recreational fishing, which often includes the successful capture of fishes. Well-being (alternatively termed satisfaction or welfare) can take many forms and can include psychological and physiological needs (Maslow *et al.*, 1970), as well as those that are cultural or societal

(Brown & Manfredo, 1987). When recreational fishing is of 'high quality', it provides utility and high well-being to the angler. This, in turn, will attract anglers aiming at reaping some of this utility, which in fisheries terms means that effort is attracted (Fenichel *et al*., 2013). At some level, the increase in effort leads to effects on the fish population, possibly aggravated by inverse density-dependent catchability, which results in the 'illusion of plenty' (Hunt *et al*., 2011). If angler utility is mainly catch related and substitutes are available, self-regulation can be expected (Hunt *et al*., 2011). Most often, however, anglers do not only value catch but also a good scenery, facilities and other aspects, which keeps effort attracted at a fishery, even if fish stocks decline (Hunt *et al*., 2011). When fishing becomes sufficiently poor that the well-being of the predator (fisher) is sufficiently low, the fishing will probably decrease, resulting in 'utility' overfishing and possible recreational demise. At that point, most resilient systems will recover until the system again begins to offer the predator an ability to generate well-being and then the process repeats itself.

This simplistic feedback and interconnectedness of the fisher and the fish have been documented over the past decade in a number of recreational fisheries. For example, in a lake district in the interior of British Columbia, *O. mykiss* stocks in different lakes are connected by a highly mobile angler population. Predator–prey theory predicts that fisheries of equivalent access costs (*i.e.* travel distance, time or financial costs) should have equal catch rates and effort. Angler behaviour and dynamics become complex such that when fishing declines due to high effort, effort shifts to other lakes. When those systems recover [provided no collapse, in British Columbia, there is active stocking (Arlinghaus *et al*., 2015) to minimize chance of collapse; Post *et al*., 2002], angler behaviour again shifts such that those systems become targeted. Prior to the last decade, these phenomena were poorly understood. Considering anglers as predators with complex behaviour linked to their well-being has enabled novel modelling exercises (Post *et al*., 2008), but those authors note that there is a need to enhance our understanding of the spatial and temporal processes involved in both the harvest and production sides of this dynamic interaction (*i.e.* the coupled social–ecological systems) if we are to design more effective management strategies. Hunt *et al.* (2011) and Massey *et al.* (2006) have pushed forward more theoretically consistent angler behavioural models, linking them to complex age- and size-structured fish population models. These integrated models can serve as a framework to improve the broadscale landscape management perspective that Lester *et al.* (2003) pioneered.

The scenario presented provides an advantage over classical assumptions of an angler as a predator by allowing multiple attributes of a site to influence utility of anglers and hence site choices. Indeed, there are many factors that influence angler behaviour and resultant effort. Hunt (2005) reviewed the factors that influence recreational fishing site choice using a random utility theory framework. Such a framework assumes that an angler will select the one fishing site from a set of relevant fishing sites that provides them with the greatest utility and that this utility measure for each fishing site is based on attributes for the site (*e.g.* fisheries quality, environmental quality, facility development, regulations, encounter levels and waterbody size) and the separation or cost of accessing the site by the individual (*e.g.* travel distance or travel costs). From a pragmatic perspective, anglers subconsciously integrate these weighted attribute measures to identify and choose the fishing site that will yield maximum utility. Utility will vary among anglers and also for a given angler through time, which can in turn be used even as a management objective to substitute maximum sustainable yield. Johnston *et al.* (2010) show how managing for angler utility can generate a biologically sustainable resource, which happens to be the case across many fish life histories (Johnston *et al*., 2013). Not all aspects of utility, however, can be easily measured, such that utility functions rarely account for the full suite of factors considered and weighed by individuals (Manski, 1977). This in turn would create uncertainty in the substitutability patterns by anglers. In other words, when preferred fishing sites are changed in some way (*e.g.* change in regulation and water quality), anglers may redistribute their fishing effort (*i.e.* substitute) to other sites in other ways as represented by a statistical utility model if important components of choice or social interactions are simplified or omitted.

As discussed earlier, there is immense heterogeneity in angler motivations. Such information is highly relevant to understanding angler behaviour so that from a biological perspective, it is possible to predict what regulation will achieve greatest satisfaction across heterogeneous anglers. Thereby, one can better understand how fishers feel and behave and relatedly which policies will receive the most support. Particularly relevant is the specialization theory as an approach to understand diversity of people involved in fishing and their motivation for doing so (Ditton, 1996, 2004). There are several good examples of how information on the human dimensions has influenced management efforts, particularly with respect to understanding effort-regulation dynamics (Johnston *et al*., 2010; Hunt *et al*., 2011).

Equally relevant is the knowledge that angling stakeholders can contribute to management actions and ensure that there are mechanisms for them to make such contributions. Doing so can solicit constituency support to facilitate rule compliance and to conserve and manage the resource base effectively (Krueger & Decker, 1999; Plummer & Fitzgibbon, 2004). Fisheries managers face complex situations in which policy may be viewed and accepted differently by multiple stakeholder groups, such as recreational fishers and the local community itself. Each group (as well as individuals and specializations within each group) can have contrasting attitudes and opinions regarding the accepted future use and development of aquatic resources (Hunt *et al*., 2011). The resulting differences of opinion among the stakeholder groups can lead to inappropriate implementation of management activities (Miranda & Frese, 1991) and lack of compliance with policy (and in some cases deceit; Sullivan,

2002) and can come across as weaknesses within the sector, leaving it vulnerable to attack from outside groups (*e.g.* the animal rights movement; Arlinghaus *et al.*, 2007*b*, 2012). Hence, information sharing and communication within (*e.g.* intra-sectoral communication within the angling sector) and among stakeholder groups have the potential to further understand and alleviate conflict, particularly in inland systems given the many competing threats. Indeed, the coupled social–ecological system perspective is only complete by also adding the managing and governance dimensions to the picture (Hunt *et al.,* 2013).

The process of inland recreational fisheries management

Fisheries management should be thought of as a process by which sound information is used to achieve management goals and objectives (Arlinghaus *et al.*, 2015). The primary goals of inland recreational fisheries management will often involve some variant of some of the goals of the Convention on Biological Diversity (CBD, 2011): (1) conservation of biodiversity, (2) biologically sustainable use of its components and (3) equitable sharing of benefits among diverse stakeholders (Welcomme, 2001; FAO, 2012). Naturally, more detailed objectives are conceivable, tailored to local and regional conditions and cultures. It is important that goals and objectives are made explicit so that normative judgements are transparent to stakeholders (Fenichel *et al.*, 2013).

Management of recreational fisheries has a longer history in inland systems than in marine systems, and the associated volume of literature and case studies are consistent with that pattern. Nonetheless, many of the fundamentals are similar including the process of recreational fisheries management which include (1) assessing the system, (2) setting goals and objectives, (3) choosing and implementing a course of action and (4) monitoring, evaluation and adjustment (FAO, 2012).

As fishery management operates at the intersection of ecological and economic, psychological and sociological realms, choosing a course of action can be difficult. Managers of recreational fisheries need tools for coping with diverse objectives, complexity and uncertainty in the decision-making process and strongly coupled interactions of recreational fishers and fish stocks (Hunt *et al.*, 2011). Structured decision-making (SDM) in an adaptive management (AM) framework (Hammond *et al.*, 1999; Kendall, 2001) can be a very useful pluralistic approach in which stakeholders play a formal role, subjective information (values and opinions) is rigorously incorporated, and knowledge and decisions are transparent to all. Legitimacy of management, learning and management itself can be facilitated by following SDM with explicit evaluation of outcomes and adjustment of the management in a cyclic fashion, as in an AM process (Arlinghaus *et al.*, 2015). Here, we briefly summarize the process of inland recreational fisheries management and consider the range of tools available to the fisheries manager. It is worth noting that many of the concepts presented here are westernized and may not translate directly to developing countries. Stock enhancement and habitat restoration are covered in detail by Arlinghaus *et al.* (2015) so are only briefly introduced.

Assess the system

The manager should characterize the system by understanding the type of fishery, the setting, the spectrum of users, the stocks to be managed and possibly non-fishing values (*e.g.* biodiversity conservation; Cowie *et al.*, 2011). An assessment of the fishery's current status is necessary before management goals and objectives can be chosen (Hilborn & Walters, 1992). In addition to information on the fish, recreational fishery managers require demographic (human), social and economic (stakeholders) and ecological (environment) information to evaluate the status of a fishery and environmental constraints and opportunities for improvement and possibly to develop objectives that meet stakeholder desires and goals. Assessment methods will depend on the environment and species of interest and are beyond the scope of this chapter (Arlinghaus *et al.*, 2015). In general, however, (1) stock assessment seeks information on vital rates of populations and their eco-evolutionary characteristics (FAO, 2006; Guy & Brown, 2007); (2) creel surveys seek information about recreational fisher catch, harvest and effort, which should be supplemented by human dimension information on preferences, satisfactions and willingness to follow rules and regulations (Pollock *et al.*, 1994); (3) ecosystem surveillance monitors status of the ecosystem (Fig. 4.4.5). The ultimate goal of stock assessment (at least at a large scale) is to understand the processes that drive the stock's dynamics and its current state, ideally in relation to agreed-upon reference points and performance metrics that, when violated, will initiate some harvest control rule or other management responses. To this end, information about fishing effort and mortality including cryptic (delayed) mortality (Coggins *et al.*, 2007) associated with catch and release is needed. In cases where managers lack the capacity to assess fish populations' vital rates (*e.g.* growth, mortality and recruitment) using fish population and fishery surveys, managers should adopt a precautionary approach until such information gathering becomes possible and use information from similar ecosystems. Unfortunately, in many recreational fisheries, managers are not formally trained in stock assessment methods, *e.g.* in the private fishing rights of Central Europe and in developing countries. Here, a more *ad hoc*, experience-based stock assessment based on broad rule of thumbs might be the only way forward. Swarm intelligence principles (*i.e.* the use of knowledge by a diverse set of resource users) and the often untapped local ecological knowledge can help in assessing and monitoring system states (Arlinghaus & Krause, 2013).

Set goals and objectives

Clear and explicit goals and objectives as well as normative criteria are essential for effective management and are required to evaluate management outcomes (Fenichel *et al.*, 2013). Goals are central to the overarching normative framework to guide the

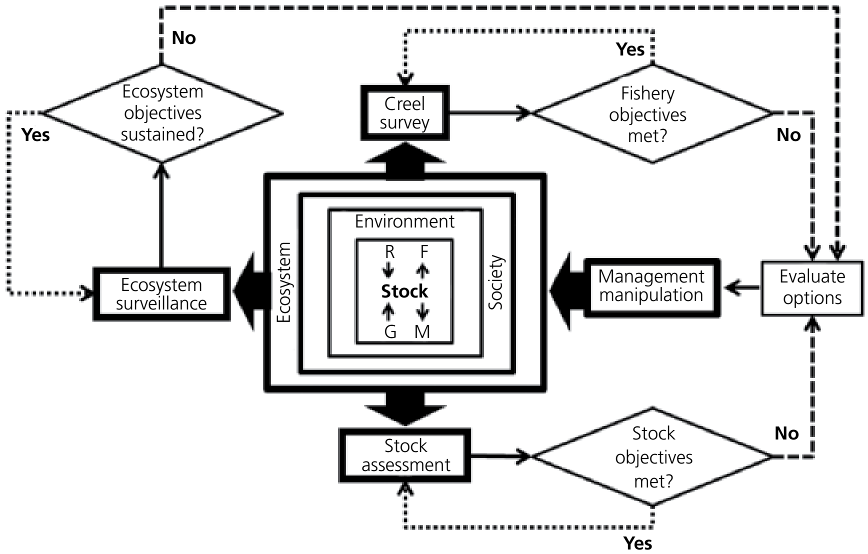

Figure 4.4.5 The traditional process by which fish and recreational fisher survey data are used to assess the status of a fishery and identify appropriate management actions and the incorporation of ecosystem considerations in fishery management. Here, the stock is defined as the fish population of interest (Hilborn & Walters, 1992); its dynamics are governed by inputs of recruitment (R) and growth (G) and outputs of natural mortality (M) and fishing mortality (F).

long-term development of the fishery (FAO, 2012). Appropriate goals may range from maintaining ecological integrity and protecting natural systems for present and future generations in the face of exploitation to maintaining and improving the quality of the fishing experience (Baker *et al.*, 1993). Goals and objectives will be highly dependent upon stakeholder attitudes and values, but the fundamental goals of fishery management should always apply, *e.g.* avoiding overfishing and optimizing socio-economic benefits. Specific objectives that are amendable to assessment (*i.e.* quantifiable) should be operationally defined as part of an AM process. The recreational fishery manager should always consider sociological, biological and ecological aspects: What do stakeholders want, what can the target population provide, and what can the ecosystem sustain? For wild fisheries, stakeholder desires must be compatible with demographic or environmental constraints on the target fish population and with ecosystem sustainability, but within these bounds, socio-economic objectives can and usually will strongly influence the direction of management (Johnston *et al.*, 2010). Thus, open discussion and disclosure of objectives are fundamental for fisheries management if a transparent and accepted process is to be achieved. In reality, multiple objectives guide almost any fisheries management decision, and these objectives may be directed at people or the fish stock or even involve stakeholder desires outside the fisheries sector (*e.g.* water quality). Ultimately, managers must work cooperatively with a spectrum of stakeholders, not only recreational fishers, to choose appropriate broad-based goals and operational objectives, but there will always be potential for disagreement. Fisheries managers should recognize that (1) some activities may be of higher social priority than recreational fishing, (2) values of recreational anglers and managers may differ from those of other stakeholders and (3) the sector should respect values, customs and objectives of other stakeholders (FAO, 2012).

Choose a course of action

Equipped with knowledge and objectives, the manager's next task is to choose a course of action to achieve the specified desires for the fishery, if the current state does not meet objectives. In some instances, no management actions will occur, but this is also a legitimate management choice (Arlinghaus, 2006). Given increasing human domination of the biosphere, all management choices can carry potentially irreversible consequences for the fish stock, ecosystem and human welfare, so in reality, in most fisheries, some form of management action will be implemented. Whereas in most commercial capture fisheries stocks are maintained through regulation of effort and harvest, recreational fishery managers have a diverse array of tools and approaches to manipulate fisheries (Welcomme, 2001; Hubert & Quist, 2010; FAO, 2012). In general, these tools have clearly defined purposes and target the three primary components of the fishery system – fish, habitat or people (Nielsen, 1993; Cowx, 2002*b*; Arlinghaus *et al.*, 2015). A thorough understanding of their scientific basis is needed before an appropriate course of action can be chosen. In many developed countries, recreational fishery managers have university training in fisheries biology and management. Where higher education is not practical, short courses and workshops can enhance managers' understanding. This is the case in Germany where fisheries managers are elected from the angler constituency and then trained in the fundamentals of fisheries management, albeit not comparable to a university degree (Daedlow *et al.*, 2011).

The choice of a management action must be justifiable on technical grounds, but, also, it must be sensible from economic and social standpoints, and most importantly, it must hold great promise to meet objectives (*e.g.* to make anglers happy or to enhance fish stocks for conservation purposes). When a management strategy has been selected, then necessary regulation changes should be pursued and a plan for monitoring and enforcement of the programme should be developed. Compliance can be improved with effective outreach such that stakeholders understand the rationale (Arlinghaus, 2004) for management actions. At this stage, a fishery management plan can be disseminated to stakeholders for their feedback and be modified accordingly. Of course, the exact set of actions depends on scale, ownership and fishery type.

Monitor, evaluate and adjust

Monitoring and evaluation are essential components of the AM cycle to enable learning from individual management actions and improve future management in the face of irreducible uncertainty about management outcomes. Managers thus should always thoroughly document their actions and results whatever the level of activity. Statistically valid sampling designs are required to obtain reliable information on fish population responses (Hansen *et al.*, 2007; Noble *et al.*, 2007), recreational fisher catch and effort (Pollock *et al.*, 1994) and recreational fisher attitudes, preferences and values (Ditton & Hunt, 2001). In many cases, managers will need training to enhance their understanding of study design, sampling methods, data analysis and inference before they can be expected to conduct meaningful monitoring projects, but if this is impractical, qualitative information can still contribute to learning from experience. To be most useful, monitoring and evaluation studies should adhere to standardized sampling and database protocols (Bonar & Hubert, 2002; Kubečka *et al.*, 2009). Recreational fishing and its management have the potential for detrimental effects (Cooke & Cowx, 2004; Lewin *et al.*, 2006). Thus, the manager should recognize that the authority to manipulate and channel recreational fishing is also a potent ecological force that can be harnessed to achieve desirable ecological changes while preserving and ideally enhancing the social and economic benefits recreational fishing provides to society. An important challenge to recreational fisheries management in multiple-use systems is achieving an appropriate balance between actions that provide for recreational fisher desires without compromising the benefits that other stakeholders may wish to enjoy from the system, today and in the future. The specific management strategies for inland recreational fisheries are discussed at length elsewhere (FAO, 2012; Arlinghaus *et al.*, 2015).

The future of inland recreational fisheries: threats and opportunities

It is informative to consider the future of inland recreational fisheries through a visioning exercise in the form of a strength–weakness–opportunity–threat (SWOT) framework. In doing so, it is worth noting that the authors consider that recreational fishing is an inherently positive activity given the many socio-economic benefits if done in a manner that is sustainable. Hence, the future that we envision for recreational fishing is one where the activity features prominently as an outdoor leisure environment for a diverse and large component of society. It is a future where recreational anglers around the globe are recognized as valued stakeholders and stewards of natural resources and one where the socio-economic benefits of recreational fishing are acknowledged by governments, particularly as it relates to connecting the public, including children, to the natural world. Of course, our vision also includes sustainable management and associated governance structures, institutions and scientific and management capacity to make informed decisions. Not surprisingly, there are a number of challenges that have the potential to impede realizing this vision for inland recreational fisheries. We briefly discuss key challenges and identify potential strategies for addressing these challenges.

Valuation of recreational fisheries

In general, inland fisheries, including the recreational sector, have been poorly valued which makes it difficult to obtain the political and public support needed to ensure that the sector has a voice with respect to resource management (Beard *et al.*, 2011). Indeed, valuation can be used to both defend the sector by placing it in the context of other resource uses and make better decisions in a cost–benefit context. Socio-economic evaluation of recreational fishing is difficult (Parkkila *et al.*, 2010), particularly when compared to commercial fisheries. The benefits of commercial fishing can be readily valued by society's willingness to purchase the fish product. In contrast, the benefits experienced by each individual recreational fisher (*e.g.* satisfaction while fishing) are not revealed by market mechanisms. A variety of economic valuation tools exist and are increasingly being applied to recreational fisheries (Loomis & Walsh, 1997; Dorow *et al.*, 2010) to quantify the utility function of various recreational fisher types, which may then be used to quantify marginal benefits generated by regulatory changes or changes to the fish stock (Massey *et al.*, 2006). Economic assessment may be particularly important where recreational and commercial fishers share the same resource and a basis for allocation is needed (Edwards, 1991) or when attempting to document the value of fisheries relative to other uses for precious water resources (*e.g.* for agriculture or hydropower).

Declining participation and an ageing angler population in urbanized societies

A common problem for recreational fishing in some highly industrialized countries is declining participation and licence sales, particularly in North America (Fedler & Ditton, 2001; Gray *et al.*, 2003), but also in some European countries (Aprahamian *et al.*, 2010). Any declines not only reduce the stakeholder base of recreational fisheries in the public domain but also affect management budgets. Declines in recreational fishing participation in some countries are probably the combined result of demographic change and an increasing urban population in which rural lifestyles and recreational outdoor activities such as hunting and fishing are becoming less popular (Arlinghaus, 2006; Arlinghaus *et al*., 2012). In fact, careful examination of the demographics of the angling community reveals an ageing angling population with reduced recruitment of new anglers. Efforts to engage youth in recreational fishing is an opportunity to forge connections with the natural world and build capacity for environmental stewardship. In North America, programmes such as 'hooked on fishing, not drugs' have been used to promote youth fishing in urban areas. In general, recreational fishing is dominated by males (unlike Scandinavian countries where there is more gender balance) so there is also an opportunity to attempt to engage females in recreational fishing. Clearly, increasing recreational fishing effort through recruitment of more anglers has the potential to be detrimental if it exceeded harvest capacity or led to intra- or inter-sectoral conflict (Arlinghaus, 2005). As such, any efforts to recruit more anglers should be coupled with educational programmes to promote responsible fishing practices (FAO, 2012).

Competition and conflict with other users and stakeholders

Recreational fishing is not the sole user of inland fisheries resources. Indeed, there is immense competition for water for important activities such as industrial processes, hydropower, agriculture and drinking water, and this competition is likely to increase in the future. There can also be direct competition for fishes among the different fisheries sectors (*e.g.* commercial and aboriginal). Also relevant is conflict within the recreational sector given that the values and motivations of different types of anglers can be diverse and sometimes in direct opposition (*e.g.* groups that release all fishes *v.* those that harvest all fishes; Churchill *et al*., 2002; Arlinghaus, 2005). On a given waterbody, there can also be conflict among different users, such as boaters, anglers, cottagers, jet skiers and bird watchers (Jones, 1996). Conflict resolution is now regarded as an important tool in the fisheries management toolbox (Hickley & Tompkins, 1998). Beyond the need to ensure that institutions and individual managers embrace conflict resolution approaches, there are also opportunities for different inter- and intra-sectoral actors to work together to address threats external to fisheries (Cooke & Cowx, 2006).

Radical anti-fishing movement

Linked to concerns regarding the treatment of fishes during recreational fishing, there is a growing anti-fishing movement that is largely directed towards freshwater recreational fisheries (Arlinghaus *et al*., 2012). The welfare of individual fish and how this welfare might be compromised in the process of recreational fishing with various gears (Huntingford *et al*., 2006; Arlinghaus *et al*., 2007*a, b*, 2009) have been the subject of much recent debate. From a pragmatic fish welfare perspective that considers recreational fishing to be a legitimate human activity in principle (Arlinghaus *et al*., 2009), any actions that minimize or even avoid stressful situations for a fish in the process of capture, kill or catch and release are preferred (Cooke & Sneddon, 2007). Nonetheless, societal values and a shift towards more urbanites disconnected from nature are associated with the anti-fishing movement (Arlinghaus *et al*., 2012). Being proactive and working with anglers to develop best practices that maintain the welfare status of angled fishes, along with recruitment of the next generation of anglers, is the most prudent approach to countering the anti-fishing movement.

A landscape approach to assessment and management of freshwater recreational fisheries

The amount of surface fresh waters (and thus fishable areas) varies extensively among jurisdictions around the globe. There has been a growing recognition that in some jurisdictions, there is simply too much water to enable monitoring and assessment on a system-by-system basis. Political boundaries, whether at the provincial, state or national scale, are rarely aligned in a manner to define logical management units (*e.g.* catchment basis and eco-regional basis). Likewise, management institutions and organizations must attempt to focus on management units that capture the ecological principles that drive system productivity. To that end, a landscape approach to assessment and management has become an increasingly popular model. This concept has extended from theory to practice in some jurisdictions such as Ontario, Canada, where the provincial resource management agency has adopted a landscape approach to fisheries management where areas with similar geology, climate and zoogeography are managed in a uniform manner with monitoring restricted to a reasonable number of representative waters (Lester *et al*., 2003). Such an approach may also have merit across political boundaries, especially where waters are interconnected. The Laurentian Great Lakes are managed as a co-ordinated system despite involving two countries and multiple provinces and states (Lauer, 2015). Moving away from lake-by-lake management, at least for the millions of small- to intermediate-sized waterbodies, is needed given the practical challenges of doing so. In large river systems that cross multiple jurisdictions (*e.g.* the Amazon Basin, Mekong Basin and Zambezi River), monitoring and management of recreational fisheries would be most effective if done on a landscape (*i.e.* catchment level) by umbrella organizations (*e.g.* the Mekong River Commission).

Information needs for inland recreational fisheries

Sound management should always be based on the best available information, and if possible, scientific methods should be used to generate this knowledge, which can then be supplemented and complemented by stakeholder and traditional knowledge and local experiences. Effective management of recreational fisheries therefore requires an understanding of the features and the dynamics of targeted fish stocks and the associated social–ecological system dynamics (Arlinghaus *et al*., 2008). Currently, recreational fisheries research is either absent or underdeveloped, and existing approaches are mainly biological in orientation (Arlinghaus *et al*., 2008). If recreational fisheries research endeavours to understand fully the system dynamics, it must extend beyond the traditional fisheries biology and integrate the social and economic sciences (Ditton, 2004; Arlinghaus, 2005; Arlinghaus *et al*., 2008). Nonetheless, studies of biological or social science phenomena in isolation can still provide essential building blocks for more integrated understanding. It is worth noting that the research capacities in many countries are minimal or only developing, partly because studies on recreational fisheries were often considered of low social priority given its leisure focus. This, of course, needs to change if the sector wants to develop sustainably and the call is for policy- and decision-makers to respond. Specific research needs vary regionally and through time, but there are some research foci that seem relevant generally. Rather than provide an exhaustive list of research and information needs or priorities, we list what we regard as research priorities [adapted and expanded from the FAO Technical Guidelines for Responsible Fisheries (FAO, 2012) to be specific to inland recreational fisheries].

Given the data-poor situation in terms of recreational fisheries in inland waters, research is needed to support policy decision-making and the integration of recreational fisheries into aquatic ecosystem management practices (*e.g.* using economic valuation of recreational fisheries as one stakeholder of fish populations).

Recreational fisheries organizations and agencies should monitor and assess the stocks and fisheries under their jurisdiction, including the impact of ecosystem changes resulting from land use, urbanization, climate change, habitat alteration and other anthropogenic sources, and do so using robust and accurate data collection and analysis strategies that incorporate appropriate standardized methods.

Recreational fisheries research should include an understanding of the social, economic, marketing and institutional factors affecting recreational fishers and fisheries and focus on feedbacks among fisher–fish as key components of the dynamics of the system.

Recreational fisheries research results should be used to establish management objectives, reference points and performance criteria and to formulate and update management plans. Fisheries research results should be used as the baseline for development of AM approaches, and outputs of research are essential for the evaluation of management effectiveness.

Research is needed to generate information to judge the developments of fisheries, such as monitoring participation and landings, using both fishery-dependent and fishery-independent surveys of fish populations and catch, and more elaborate analytical tasks such as developing integrative fisheries models that incorporate salient social–ecological feedbacks, biological variables of exploited stocks and recreational fisher behaviour, in light of social and economic objectives (bioeconomics models; Johnston *et al*., 2010).

A critical research need is an improved understanding of the long-term benefits and costs of stocking and other traditional regulations compared to other policy options (Beard *et al*., 2011), as is policy analysis of allocations across potentially competing fisheries sectors.

Research focused on the fish should aim to improving understanding of the effect of recreational fisheries exploitation (including potential for evolutionary consequences of selective harvest), the interaction of fishes and fishers (*e.g.* how fishers distribute in space and time), fish welfare, fate of released fish, sustainable harvest regulations, stocking and habitat management.

Conclusion

Most recently, recreational fishing is being recognized on the global scale as evidenced by the development of the FAO Technical Guidelines for Responsible Fisheries (FAO, 2012). In addition, there seems to be evidence that the plight of inland waters is receiving some attention (Welcomme, 2011; Beard *et al*., 2011), despite being overshadowed by marine fisheries. These developments serve as opportunities to promote inland recreational fisheries and their sustainable management. The socio-economic benefits of inland recreational fisheries are immense. Management tools and governance structures are needed that are capable of balancing the needs and wants of the recreational fishing community with other objectives related to biodiversity (Cowx *et al*., 2010). Unfortunately, the lack of appropriate statistical information makes it difficult to make direct quantitative comparisons of the status and trends in marine recreational fisheries. With increased recognition of the value of recreational fishing and inland fisheries should come interest in attempting to develop tools and survey instruments that are capable of monitoring recreational fishing trends on a regional and global basis. The development of inland recreational fisheries in emerging economies and developing countries presents some unique challenges with respect to governance and management capacity. Rather than waiting for issues and problems to develop in the sector, there is a need to be proactive and build the capacity and governance structures necessary to ensure sustainable management of recreational fisheries in developing countries.

Acknowledgments

We thank several individuals and organizations for sharing photographs including Sean Landsman, Greg Bulte, Mark Taylor, the New Zealand Bowhunters Society (especially Dave Gousmett and Len Purser) and the Sekoma Island Lodge in Zambia (especially Garreth Coombes). The components of the manuscript are derived from the FAO Technical Guidelines for Recreational Fisheries written by RA, SJC and BMJ with permission from Raymon Van Anrooy. SJC is supported by the Canada Research Chairs programme. RA thanks the Federal Ministry of Education and Research for funding the project Besatzfisch (www.besatzfisch.de) within the Program for Social-Ecological Research (grant # 01UU0907).

References

Altieri, A. H., Bertness, M. D., Coverdale, T. C., Herrmann, N. C. & Angelini, C. (2012). A trophic cascade triggers collapse of a salt-marsh ecosystem with intensive recreational fishing. *Ecology* **93**, 1402–1410.

Anderson, L. G. (1994). An economic analysis of high grading in ITQ fisheries regulation programs. *Marine Resource Economics* **9**, 209–226.

Aprahamian, M. W., Hickley, P., Shields, B. A. & Mawle, G. W. (2010). Examining changes in participation in recreational fisheries in England and Wales. *Fisheries Management and Ecology* **17**, 93–105.

Arlinghaus, R. (2004). *A Human Dimensions Approach Towards Sustainable Recreational Fisheries Management*. London: Turnshare Ltd.

Arlinghaus, R. (2005). A conceptual framework to identify and understand conflicts in recreational fisheries systems, with implications for sustainable management. *Aquatic Resources, Culture and Development* **1**, 145–174.

Arlinghaus, R. (2006). Understanding recreational angling participation in Germany: preparing for demographic change. *Human Dimensions of Wildlife* **11**, 229–240.

Arlinghaus, R. (2008). The challenge of ethical angling: the case of C&R and its relation to fish welfare. In *Global Challenges in Recreational Fisheries* (Aas, Ø., Arlinghaus, R., Ditton, R. B., Policansky, D. & Schramm Jr., H. L., eds), pp. 223–236. Oxford: Blackwell Publishing.

Arlinghaus, R. & Cooke, S. J. (2009). Recreational fisheries: socioeconomic importance, conservation issues and management challenges. In *Recreational Hunting, Conservation and Rural Livelihoods: Science and Practice* (Dickson, B., Hutton, J. & Adams, W. M., eds), pp. 39–58. Oxford: Blackwell Publishing.

Arlinghaus, R. & Krause, J. (2013). Wisdom of the crowd and natural resource management. *Trends in Ecology & Evolution* **28**, 8–11.

Arlinghaus, R., Mehner, T. & Cowx, I. G. (2002). Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europe. *Fish and Fisheries* **3**, 261–316.

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

Arlinghaus, R., Cooke, S. J., Schwab, A. & Cowx, I. G. (2007*b*). Fish welfare: a challenge of the feelings-based approach, with implications for recreational fishing. *Fish and Fisheries* **8**, 57–71.

Arlinghaus, R., Johnson, B. M. & Wolter, C. (2008). The past, present and future role of limnology in freshwater fisheries science. *International Review of Hydrobiology* **93**, 541–549.

Arlinghaus, R., Schwab, A., Cooke, S. J. & Cowx, I. G. (2009). Contrasting pragmatic and suffering-centred approaches to fish welfare in recreational angling. *Journal of Fish Biology* **75**, 2448–2463.

Arlinghaus, R., Schwab, A., Riepe, C. & Teel, T. (2012). A primer on anti-angling philosophy and its relevance for recreational fisheries in urbanized societies. *Fisheries* **37**, 153–164.

Arlinghaus, R., Lorenzen, K., Johnson, B. M., Cooke, S. J. & Cowx, I. J. (2015). Management of freshwater fisheries: addressing habitat, people and fishes. In *Freshwater Fisheries Ecology* (Craig, J. F., ed.), pp. 557–579. Oxford: Wiley Blackwell.

Baker, J. P., Olem, H., Creager, C. S., Marcus, M. D. & Parkhurst, B. R. (1993). *Fish and Fisheries Management in Lakes and Reservoirs*. Washington, DC: The Agency.

Beard, T. D., Arlinghaus, R., Cooke, S. J., McIntyre, P. B., De Silva, S., Bartley, D. & Cowx, I. G. (2011). Ecosystem approach to inland fisheries: research needs and implementation strategies. *Biology Letters* **7**, 481–483.

Beardmore, B., Haider, W., Hunt, L. & Arlinghaus, R. (2011). The importance of trip context for determining primary angler motivations: are more specialized anglers more catch-oriented than previously believed? *North American Journal of Fisheries Management* **31**, 861–879.

Bonar, S. A. & Hubert, W. A. (2002). Standard sampling of inland fish: benefits, challenges, and a call for action. *Fisheries* **27**, 10–16.

Brown, P. J. & Manfredo, M. J. (1987). *Social Values Defined. Valuing Wildlife: Economic and Social Perspectives*. Boulder, CO: Westview Press.

Bryan, H. (1977). Leisure value systems and recreational specialization: the case of trout fishermen. *Journal of Leisure Research* **9**: 174–187.

Carpenter, S. R. & Brock, W. A. (2004). Spatial complexity, resilience, and policy diversity: fishing on lake-rich landscapes. *Ecology and Society* **9**, 8. http://www.ecologyandsociety.org/vol9/iss1/art8/

Churchill, T. N., Bettoli, P. W., Peterson, D. C., Reeves, W. C. & Hodge, B. (2002). Angler conflicts in fisheries management: A case study of the striped bass controversy at Norris Reservoir, Tennessee. *Fisheries* **27**, 10–19.

Coggins, L. G., Catalano, M. J., Allen, M. S., Pine, W. E. & Walters, C. J. (2007). Effects of cryptic mortality and the hidden costs of using length limits in fishery management. *Fish and Fisheries* **8**, 196–210.

Coleman, F. C., Figueira, W. F., Ueland, J. S. & Crowder, L. B. (2004). The impact of United States recreational fisheries on marine fish populations. *Science* **305**, 1958–1960.

Cooke, S. J. & Cowx, I. G. (2004). The role of recreational fisheries in global fish crises. *BioScience* **54**, 857–859.

Cooke, S. J. & Cowx, I. G. (2006). Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation* **128**, 93–108.

Cooke, S. J. & Sneddon, L. U. (2007). Animal welfare perspectives on catch-and-release recreational angling. *Applied Animal Behaviour Science* **104**, 176–198.

Cooke, S. J., Dunlop, W. I., McLennan, D. M. & Power, G. (2000). Applications and characteristics of angler diary programs in Ontario, Canada. *Fisheries Management and Ecology* **7**, 473–487.

Cowie, A. L., Penman, T. D., Gorissen, L., Winslow, M. D., Lehmann, J., Tyrrell, T. D., Twomlow, S., Wilkes, A., Lal, R., Jones, J. W., Paulsch, A., Kellner, K. & Akhtar-Schuster, M. (2011). Towards sustainable land management in the drylands: scientific connections in monitoring and assessing dryland degradation, climate change and biodiversity. *Land Degradation & Development* **22**, 248–260.

Cowx, I. G. (Ed.) (1998). *Stocking and Introduction of Fish*. Oxford: Fishing News Books, Blackwell Science.

Cowx, I. G. (2002*a*). Analysis of threats to freshwater fish conservation: past and present challenges. In *Conservation of Freshwater Fishes: Options for the Future* (Collares-Pereira, M. J., Cowx, I. G. & Coelho, M. M., eds), pp. 201–220. Oxford: Blackwell Science.

Cowx, I. G. (2002*b*). Recreational fishing. In *Handbook of Fish Biology and Fisheries*, Vol. 2 (Hart, P. & Reynolds, J., eds), pp. 367–390. London: Blackwell Science.

Cowx, I. G. & van Anrooy, R. (2010). Social, economic and ecological objectives of commercial and recreational fisheries and aquaculture. *Fisheries Management and Ecology* **17**, 89–92.

Cowx, I. G., Arlinghaus, R. & Cooke, S. J. (2010). Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. *Journal of Fish Biology* **76**, 2194–2215.

Daedlow, K., Beckmann, V. & Arlinghaus, R. (2011). Assessing an adaptive cycle in a social system under external pressure to change: the importance of intergroup relations in recreational fisheries governance. *Ecology and Society* **16**, 3.

DFO (2012). *Survey of Recreational Fishing in Canada (2010)* Ottawa, ON: Fisheries and Oceans Canada Statistics Division.

Ditton, R. B. (1996). Understanding the diversity among largemouth bass anglers. *American Fisheries Society Symposium* **16**, 135–144.

Ditton, R. B. (2004). Human dimensions of fisheries. In *Society and Natural Resources: A Summary of Knowledge Prepared for the 10th International Symposium on Society and Resource Management* (Manfredo, M. J., Vaske, J. J., Bruyere, B. L., Field, D. R. & Brown, P. J., eds), pp. 199–208. Jefferson, MO: Modern Litho.

Ditton, R. B. & Hunt, K. M. (2001). Combining creel intercept and mail survey methods to understand the human dimensions of local freshwater fisheries. *Fisheries Management and Ecology* **8**, 295–301.

Ditton, R. B., Loomis, D. K. & Choi, S. (1992). Recreation specialization: re-conceptualization from a social worlds perspective. *Journal of Leisure Research* **24**, 33–51.

Dorow, M. & Arlinghaus, R. (2011). A telephone-diary-mail approach to survey recreational fisheries on large geographic scales, with a note on annual landings estimates by anglers in northern Germany. In *The Angler in the Environment: Social, Economic, Biological and Ethical Dimensions* (Beard, T. D., Arlinghaus, R. & Sutton, S. G., eds), pp. 319–344. Bethesda, MD: American Fisheries Society.

Dorow, M., Beardmore, B., Haider, W. & Arlinghaus, R. (2010). Winners and losers of conservation policies for European eel, Anguilla anguilla: an economic welfare analysis for differently specialised anglers. *Fisheries Management and Ecology* **17**, 106–125.

Driver, B. L. & Knopf, R. C. (1976). Temporary escape: one product of sport fisheries management. *Fisheries* **1**, 21, 24–29.

Edwards, S. F. (1991). A critique of three "economics" arguments commonly used to influence fishery allocations. *North American Journal of Fisheries Management* **11**, 121–130.

FAO (2006). *Stock Assessment for Fishery Management. A Framework Guide to the Stock Assessment Tools of the Fisheries Management Science Programme*. Rome: FAO.

FAO (2010). *State of the World's Fisheries and Aquaculture*. Rome: Food and Agriculture Organization of the United Nations.

FAO (2012). *Recreational Fisheries*. Rome: FAO (written under contract by R. Arlinghaus, S. J. Cooke and B. Johnson).

Fedler, A. J. & Ditton, R. B. (1994). Understanding angler motivations in fisheries management. *Fisheries* **19**, 6–13.

Fedler, A. J. & Ditton, R. B. (2001). Dropping out and dropping in: a study of factors for changing recreational fishing participation. *North American Journal of Fisheries Management* **21**, 283–292.

Fenichel, E. P., Abbott, J. K. & Huang, B. (2013). Modelling angler behaviour as part of the management system: synthesizing a multidisciplinary literature. *Fish and Fisheries* **14**, 137–157.

Fisher, M. R. (1997). Segmentation of the angler population by catch preference, participation, and experience: a management-oriented application of recreation specialization. *North American Journal of Fisheries Management* **17**, 1–10.

Franklin, A. (1998). Naturalizing sports: hunting and angling in modern environments. *International Review for the Sociology of Sport* **33**, 355–366.

Gray, P. A., Duwors, E., Villeneuve, M., Boyd, S. & Legg, D. (2003). The socioeconomic significance of nature-based recreation in Canada. *Environmental Monitoring and Assessment* **86**, 129–147.

Gregory, R. (1987). Nonmonetary measures of nonmarket fishery resource benefits. *Transactions of the American Fisheries Society* **116**, 374–380.

Guy, C. S. & Brown, M. L. (Eds) (2007). *Analysis and Interpretation of Freshwater Fisheries Data*. Bethesda, MD: American Fisheries Society.

Hammond, J. S., Keeney, R. L. & Raifa, H. (1999). *Smart Choices: A Practical Guide to Making Better Decisions*. Boston, MA: Harvard Business School Press.

Hansen, M. J., Beard, T. D. & Hayes, D. B. (2007). Sampling and experimental design. In *Analysis and Interpretation of Freshwater Fisheries Data* (Guy, C. S. & Brown, M. L., eds), pp. 51–120. Bethesda, MD: American Fisheries Society.

Hendee, J. C. (1974). A multiple-satisfaction approach to game management. *Wildlife Society Bulletin* **2**, 104–113.

Hickley, P. & Tompkins, H. (1998). *Recreational Fisheries: Social, Economic and Management Aspects*. Oxford: Fishing News Books, Blackwell Science.

Hickley, P., Arlinghaus, R., Tyner, R., Aprahamian, M., Parry, K. & Carter, M. (2004). Rehabilitation of urban lake fisheries for angling by managing habitat: general overview and case studies from England and Wales. *Rehabilitation* **4**, 365–378.

Hilborn, R. & Walters, C. J. (1992). *Quantitative Fish Stock Assessment*. New York: Chapman & Hall.

Hubert, W. A. & Quist, M. C. (Eds) (2010). *Inland Fisheries Management in North America*. Bethesda, MD: American Fisheries Society.

Hunt, L. M. (2005). Choice models and recreational fishing site choice: insights and future opportunities. *Human Dimensions of Wildlife* **10**, 153–172.

Hunt, L. M., Arlinghaus, R., Lester, N. & Kushneriuk, R. (2011). The effects of regional angling effort, angler behavior, and harvesting efficiency on landscape patterns of overfishing. *Ecological Applications* **21**, 2555–2575.

Hunt, L., Sutton, S. G. & Arlinghaus, R. (2013). Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology* **20**, 111–124.

Huntingford, F. A., Adams, C., Braithwaite, V. A., Kadri, S., Pottinger, T. G., Sandøe, P. & Turnbull, J. F. (2006). Current issues in fish welfare. *Journal of Fish Biology* **68**, 332–372.

Johnson, B. M. & Carpenter, S. R. (1994). Functional and numerical responses: a framework for fish-angler interactions? *Ecological Applications* **4**, 808–821.

Johnston, F. D., Arlinghaus, R. & Dieckmann, U. (2010). Diversity and complexity of angler behaviour drive socially optimal input and output regulations in a bioeconomic recreational-fisheries model. *Canadian Journal of Fisheries and Aquatic Sciences* **67**, 1507–1531.

Johnston, F. D., Arlinghaus, R. & Dieckmann, U. (2013). Fish life history, angler behaviour, and optimal management of recreational fisheries. *Fish and Fisheries* **14**, 554–579.

Johnston, T. A., Lester, N .P. & Shuter, B. J. (2015). Recruitment. In *Freshwater Fisheries Ecology* (Craig, J. F., ed.), pp. 832–847. Oxford: Wiley Blackwell.

Jones, W. W. (1996). Balancing recreational user demands and conflicts on multiple use public waters. In *Multidimensional Approaches to Reservoir Fisheries Management* (Miranda, L. E. & DeVries, D. R., eds), pp. 179–185. Bethesda, MD: American Fisheries Society.

Kearney, R. E. (2002). Recreational fishing: value is in the eye of the beholder. In *Recreational Fisheries: Ecological, Economic and Social Evaluation* (Pitcher, T. J. & Hollingworth, C. E., eds), pp. 17–33. Oxford: Blackwell Science.

Kendall, W. L. (2001). Using models to facilitate complex decisions. In *Modeling in Natural Resource Management* (Shenk, T. M. & Franklin, A. B., eds), pp. 147–170. Washington, DC: Island Press.

Krueger, C. C. & Decker, D. J. (1999). The process of fisheries management. In *Inland Fisheries Management in North America*, 2nd edn (Kohler, C. C. & Hubert, W. A., eds), pp. 31–59. Bethesda, MD: American Fisheries Society.

Kubečka, J., Hohausová, E., Matena, J., Peterka, J., Amarasinghe, U. S., Bonar, S. A., Hateley, J., Hickley, P., Suuronen, P., Tereschenko, V., Welcomme, R. & Winfield, I. J. (2009). The true picture of a lake or reservoir fish stock: a review of needs and progress. *Fisheries Research* **96**, 1–5.

Lauer, T. E. (2015). Fishery of the Laurentian Great Lakes. In *Freshwater Fisheries Ecology* (Craig, J. F., ed.), pp. 134–150. Oxford: Wiley Blackwell.

Lester, N. P., Marshall, T. R., Armstrong, K., Dunlop, W. I. & Ritchie, B. (2003). A broad-based approach to management of Ontario's recreational fisheries. *North American Journal of Fisheries Management* **23**, 1312– 1328.

Lewin, W. C., Arlinghaus, R. & Mehner, T. (2006). Documented and potential biological impacts of recreational fishing: insights for management and conservation. *Reviews in Fisheries Science* **14**, 305–367.

Liu, J., Dietz, T., Carpenter, S. R., Folke, C., Alberti, M., Redman, C. L., Schneider, S. H., Ostrom, E., Pell, A. N., Lubchenco, J., Taylor, W. W., Ouyang, Z., Deadman, P., Kratz, T. & Provencher, W. (2007a). Coupled human and natural systems. *AMBIO: A Journal of the Human Environment* **36**, 639–649.

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., Pell, A. N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C. L., Schneider, S. H. & Taylor, W. W. (2007b). Complexity of coupled human and natural systems. *Science* **317**, 1513–1516.

Loomis, J. & Walsh, R. G. (1997). *Recreation Economic Decisions: Comparing Benefits and Costs*, 2nd edn. State College, PA: Venture Publishing.

Lyle, J. M., Coleman, A. P., West, L., Campbell, D. & Henry, G. W. (2002). New large-scale survey methods for evaluating sport fisheries. In *Recreational Fisheries: Ecological, Economic and Social Evaluation* (Pitcher, T. J. & Hollingsworth, C., eds), pp. 207–226. Oxford: Blackwell Publishing.

Manfredo, M. J., Driver, B. L. & Tarrant, M. A. (1996). Measuring leisure motivation: a meta-analysis of the recreation experience preference scales. *Journal of Leisure Research* **28**, 188–213.

Manski, C. F. (1977). The structure of random utility models. *Theory and decision* **8**, 229–254.

Maslow, A. H., Frager, R. & Fadiman, J. (1970). *Motivation and Personality*, 2nd edn. New York, NY: Harper & Row.

Massey, M., Newbold, S. & Gentner, B. (2006). Valuing water quality changes using a bioeconomic model of a coastal recreational fishery. *Environmental Economics and Management* **52**, 482–500.

Miranda, L. E. & Frese, W. (1991). Can fishery scientists predict angler preferences? *American Fisheries Society Symposium* **12**, 375–379.

Mora, C., Myers, R. A., Cool, M., Libralato, S., Pitcher, T. J., Sumaila, R. U., Zeller, D., Watson R., Gaston, K. J. & Worm, B. (2009). Management effectiveness of the world's marine fisheries. *Public Library of Science Biology* **7**, e1000131.

Moss, B. (2015). The dynamics of lakes in relation to fishes and fisheries. In *Freshwater Fisheries Ecology* (Craig, J. F., ed.), pp. 31–47. Oxford: Wiley Blackwell.

Nielsen, L. A. (1993). History of inland fisheries management in North America. In *Inland Fisheries Management in North America* (Kohler, C. C. & Hubert, W. A., eds), pp. 3–32. Bethesda, MD: American Fisheries Society.

Noble, R. L., Austen, D. J. & Pegg, M. A. (2007). Fisheries management study design considerations. In *Analysis and Interpretation of Freshwater Fisheries Data* (Guy, C. S. & Brown, M. L., eds), pp. 31–49. Bethesda, MD: American Fisheries Society.

Oh, C. O. & Ditton, R. B. (2006). Using recreation specialization to understand multi-attribute management preferences. *Leisure Sciences* **28**, 369–384.

Parkkila, K., Arlinghaus, R., Artell, J., Gentner, B., Haider, W., Aas, Ø. & Sipponen, M. (2010). *European Inland Fisheries Advisory Commission Methodologies for Assessing Socio-Economic Benefits of European Inland Recreational Fisheries*. Ankara: FAO.

Petts, G., Gosselin, M.-P. Gosselin, & Gray, J. (2015). The dynamics of rivers in relation to fishes and fisheries. In *Freshwater Fisheries Ecology* (Craig, J. F., ed.), pp. 9–30. Oxford: Wiley Blackwell.

Pitcher, T. J. & Hollingworth, C. E. (Eds) (2002). *Recreational Fisheries: Ecological, Economic and Social Evaluation*. Oxford: Blackwell Science.

Plummer, H. R. & FitzGibbon, J. E. (2004). Co-management of natural resources: a proposed framework. *Journal of Environmental Management* **33**, 876–885.

Pollock, K. H., Jones, C. M. & Brown, T. L. (1994). *Angler Survey Methods and Their Applications in Fisheries Management*. Bethesda, MD: American Fisheries Society.

van Poorten, B. T., Arlinghaus, R., Daedlow, K. & Haertel-Borer, S. S. (2011). Social-ecological interactions, management panaceas, and the future of wild fish populations. *Proceedings of the National Academy of the United States of America* **108**, 12554–12559.

Potter, I. C., Warwick, R. M., Hall, N. G. & Tweedley, J. R. (2015). The physio-chemical characteristics, biota and fisheries of estuaries. In *Freshwater Fisheries Ecology* (Craig, J. F., ed.), pp. 48–79. Oxford: Wiley Blackwell.

Post J. R. (2013). Resilient recreational fisheries or prone to collapse? A decade of research on the science and management of recreational fisheries. *Fisheries Management and Ecology* **20**, 99–110.

Post, J. R., Sullivan, M., Cox, S., Lester, N. P., Walters, C. J., Parkinson, E. A., Paul, A. J., Jackson, L. & Shuter, B. J. (2002). Canada's recreational fishery: the invisible collapse? *Fisheries* **27**, 6–17.

Post, J. R., Persson, L., Parkinson, E. A. & van Kooten, T. (2008). Angler numerical response across landscapes and the collapse of freshwater fisheries. *Ecological Applications* **18**, 1038–1049.

Probst, D. B. & Gavrilis, D. G. (1987). Role of economic impact assessment procedures in recreational fisheries management. *Transactions of the American Fisheries Society* **116**, 450–460.

Riechers, R. K. & Fedler, A. J. (1996). An overview of economic impact and value of recreational fisheries. *American Fisheries Society Symposium* **16**, 245–250.

Schorr, M. S., Sah, J., Schreiner, D. F., Meador, M. R. & Hill, L. G. (1995). Regional economic impact of the Lake Texoma (Oklahoma-Texas) striped bass fishery. *Fisheries* **20**, 14–18.

Sigler, J. W. & Sigler, W. F. (1990). *Recreational Fisheries: Management, Theory, and Application*. Reno, NV: University of Nevada Press.

Sullivan, M. G. (2002). The illegal harvest of walleye protected by size limits in Alberta. *North American Journal of Fisheries Management* **22**, 1058–1068.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A. & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology* **11**, 201–230.

Vanderpool, C. K. (1987). Social impact assessment and fisheries. *Transactions of the American Fisheries Society* **116**, 479–485.

Weithman, A. S. (1999). Socioeconomic benefits of fisheries. In *Inland Fisheries Management in North America*, 2nd edn (Kohler, C. C. & Hubert, W. A., eds), pp. 193–213. Bethesda, MD: American Fisheries Society.

Welcomme, R. L. (2001). *Inland Fisheries: Ecology and Management*. Oxford: Blackwell Publishing.

Welcomme, R. L. (2011). An overview of global catch statistics for inland fish. *ICES Journal of Marine Science* **68**, 1751–1756.

World Bank (2012). *Hidden Harvest: The Global Contribution of Capture Fisheries*. Washington, DC: International Bank for Reconstruction and Development/The World Bank.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., Fogarty, M. J., Fulton, E. A., Hutchings, J. A., Jennings, S., Jensen, O. P., Lotze, H. K., Mace, P. M., McClanahan, T. R., Minto, C., Palumbi, S. R., Parma, A. M., Ricard, D., Rosenberg, A. A., Watson, R. & Zeller, D. (2009). Rebuilding global fisheries. *Science* **325**, 578–585.

Electronic References

CBD (2011). Article 1. Objectives. In *Convention on Biological Diversity*. Montreal, QC: CBD. Available at http://www.cbd.int (last accessed 20 January 2014).

Indecon (2003). *An Economic/Socio-economic Evaluation of Wild Salmon in Ireland*. Prepared For The Irish Government. Available at http://www.fisheriesireland.ie/fish-species/atlantic-salmon.html (last accessed 27 December 2014).