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FAO TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES

13

RECREATIONAL FISHERIES

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RECREATIONAL FISHERIES

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PREPARATION OF THIS DOCUMENT

These technical guidelines have been prepared by Robert Arlinghaus (Leibniz-Institute of Freshwater Ecology and Inland Fisheries [IGB] and Humboldt-Universität zu Berlin, Germany), Steven J. Cooke (Carleton University, Canada) and Brett M. Johnson (Colorado State University, the United States of America) under the coordination of Raymon van Anrooy (FAO, Subregional Office for Central Asia, now at the Subregional Office for the Caribbean). Their production has been supported by Devin Bartley and Blaise Kuemlangan from FAO.

The FAO Code of Conduct for Responsible Fisheries (the Code), owing to its history, is focused on marine capture fisheries, with some coverage of aquaculture. Recreational fisheries issues, while implicit, are not specifically addressed, and many of the provisions in the Code are not well aligned to the sector's requirements. The FAO Resolution 4/95 adopting the Code on 31 October 1995 requested FAO *inter alia* to elaborate appropriate technical guidelines in support of the implementation of the Code in collaboration with members and interested relevant organizations. The only previous FAO-related document that directly targets recreational fisheries issues is the *EIFAC Code of Practice for Recreational Fisheries* of the European Inland Fisheries Advisory Commission (EIFAC). These Technical Guidelines for Responsible Fisheries: Recreational Fisheries (TGRF) are based on the Code, embrace the EIFAC Code of Practice for Recreational Fisheries, and overall fill an important gap by explicitly dealing with the salient issues faced by recreational fisheries inland and marine ecosystems.

Initial discussions leading to the preparation of these Guidelines took place: at an International EIFAC Workshop on a Code of Practice for Recreational Fisheries on 5–6 November 2007, in Bilthoven, the Netherlands; at the Twenty-fifth Session of EIFAC, 21–28 May 2008, in Antalya, Turkey, held in conjunction with the EIFAC Symposium on Interactions between Economic and Ecological Objectives of Inland Commercial and Recreational Fisheries and Aquaculture; at the FAO Regional Workshop on Recreational Fisheries in Central Asia, 14–16 September 2009, in Issyk Kul, Kyrgyzstan; and at the FAO Workshop on Implementation of the Ecosystem Approach in Inland Fisheries, held 7–10 December 2010, in the Lao People's Democratic Republic. After completion of a first draft by Robert Arlinghaus, Steven J. Cooke and Brett M. Johnson, an FAO Expert Consultation on the Technical Guidelines for

Responsible Fisheries: Recreational Fisheries was convened on 5–6 August 2011 in Berlin, Germany, under the auspices of FAO staff consisting of Raymon van Anrooy, Devin Bartley, Blaise Kuemlangan, Karine Erikstein and Cana Salur. This was in conjunction with the Sixth World Recreational Fishing Conference, held 1–4 August 2011 at Humboldt-Universität zu Berlin. The Consultation was hosted by the Department of Biology and Ecology of Fishes of the IGB in Berlin, Germany, and was organized by Raymon van Anrooy and Cana Salur (FAO), and Robert Arlinghaus and Leonore Osswald (IGB). The Consultation was attended by ten international experts (Ian Cowx, Michel Dedual, Jan Kappel, Robert Kramer, Katia de Meirelles Felizola Freire, Mucai Muchiri, Warren Potts, Claudia Stella Beltran Turriago, Roy Stein, and Joko Tamura), three resource persons (Robert Arlinghaus, Steven J. Cooke, Brett M. Johnson) and six observers (Andy Danylchuk, Russell Dunn, Phil Hickley, Tom Ratfican, Jason Schratwieser, and Matti Sipponen). These people collectively represented a wide range of recreational fisheries expertise, experience and geographical areas, including Africa, Asia and the Pacific, Europe, Latin America and North America.

The initial drafts of the guidelines and all subsequent revisions were prepared by Robert Arlinghaus, Steven J. Cooke and Brett M. Johnson. Phil Hickley edited the final draft and Eva-Maria Cyrus provided editorial assistance with the reference list. Drafts were commented by the above-mentioned experts, and Devin Bartley, Blaise Kuemlangan and Raymon van Anrooy provided editorial assistance in finalizing the manuscript. Sean Landsman and Andy Danylchuk provided the photographs for Figure 16. Core project funding was provided by FAO. Further funding was received by Robert Arlinghaus through the project Besatzfisch (www.besatz-fisch.de, funding period 2010–13, grant No. 01UU0907) granted by the Federal German Ministry for Education and Research in the Social-ecological Research programme. Steven J. Cooke was further supported by the Canada Research Chairs Program, the Ontario Ministry of Research and Innovation, Carleton University, and the Natural Sciences and Engineering Research Council of Canada.

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ABSTRACT

Recreational fishing is defined as fishing of aquatic animals (mainly fish) that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets. Recreational fishing constitutes the dominant use of wild fish stocks in all freshwaters of industrialized countries, and it is prominent in many coastal ecosystems. The importance of recreational fisheries is increasing rapidly in many transitional economies. The present Technical Guidelines for Responsible Fisheries are focused on recreational fisheries and describe strategies to promote environmentally sustainable and socially responsible management of such fisheries. To this end, the document details policy, management and behavioural recommendations for sustainable recreational fisheries that are an increasingly important component of global fisheries. Specifically, the Guidelines translate the relevant provisions of the FAO Code of Conduct for Responsible Fisheries into specific advice for recreational fisheries. The concept of aquatic stewardship is introduced as an overarching ethical framework needed to achieve ecologically sustainable recreational fisheries on a global scale. Within this normative mindset, the adaptive management philosophy based on quantifiable and transparent objectives and continuous learning and feedback loops is proposed along with the acknowledgement of principles such as the ecosystem approach and the precautionary approach. Detailed sections on policy and institutional frameworks (tailored towards policy-makers), recreational fisheries management actions and strategies (tailored towards fisheries managers), recreational fisheries practices (tailored towards individual recreational fishers) and recreational fisheries research (tailored to researchers and managers) provide tangible advice for responsible recreational fisheries. The special considerations necessary for recreational fisheries in developing countries and economies in transition are acknowledged. Adherence to the guidelines and recommendations presented in the present document will enable policy-makers, managers and the entire recreational fisheries sector to orient recreational fisheries towards maintaining or achieving sustainability.

CONTENTS

ACRONYMS AND ABBREVIATIONS

AM	adaptive management
Code	FAO Code of Conduct for Responsible Fisheries
CoP	EIFAC Code of Practice for Recreational Fisheries
COFI	FAO Committee on Fisheries
EAF	ecosystem approach to fisheries
EEZ	exclusive economic zone
EIFAC	European Inland Fisheries Advisory Commission (former name)
MSY	maximum sustainable yield
NGO	non-governmental organization
PA	precautionary approach
RFB	regional fishery body
RFMO	regional fisheries management organization
SDM	structured decision-making
STK	stakeholder and traditional knowledge
TGRF	Technical Guidelines for Responsible Fisheries

BACKGROUND

1. From ancient times, fishing from oceans, lakes and rivers has been a major source of food, a provider of employment and other economic benefits for humanity. Ocean productivity seemed particularly unlimited. However, with increased knowledge and the dynamic development of fisheries and aquaculture, it was realized that living aquatic resources, although renewable, are not infinite and need to be properly managed, if their contribution to the nutritional, economic and social well-being of the growing world's population was to be sustained.

2. However, for nearly three decades, because of the dramatic increase of pollution, abusive fishing techniques worldwide, and illegal, unreported and unregulated fishing, catches and landings have been shrinking and fish stocks declining, often at alarming rates.

3. Stock depletion has negative implications for food security and economic development and reduces social welfare in countries around the world, especially those relying on fish as their main source of animal protein and income such as subsistence fishers in developing countries. Living aquatic resources need to be properly managed, if their benefits to society are to be sustainable.

4. Sustainability of societal benefits requires a recovery of depleted stocks and maintenance of the still-healthy ones, through sound management. In this regard, the adoption of the United Nations Convention on the Law of the Sea, in 1982 was instrumental. The law provides a new framework for the better management of marine resources. The new legal regime of the oceans gave coastal States rights and responsibilities for the management and use of fishery resources within the areas of their national jurisdiction, which embrace some 90 percent of the world's marine fisheries.

5. In recent years, world fisheries have become dynamically developing sectors of the food industry, and many States have striven to take advantage of their new opportunities by investing in modern fishing fleets and processing factories in response to growing international demand for fish and fishery products. It became clear, however, that many fisheries resources could not sustain an often uncontrolled increase of exploitation. Overexploitation of

important fish stocks, modifications of ecosystems, significant economic losses, and international conflicts on management and fish trade still threaten the long-term sustainability of fisheries and the contribution of fisheries to food supply.

6. In light of this situation, while recognizing that the recovery of depleted stocks is still urgent and avoiding depleting still-healthy stocks as important, FAO Member States have expressed the need to further develop aquaculture as the only immediate way to bridge the gap between the dipping capture fisheries output and the increasing world demand for seafood.

7. Indeed, in the last three decades, aquaculture has recorded a significant and most rapid growth among the food-producing sectors and has developed into a globally robust and vital industry. However, aquaculture also has been shown at times to carry the potential to cause significant environmentally and socially adverse impacts.

8. Thus, the Nineteenth Session of the FAO Committee on Fisheries (COFI), held in March 1991, recommended that new approaches to fisheries and aquaculture management embracing conservation and environmental, as well as social and economic, considerations were urgently needed. FAO was asked to develop the concept of responsible fisheries and elaborate a Code of Conduct to foster its application.

9. Subsequently, the Government of Mexico, in collaboration with FAO, organized an International Conference on Responsible Fishing in Cancún in May 1992. The Declaration of Cancún, endorsed at that Conference, was brought to the attention of the United Nations Conference on Environment and Development Summit in Rio de Janeiro, Brazil, in June 1992, which supported the preparation of a Code of Conduct for Responsible Fisheries. The FAO Technical Consultation on High Seas Fishing, held in September 1992, further recommended the elaboration of a code to address the issues regarding high seas fisheries.

10. The One Hundred and Second Session of the FAO Council, held in November 1992, discussed the elaboration of the Code, recommending that priority be given to high seas issues and requested that proposals for the Code be presented to the 1993 session of the Committee on Fisheries.

11. The twentieth session of COFI, held in March 1993, examined in general the proposed framework and content for such a Code, including the elaboration of guidelines, and endorsed a time frame for the further elaboration of the Code. It also requested FAO to prepare, on a "fast track" basis, as part of the Code, proposals to prevent reflagging of fishing vessels which affect conservation and management measures on the high seas. This resulted in the FAO Conference, at its Twenty-seventh Session in November 1993, adopting the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, which, according to FAO Conference Resolution 15/93, forms an integral part of the Code. It was also recognized and confirmed that issues of responsible aquaculture development and aquaculture sustainability should be addressed in the formulation process so that these be appropriately covered in the envisaged Code.

12. This implicit recognition of the importance of governance in aquaculture is underlined in Article 9.1.1 of the Code, which requires states to "establish, maintain and develop an appropriate legal and administrative framework to facilitate the development of responsible aquaculture". In addition, at the beginning of the new millennium, there is growing recognition of the significant potential for the use of ocean and coastal waters for mariculture expansion. The outstanding issue in this area is that, unlike in capture fisheries, the existing applicable principles of public international law and treaty provisions provide little guidance on the conduct of aquaculture operations in these waters. Yet, experts agree that most of the future aquaculture expansion will occur in the seas and oceans, certainly further offshore, perhaps even as far as the high seas. The regulatory vacuum for aquaculture in the high seas would have to be addressed should aquaculture operations expand there.

13. The Code was formulated so as to be interpreted and applied in conformity with the relevant rules of international law, as reflected in the 10 December 1982 United Nations Convention on the Law of the Sea. The Code is also in line with the Agreement for the Implementation of the Provisions of this Law, namely the 1995 Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. It is equally in line with, *inter alia*, the 1992 Declaration of Cancún and the 1992 Rio Declaration on Environment and Development, in particular Chapter 17 of Agenda 21.

14. The development of the Code was carried out by FAO in consultation and collaboration with relevant United Nations Agencies and other international organizations, including non-governmental organizations.

15. The Code of Conduct consists of five introductory articles: Nature and scope; Objectives; Relationship with other international instruments; Implementation, monitoring and updating; and Special requirements of developing countries. These introductory articles are followed by an article on General principles, which precedes the six thematic articles on Fisheries management, Fishing operations, Aquaculture development, Integration of fisheries into coastal area management, Post-harvest practices and trade, and Fisheries research. As already mentioned, the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas forms an integral part of the Code.

16. The Code is voluntary. However, certain parts of it are based on relevant rules of international law, as reflected in the United Nations Convention on the Law of the Sea of 10 December 1982. In capture fisheries, the Code also contains provisions that may be or have already been given binding effect by means of other obligatory legal instruments amongst the Parties, such as the Agreement to Promote Compliance with Conservation and Management Measures by Fishing Vessels on the High Seas, 1993. In aquaculture, the provisions of the Code implicitly encourage participatory governance of the sector, which extends from industry self-regulation, to co-management of the sector by industry representatives and government regulators and to community partnerships. Compliance is self or enforced by peer pressure, with industry organizations having the ability to exclude those who do not comply and governments only checking periodically.

17. The Twenty-eighth Session of the Conference in Resolution 4/95 adopted the Code of Conduct for Responsible Fisheries on 31 October 1995. The same Resolution requested FAO *inter alia* to elaborate appropriate technical guidelines in support of the implementation of the Code in collaboration with members and interested relevant organizations.

18. The expanding role and increasing contribution of aquaculture to economic growth, social welfare as well as global food security was recognized and reiterated at international levels such as the 1995 FAO/Japan Conference

on the Contribution of Fisheries and Aquaculture to Food Security, the 1996 World Food Summit, the 1999 Ministerial Meeting on Fisheries, the 2000 FAO/NACA [Network of Aquaculture Centres in Asia and the Pacific] Conference on Aquaculture in the Third Millennium and its Bangkok Declaration and Strategy, and most recently, the 2009 World Summit on Food Security.

19. The application of the ecosystem approach to fisheries and aquaculture as strategies for the development of the sector contributes to the implementation of the provisions of the Code, thereby enforcing the technical, ecological, economic and social sustainability of the industry.

1. INTRODUCTION

Recreational fisheries constitute the dominant or sole user of many wild freshwater fish stocks in most industrialized countries (Arlinghaus, Mehner and Cowx, 2002). However, the prevalence of recreational fisheries is not confined to freshwaters and is present in 76 percent of the world's exclusive economic zones (EEZs) (Mora *et al*., 2009). Some coastal marine stocks in more industrialized nations are exclusively exploited for recreation, or intensive coexploitation for commercial and recreational purposes occurs (Ihde *et al*., 2011). Overall, there is a growing recognition of the immense economic, sociocultural and ecological importance of recreational fishing as a significant component of global capture fisheries (Pawson, Glenn and Padda, 2008; Mora *et al*., 2009; Ihde *et al*., 2011).

Recreational fisheries involve millions of people globally, generating billions of US dollars in economically developed countries, and, in addition, they are emerging as a social and economic factor in many economies in transition (e.g. Argentina, Brazil, China, India) and some developing countries (FAO, 2010). On average, across countries with reliable statistics, the participation rate in recreational fishing by the total population in a given country is 10.6 ± 6.1 percent (SD) (Arlinghaus and Cooke, 2009). In light of this estimate, about 140 million recreational fishers are present in three of the most industrialized continents alone, North America, Europe and Oceania. Extrapolating to the global level is more difficult because of a paucity of information on participation rates for recreational fishing in less developed/wealthy countries, but a rough estimate is a maximum of 700 million recreational fishers worldwide (Cooke and Cowx, 2004).

In many industrialized countries where public wealth increase coincides with changes in consumer demand, habitat loss, overexploitation and the emergence of service sectors as alternatives to primary industries, the intensity and attractiveness of commercial capture fisheries typically declines. Recreational fishing then emerges as the dominant use of wild fish stocks, particularly in inland fisheries (Arlinghaus, Mehner and Cowx, 2002). Because recreational fishing can be as intensive as commercial operations, and because potentially unsustainable management actions can be associated with the development of recreational fisheries, e.g. release of non-native fish to establish new fisheries (Johnson, Arlinghaus and Martinez, 2009), a number of sustainability and biodiversity conservation issues have emerged (Cowx, Arlinghaus and Cooke, 2010). The two conditions expounded so far – high and increasing socio-economic and ecological significance – justify a need for guidance on how to orient the sector towards biological sustainability on an international level. In addition, guidelines for recreational fisheries management are needed in light of the potential for fisheries resource allocation conflicts among commercial fisheries, artisanal/subsistence fisheries, and other users of fish and water and recreational fisheries.

This document provides the needed guidance to orient recreational fisheries towards sustainable pathways in light of the FAO Code of Conduct for Responsible Fisheries (the Code) (FAO, 1995) in general, and the EIFAC Code of Practice for Recreational Fisheries (CoP) in particular (EIFAC, 2008), and should be particularly useful for countries lacking experience in recreational fisheries development and management. It might also make existing approaches more coherent within experienced nations and regions. These Guidelines are directed at the core recreational fisheries sector meaning all people, organizations and actors with direct involvement in fishery resource use and fisheries management, e.g. fisheries policy, governance, management bodies, representatives of recreational fishers stakeholders, recreational fishers, and to some degree the recreational gear industry and recreational fishing media. The document relates to stock assessment, fisheries management and recreational fisheries practice and does not focus on best practices in business or industry.

1.1 DEFINITIONS

An individual's motivation to fish differs in recreational as compared with commercial or subsistence fisheries. Personal objectives, incentives and rewards sought in the pursuit of fishing are useful to demarcate the various types of fisheries. Recreational fishers fish for many reasons, but not primarily to secure survival and generate resources to meet essential, nutritional needs. Recreational fishing is thus defined as fishing of aquatic animals (mainly fish) that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets (EIFAC, 2008; see Mike and Cowx, 1986 for exceptions where recreational fishers sell surpluses to offset costs). In contrast, commercial and subsistence fisheries are primarily directed towards the livelihood of the fisher (and family), with fishing contributing substantially to meeting nutritional needs of the individual.

While the difference between commercial and recreational capture fisheries may be obvious, the issue becomes more difficult in the case of subsistence fisheries. It is acknowledged that the unambiguous demarcation between recreational fisheries and subsistence fisheries is impossible because many recreational fishers, even in wealthy countries, have strong subsistence-like incentives to harvest fish (Macinko and Schumann, 2007). However, the perspective of individual fishing protagonists using fishing activity to generate resources for their livelihood does differentiate between recreational fisheries and subsistence fisheries. Moreover, as a rule, recreational fishers have the financial capacity to substitute the fishing products by other products to meet nutritional needs and secure protein intake and survival. However, the fact that recreational fishing does not contribute substantially to generating resources for survival of the fisher does not mean that there is no economic activity associated with recreational fisheries. In fact, the spill-over economic effects associated with recreational fishing create a multibillion-dollar industry that supports economic activity and livelihoods for many (Arlinghaus, Mehner and Cowx, 2002).

Globally, angling is by far the most common recreational fishing technique, which is why recreational fishing is often used synonymously with angling (Arlinghaus *et al.*, 2007a). However, in some countries, recreational fishers use gear such as spears, bows and arrows, rifles, traps and gillnets (Arlinghaus and Cooke, 2009). Accordingly, in this document, recreational fishing will be used as the standard term, and only where the specific context requires will angling or angler be referred to. In addition, although recreational fishing can target aquatic organisms other than finfish (e.g. lobster and crabs), the term fish is used in the document to mean aquatic animals. The recreational fisheries sector is defined as the entire network of stakeholders involved in or fully or partly dependent on recreational fisheries. Included, among others, are fisheries ministries and agencies (local, national, and international including regional fisheries organizations and bodies), managers, non-governmental organizations (NGOs, e.g. umbrella angling associations and clubs), anglers, non-angling recreational fishers, tackle shops and tackle manufacturers, bait suppliers, charter-boat industry, recreational boat builders and chandlery suppliers, marina operators, specialized angling and fishing media, recreational fishing tourism and other related business and organizations, as well as all other enterprises supporting recreational fisheries such as aquaculture operations that produce stocking material or fishery owners that sell angling permits for their waters. A range of other stakeholders and managerial regimes are not included in this definition even though they may run or advocate activities and developments that have a direct impact on recreational fishing quality and the recreational fisheries sector's viability and growth potential (e.g. hydropower generation, water management, irrigation, commercial fisheries, nature conservation groups). In the following, they will be referred to as "external sectors", as appropriate. More definitions can be found in the glossary at the end of this document

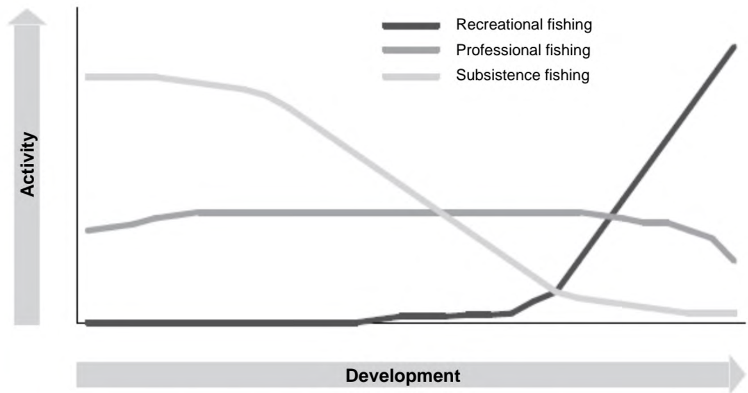
1.2 GLOBAL TRENDS IN RECREATIONAL FISHERIES

Although of high importance globally, relative to commercial and subsistence fisheries, the relevance of recreational fisheries varies according to country. Broadly speaking, recreational fishing activity increases with the economic development of societies because people can afford to spend time fishing for leisure rather than fishing to secure nutrient input or survival. Although the use of coastal, and sometimes offshore, marine fish stocks by recreational fisheries also develops with a society's economic development, the shift from subsistence to commercial and, finally, to an often exclusive recreational use of wild fish stocks is particularly pervasive in inland fisheries (Figure 1).

According to FAO (2010), an almost linear increase in recreational fishing interest in a society is expected to occur with its economic development. However, in reality, infinite growth of recreational fisheries (Figure 1) is not to be expected. Specific for inland fisheries, for example, the "life cycle" of fisheries introduced by Smith (1986) and further developed by Arlinghaus, Mehner and Cowx. (2002) and Cowx, Arlinghaus and Cooke (2010) predicts a levelling off of or even decline in recreational fishing growth after an initial rise with economic development of societies. According to this model, a maximum recreational fishing participation is expected to occur in an intermediate phase of economic development (industrialization) (Figure 2), after which recreational fishing interest again declines with urbanization and modernization. Before this eventual decline, likely to be caused by now-urbanized people losing contact with and interest in fish and wildlife, a rapid rise in freshwater recreational fishing interest coupled with a decline in subsistence or commercial is to be expected in all countries that experience explosive economic development. Indeed, many countries in transitional economies in Asia, Latin America and Africa are currently experiencing fast-growing recreational fisheries (FAO, 2010; Welcomme *et al.*, 2010), and in many regions (e.g. southern Pantanal of Brazil) catches by recreational fisheries have surpassed those by commercial fishers (Catella, 2006). This is due to the fact that, with economic development,

Figure 1
Predicted shifts in the main type of inland fishing in relation to economic development of a society

Evolution of inland fisheries

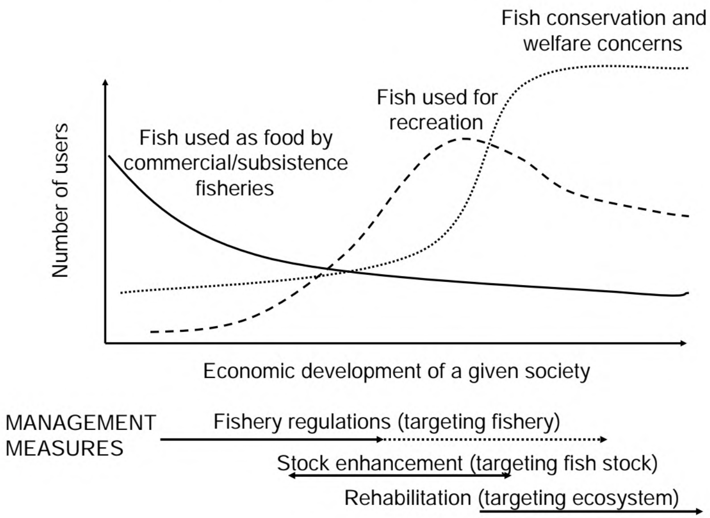


Note: The depicted situation is thought of as a prototypical trend across much of the world.
Source: FAO (2010).

subsistence fisheries transform into, or are replaced by, more leisure-based forms of fishing and/or because in some developing countries recreational fishing tourism has become a locally and regionally important activity (Mike and Cowx, 1986; Potts *et al.*, 2009; Everard and Kataria, 2011).

Because recreational fisheries increase with economic development of societies, many today are in pervasively anthropogenically altered habitats and ecosystems that are affected by a range of impacts unrelated to fishing (Arlinghaus, Mehner and Cowx, 2002). Such fisheries are characterized by multiuse patterns and a long history of habitat change in conjunction with coastal zone management, flood control, damming, channelization, pollution, water abstraction, overfishing by commercial harvesting, etc. Moreover, recreational fisheries are often not a top sociocultural priority in many contemporary societies, which makes it difficult to attract funding for the development and management of recreational fisheries resources. The situation is different in less-developed countries, where subsistence and commercial fisheries are usually dominant and strongly influence the management and development

Figure 2
A sketch of the life cycle of inland fisheries



Note: The number of "users" involves all stakeholders of aquatic ecosystems (direct and indirect).

Source: Modified from Cowx, Arlinghaus and Cooke (2010).

of recreational fisheries. However, recreational fisheries rarely operate in a vacuum and, thus, must take a range of stakeholders, activities and interest into account during development. The strong effects of non-fishery on aquatic ecosystems, particularly in freshwaters of industrialized countries, not only affect the quality of many recreational fisheries but motivates conservation and fish welfare concerns by the wider society (Arlinghaus *et al.*, 2009a) (Figure 2). One consequence of rising societal demands for conservation of wild living resources and the avoidance of biodiversity impacts (Cowx, Arlinghaus and Cooke, 2010) is that recreational fisheries must today be managed using integrated (i.e. across various sectors) policies involving a range of tools, including habitat management approaches, in addition to the more traditionally employed harvest regulations, effort controls, fish stocking or closed seasons (Chapter 5).

1.3 TYPES AND BENEFITS OF RECREATIONAL FISHERIES

Recreational fishing takes many forms and formats, from the fisheries for naturally recruited wild fish stocks in lakes, rivers and coastal areas, to the stocking-enhanced fisheries in natural or artificial waterbodies, which culminates in artificial, purely put-and-take-operated high-intensity fisheries that can be found in small impoundments or ponds and in more urban areas (Cowx, 2002). Not only do the types of fishery differ dramatically within and across countries, but so do the types of recreational fishers, leaving little room for an adequate generalization. The various dimensions are those such as orientation of the catch (harvest all to total catch-and-release), gear choice (from handlining to long-distance motorized boat fishing with modern echo-sounder technology, from organic bait to advanced artificial baits such as fly), type of fishing (bottom, float, casting, trawling, fly fishing) and destination (resident fishing close to home in urban ponds or small lakes to long-distance angling tourism holidays abroad in offshore or remote, unexploited areas).

Some fishers specialize temporarily or over time on species and techniques. Angler specialization theory by Bryan (1977) provides a framework to describe the diversity of fishing styles from the "general to the particular" distinguishing the occasional fisher from the avid, specialized angler whose lifestyle revolves around fishing. As a general rule, as commitment to the activity increases, consumptive orientation declines and the importance of size of fish increases. In line with this, Beardmore *et al.* (2011) recently provided a motivational clustering of recreational fishers in Germany describing less-committed anglers as consumptive, social and nature/relaxation-oriented anglers, while the more committed types include trophy and non-trophy challenge-oriented anglers, which may involve the desire to seek records and other rewards (e.g. fishing competitions). There is also a strong cultural influence on how the harvest desire of anglers shifts with specialization and commitment levels. For example, in Germany, even highly committed anglers may maintain a strong harvest interest (Dorow *et al.*, 2010) although, as a rule, alongside commitment the propensity for catch-and-release fishing increases. Overall, globally, about 60 percent of all captured fish are estimated to be released in recreational angling which translates into billions of individual fish (Cooke and Cowx, 2004).

The fact that there are hundreds of millions of people participating in recreational fishing in inland, coastal and marine fisheries worldwide suggests that there are many associated benefits to the individual that collectively also influence society positively (Weithman, 1999; Arlinghaus, Mehner and Cowx, 2002; Parkkila *et al.*, 2010). One of the most obvious is the employment fed by recreational fishing expenditure, which can constitute a multibillion-dollar industry in some countries. For marine recreational fishing only, Cisneros-Montemajor and Sumaila (2010) estimated that, globally, a minimum of 58 million anglers generate a total of US$40 billion, supporting more than 954 000 jobs. However, given the lack of reliable statistics from many countries of the world and the omission of freshwater fisheries, this could well be a considerable underestimate.

Benefits of recreational fishing extend beyond employment and include the social and cultural domains. For example, recreational fisheries as a provisioning service give households a resource for food. However, there are also many less-tangible cultural ecosystem services, including recreation, environmental education, social cohesion and the enjoyment of aesthetic pleasures during fishing. Moreover, recreational fisheries motivate a sizable fraction of society to maintain and enhance such ecosystem services and the recreational experience they support through fisheries management and sometimes legal actions (Parkkila *et al.*, 2010). The value of recreational fishing for conservation of aquatic systems in general has a simple economic root; recreational fishers have a vested interest in preserving or enhancing the resources they depend on. There is ample evidence that recreational fishers work proactively to conserve, and where possible enhance, aquatic biodiversity, either directly, e.g. by stocking of native fish, or indirectly through habitat management and other fisheries management actions, often financed by recreational fishing licence money (Granek *et al.*, 2008). There is also evidence that anglers are instrumental in shaping pro-environmental legislation and combating environmental harm through legal action (Bate, 2001; Kirchhofer, 2002). In addition, in some countries (e.g. Nicaragua, Costa Rica), recreational fisheries have promulgated regulations that constrain commercial fisheries and allocate important fisheries (e.g. billfish) exclusively to recreational fishing. Such regulations may involve restrictive regulations on harvest or even demand total catch-and-release, which may alleviate fishing pressure on stocks (but see Coggins *et al.*, 2007). There can be a downside to well-meant recreational fisheries management actions, such as release of fish carrying diseases or non-native genes, strongly and sometimes irreversibly affecting aquatic biodiversity (Laikre *et al.*, 2010; van Poorten *et al.*, 2011) and the ecosystem (Eby *et al.*, 2006). In addition, recreational fishing can negatively affect stocks (Post *et al.*, 2002; Lewin, Arlinghaus and Mehner, 2006). Production of these Guidelines for responsible and sustainable recreational fisheries is thus further justified.

1.4 BIOLOGICAL ISSUES OF RECREATIONAL FISHERIES

Unintended consequences of capture fisheries, including habitat destruction, incidental mortality of non-target species, shifts in population structure and demographics, and changes in the function and structure of ecosystems, are being increasingly recognized (Welcomme, 2001; Worm *et al.*, 2009). Recreational fishing can also induce similar changes in fish communities and aquatic ecosystems through actions such as excessive harvest mortality, selective mortality, unwanted catch-and-release mortality, injury and disease transmission, illegal release of non-native genotypes, introduction of non-native species, stocking, litter, ground-baiting, and disturbance of the environment and wildlife from, for example, gaining access to the water or boat noise (Chapter 6 and Post *et al.*, 2002; Cooke and Cowx, 2004, 2006; Lewin, Arlinghaus and Mehner, 2006). Such impacts provide potential for particularly troublesome issues such as genetic change in fish stocks, which may result from recreational fishing-induced mortality (Cooke and Cowx, 2006; Philipp et al., 2009; Matsumura, Arlinghaus and Dieckmann, 2011), or from detrimental actions, especially stocking of native, hatchery-reared fish and introduction of non-native species or genotypes, or transfer of fish or diseases across catchments (Lewin, McPhee and Arlinghaus, 2008; Johnson, Arlinghaus and Martinez, 2009; Laikre et al., 2010).

Historically, recreational fisheries managers have focused on measures that manipulate the interaction between a pool of recreational fishers and a single targeted fish population using tools such as size-based harvest limits, daily bag limits, quotas, buy-out of commercial fishing and stock enhancements. However, it is now recognized that recreational exploitation of key components of a food web (e.g. the top predators) (Post *et al.*, 2002; Roth *et al.*, 2007, 2010), sometimes facilitated by recreational fishing-induced alterations of key habitat features (e.g. removal of dead woody debris in lakes [Carpenter and Brock, 2004]; altered nutrient cycling owing to stocking of large number of benthivorous fish in lakes [Eby *et al.*, 2006]), and deliberate or accidental release of non-native fish (Johnson, Arlinghaus and Martinez, 2009), can have important ecological and evolutionary consequences for entire communities and ecosystems that extend the target fish stock (Walters and Kitchell, 2001; Lewin, Arlinghaus and Mehner, 2006). Moreover, beyond the direct effects on target species, the selective exploitation of keystone species such as top predators may be responsible for the successful invasion by non-native species once a threshold exploitation rate is crossed that when looked at in isolation is biologically sustainable for the exploited species (Roth *et al.*, 2010).

Therefore, responsible recreational fisheries management must consider the broader impacts of fishing on the ecosystem as a whole, taking ecosystem traits, food webs and biodiversity across genetic, species and population levels into account. Tackling this issue may demand an ecosystem approach to recreational fisheries in some instances (Chapters 3 and 6).

That said, many declines in wild fish stocks are only partly due to recreational fishing or its management practices. In particular, in freshwater ecosystems, non-fishing related activities, such as agriculture, damming, deforestation, navigation, wetland reclamation, urbanization, water abstraction and transfer and waste disposal, have altered freshwater ecosystems profoundly, probably more than terrestrial ecosystems (Arlinghaus, Mehner and Cowx, 2002). Consequently, in most areas of the world, the principal impacts on fish stocks do not originate from the fishery itself but from outside the fishery (Cowx, Arlinghaus and Cooke, 2010). In addition to ecological impacts, social conflicts occur in recreational fisheries, e.g. between nature preservation and fisheries interests, or among commercial and recreational sectors.

1.5 OBJECTIVES AND TARGET AUDIENCE OF GUIDELINES

The objective of the present Technical Guidelines for Responsible Fisheries: Recreational Fisheries (TGRF) is to provide guidance on responsible recreational fisheries conforming to the generic principles outlined in the Code (FAO, 1995) in order to help the international fisheries community develop or maintain sustainable recreational fisheries. The objectives are:

- to describe an ethical and managerial framework along with associated best fisheries practice and management principles, guidelines and strategies for responsible recreational fisheries, always in accordance with relevant national and regional legislation and international law;
- to serve as a guiding instrument of reference in establishing or improving national institutional and policy frameworks required to exercise responsible management of recreational fisheries;
- to promote international exchange of knowledge and experiences on recreational fisheries, on their management and sustainable development;
- to facilitate and promote cooperation among fisheries bodies, NGOs and individual stakeholders in the conservation, management and development of recreational fisheries resources, including the aquatic ecosystems of which they are an intrinsic part;

- to promote recreational fisheries in the long term by outlining and facilitating best practices within the sector for long-term sustainability, and for the responsible use of all ecological services generated by aquatic ecosystems and aquatic organisms;
- to promote research into recreational fisheries as well as on associated aquatic ecosystems and the relevant environmental factors that influence recreational fisheries.

The Guidelines are tailored particularly towards policy and management decision-makers, and all stakeholders involved in developing and implementing policy and technical interventions relevant to recreational fisheries. The Guidelines will also be of use to all representatives of the recreational fisheries sector and their NGOs, environmental organizations, and academic and scientific institutions, and all entities, parties, organizations and individuals that are concerned with, or directly or indirectly affect or depend on, aquatic ecosystems, recreational fisheries resources and recreational fishing activity. This includes human activities that support recreational fisheries, such as aquaculture production of fish for stocking, the manufacture of gear, the tourism industry, the media, as well as fisheries management and research. In some sections, the individual recreational fisher will find pertinent information on how to improve fisheries practices (Chapter 6). The overall focus of the present TGRF is on the core recreational fisheries sector and recreational fisheries resource use and management. Accordingly, these best practice guidelines are tailored to fisheries practice, assessments and management and, thus, do not overtly deal with the supply (e.g. gear) and demand (e.g. marketing) chains in the recreational fisheries sector.

1.6 A GUIDE TO THE USE OF THE GUIDELINES AND RELATION TO OTHER FAO DOCUMENTS

This TGRF document is structured in separate chapters, each fulfilling a separate purpose and having a slightly different audience (Figure 3).

Content moves from the general to the particular, emphasizing generic guidance for sustainable recreational fisheries and then tailoring such to regional and local situations. Figure 3 shows the theme of each chapter, its content, and its target audience. Because all management and policy decisions are influenced by values and social choices, it was deemed necessary to outline initially one possible normative framework that corresponds with the contemporary zeitgeist and the provisions of the Code, before later outlining in a “how to” approach the more specific management recommendations directed

Figure 3
An overview of the Technical Guidelines for Responsible Fisheries: Recreational Fisheries, including chapter titles, major content of each chapter and target audience

Chapter	Content	Audience
Ethical Framework	Introduces **aquatic stewardship** as normative framework for sustainble recreational fisheries	All
Management Philosophy	Introduces **adaptive management** and structured decision-making as managerial philosophy	Managers
Policy/Institutional Frameworks	Discusses important elements of a functioning **policy framework**	Policy makers
Recreational Fisheries Management	Outlines decision-frameworks to **operational fisheries management**	Managers
Recreational Fisheries Practices	Gives recomendation for responsibe **recreational-fishing practices**, including those related to addressing fish welfare issues	Fishers
Information and Research	Provides guidance how to generate **new knowledge** to direct sustainable recreational fisheries	Researchers & managers
Developing countries	Special guidance for **developing countries** is provided	Policy makers
Implementation	Provides guidance how to **implement** the Guidelines	All

at policy-makers, managers, individual recreational fishers and research workers. The level of detail in the more technical substance-oriented chapters is commensurate with the need to remain useful for the many recreational fisheries worldwide. Many management decisions are context-specific, so the more procedural aspects have been emphasized. The chapter devoted to developing countries is in recognition of recreational fishing being most prevalent in the more wealthy countries and that generic advice was needed on how to take advantage of recreational fisheries to complement subsistence and commercial fisheries.

At the end of the document, the Annex lists all the recommended guidelines for each specific area of recreational fisheries governance and management.

While these Technical Guidelines orient the Code towards recreational fisheries and the particular practices and management demands, other FAO Technical Guidelines for Responsible Fisheries are relevant for in-depth consideration of aspects that pertain to recreational fisheries but cannot be dealt with in detail here. Box 1 provides a summary of relevant work.

Box 1

Overview of FAO Technical Guidelines of relevance to recreational fisheries

Many recreational fisheries operate based on extraction of fish from natural fish stocks without stock enhancement or coexploit wild-living organisms alongside commercial/subsistence fisheries (e.g. many coastal areas). Such situations mirror unconstrained (marine) capture fisheries in that they do not seek to manipulate the stock other than by removal of fish. Here, in addition to consulting the Technical Guidelines for Responsible Fisheries: Recreational Fisheries (TGRF), readers should refer to the provisions of:

- FAO. 1997. *Fisheries management*. FAO Technical Guidelines for Responsible Fisheries No. 4. Rome. 82 pp.
- FAO. 2003. *Fisheries management. 2. The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome. 112 pp.
- FAO. 2009. *Fisheries management. 2. The ecosystem approach to fisheries. 2.2 The human dimensions of the ecosystem approach to fisheries.* FAO Fisheries Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2, Add. 2. Rome. 88 pp.

Many recreational fisheries that are stock-enhanced share similarities to extensive aquaculture systems and occur as inland stillwater fisheries. Here, in addition to consulting the TGRF, readers should refer to the provisions of:

- FAO. 1996. *Precautionary approach to capture fisheries and species introductions*. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome. 54 pp.
- FAO. 1997. *Aquaculture development*. FAO Technical Guidelines for Responsible Fisheries No. 5. Rome. 40 pp.
- FAO. 1997. *Inland fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 6. Rome. 36 pp.

(Box Cont.)

- FAO. 2008. *Aquaculture development. 3. Genetic resource management*. FAO Technical Guidelines for Responsible Fisheries No. 5, Suppl. 3. Rome. 125 pp.

Recreational fisheries are particularly relevant in freshwater ecosystems in industrialized countries. These are characterized by multiuse patterns and, in addition to fish capture, suffer a range of activities not related to fisheries related that affect aquatic ecosystems. To address these issues, interested readers are directed to:

- FAO. 1997. *Inland fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 6. Rome. 36 pp.
- FAO. 2008. *Inland fisheries. 1. Rehabilitation of inland waters for fisheries. The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries No's, Suppl. 1. Rome. 122 pp.

2. NORMATIVE FRAMEWORK FOR RESPONSIBLE RECREATIONAL FISHERIES

2.1 A GENERAL OVERVIEW

To provide recommendations on recreational fisheries within the TGRF it was necessary to use an explicit normative (or ethical) framework because all decisions on fisheries have implications for human beings or aspects that they value (e.g. fish stocks, biodiversity). Therefore, all fisheries management has a strong moral dimension. Fisheries ethics deals with the values, rules, duties and virtues of relevance to both human well-being and ecosystems, providing a critical moral compass on which subsequent goals, management objectives and management measures are to be based (FAO, 2005a; see Chapter 5 for details on objectives). Because social values and norms continuously change, the guiding ethical framework will also change over time, reflecting the mindset of a contemporary society or culture. The ethical framework followed in the present document follows key normative statements in the Code (FAO, 1995), *viz.*:

- "…users of living aquatic resources should conserve aquatic ecosystems. The right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources" (Article 6.1);
- "Fisheries management should promote the maintenance of the quality, diversity and availability of fishery resources in sufficient quantities for present and future generations in the context of food security, poverty alleviation and sustainable development" (Article 6.2)
- "States should … ensure that decision-making processes are transparent and achieve timely solutions to urgent matters. States, in accordance with appropriate procedures, should facilitate consultation and the effective participation of … interested organizations in decision-making with respect to the development of laws and policies related to fisheries management, development, international lending and aid" (Article 6.13).

When transferred to recreational fisheries, these articles call for building and implementing governance and management strategies that represent all stakeholders and their potentially diverse views in decision-making to maximize socio-economic benefits and engage in actions and behaviours that are ecologically sustainable by avoiding overfishing and maintaining aquatic biodiversity at all levels (Arlinghaus, Mehner and Cowx, 2002). Put differently, the guiding norm of sustainable management as suggested in the ethical framework of the Code entails biological, social and economic dimensions along with an appropriate policy and institutional structures (Chapter 4) conducive to achieving sustainability (Arlinghaus, 2006a). In this context, a popular view, shared by the TGRF, is that recreational fisheries are biologically sustainable if irreversible or costly change to wild exploited fish populations is avoided and the structure and function of aquatic habitats and the ecological services delivered by them to recreational fisheries and other stakeholders are conserved (Cowx, Arlinghaus and Cooke, 2010). This includes the supporting and regulating services generated by fish (Holmund and Hammer, 1999). Contingent on meeting these biological conservation goals, the social and economic benefits of recreational fisheries resource use should be maximized to achieve socio-economic sustainability, often a parallel process, as an overfished stock can negatively affect fishing quality (Johnston, Arlinghaus and Dieckmann, 2010).

Other social and cultural dimensions may also be relevant and affect final policy choices, e.g. issues of distributional justice and equity (Welcomme, 2001), when debating access to and allocation of resources to potentially competing fishery types (e.g. commercial, subsistence and recreational fisheries). However, as the social and economic realities are so diverse across the globe in various localities and fisheries, it is considered impossible to suggest generally applicable social and economic objectives to be followed by all recreational fisheries worldwide. Ultimately, it is the decision of local, regional and national decision-makers how to weight the utilities of different fisheries forms and types of fishers in the light of fundamental trade-offs inherent in all recreational fisheries management. For example, it is generally impossible to maximize both harvest (yield) and number of trophy fish in a stock (García-Asorey *et al.*, 2011), so it might be impossible to maximize the quality of fishing experiences for trophy and more harvest-oriented fishers in the same fishery. It is advisable to accept trade-offs and work around them by taking a broad-based view of single fisheries being a nested component of an overall set of multiple fisheries in a landscape or a coastal area, and to manage such using suitable compromise solutions (Hunt *et al.*, 2011). What is important is that any normative framework based on the sustainability paradigm will demand difficult choices to be made. These should be explicit because the choice of social and economic criteria for management will strongly affect which regulations and actions are considered socially and economically “optimal” (see, for example, the result of a recreational fisheries model by Johnston, Arlinghaus and Dieckmann [2010]).

Notwithstanding the difficult issue of deciding which social, cultural and economic criteria to include in a normative framework, a common denominator for all recreational management worldwide is the biological component, including overfishing and changes to aquatic biodiversity. Therefore, sustainable recreational fisheries management is based on an approach that is risk-averse to environmental impact (see Chapter 3 for details). In this context, recreational fisheries are conceptualized as a subsystem of the overarching ecological life-support system. There are a few exceptions to this, particularly in recreational fisheries that depend almost entirely on external inputs, do not interact with other stakeholders strongly and do not exploit self-reproduction stocks. Such an exception might be artificially created, e.g. high-intensity put-and-take recreational fisheries in semi-urban environments (North, 2002), which need not be judged against strict criteria of biological sustainability but instead emphasize social and economic sustainability more strongly (e.g. Hickley and Chare, 2004).

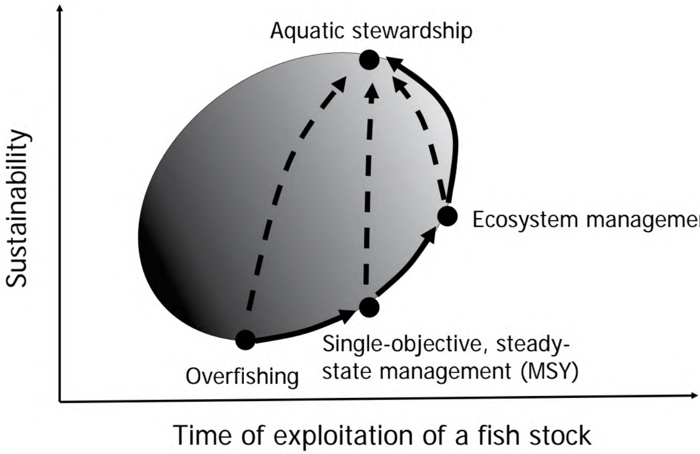
Achieving sustainability in recreational fisheries, and in capture fisheries in general, will almost always involve the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations (FAO, 1997a). Such a process conserves natural resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable (FAO, 1995). Because many recreational fisheries are strongly affected by stakeholders and actions outside recreational fisheries (e.g. habitat loss in engineered rivers, overexploitation by commercial fisheries), sustainability of recreational fisheries will be facilitated by integrated management plans and depends on cross-sectoral interactions (Cowx, 1998). One important caveat is the need to address the low sociopolitical priority that recreational fisheries experience in some countries (Arlinghaus, Mehner and Cowx, 2002), which may even result in access constraints (e.g. in nature conservation areas, Arlinghaus [2005, 2006a]) and the disregard of the legitimate interest of recreational fisheries in water management decision-making.

2.2 TOWARDS AQUATIC STEWARDSHIP

Promoting sustainable recreational fisheries not only demands their integration into overarching decision-making affecting aquatic ecosystems and water, but also depends on the internalization of a suitable moral compass guiding thought and action within the recreational fisheries sector. The zeitgeist that best aligns with a number of challenging issues characterized by coupled social-ecological systems such as recreational fisheries is the concept of aquatic stewardship (Figure 4). Aquatic stewardship, or environmental stewardship as more generally developed by Chapin, Kofina and Folke (2009) and Chapin *et al.* (2010), constitutes an action-oriented normative framework to foster the social-ecological sustainability of natural resource use. The central goal of a stewardship approach for the management and governance actors is to achieve sustainability by maintaining the capacity of aquatic ecosystems to provide the full range of services that benefit society (or part of it, e.g. recreational fisheries). This is contingent on sustaining and enhancing the integrity and diversity of ecosystems as well as fostering the adaptive capacity and well-being of the social system to be able to deal with complex adaptive systems. From the perspective of each individual actor or fisher in recreational fisheries, aquatic stewardship constitutes the moral obligation to care for aquatic environments, and the actions undertaken to provide that care (Knuth and Siemer, 2007). This includes care for habitats and the exploited fish populations and also the care for each individual fish that is captured. (Chapter 6, and Cooke and Sneddon, 2007). Because diversity provides the raw material on which selection and future innovation are based, both in the human and the non-human world, its maintenance across all levels is key to the aquatic stewardship framework.

The proposed framework of aquatic stewardship is an explicit strategy to respond to and shape social-ecological systems, such as recreational fisheries, under conditions of uncertainty and change, both ecologically and socially, to sustain the supply and opportunities for use of ecosystem services to support human well-being (Chapin, Kofina and Folke, 2009; Chapin *et al.*, 2010). This requires not only appropriate individual actions by recreational fishers, but also a radical shift in how management of recreational fisheries, and indeed fisheries in general, is perceived (Chapter 3 and 5). The framework of traditional stock management, often with ill-defined objectives, such as maximum sustainable yield (MSY) (Larkin, 1977), or a rigid approach to ecosystem management, is complemented by emphasis on multiple objectives and precautionary, adaptive and flexible (Chapter 3) management of critical, low turnover rate variables. These critical variables involve spawning habitat, genotypic diversity, biodiversity, human value diversity, institutional diversity, and the feedbacks between social and natural systems. These variables might be slow in turnover, but they are the key ingredients determining the future trajectory of a social-

Figure 4
Schematic diagram showing the evolution of renewable resource-management regimes observed in many Western nations



Notes: Dashed arrows show opportunities for developing nations to "leapfrog" from current management directly based on single objective, "steady-state" management (such as maximum sustainable yield [MSY]) to ecosystem stewardship. The dark-to-light gradient represents the probability of increased sustainability.

Source: Modified from Chapin *et al.* (2010).

ecological system and, therefore, require particular management attention (Figure 4, Biggs, Carpenter and Brock, 2009; Carpenter *et al*., 2011).

Critical slow variables are important in contemporary recreational fisheries management because they determine system thresholds and regime shifts (Carpenter *et al*., 2011). From many ecosystems and recreational fisheries (e.g. Persson *et al*. 2007), it is known that abrupt, sudden shifts in system states are possible once critical thresholds are reached, many of which are affected by exploitation or fisheries management strategies such as stocking (Box 2). The critical states are usually not known and difficult for a fisheries manager to predict because changes in critical slow variables tend not to induce marked impacts over a large range of the variable, and thus tend to go initially unnoticed for a long time. Therefore, managers and recreational fishers tend to

Box 2
Alternative stable states and regime shifts in recreational fisheries

There is a range of examples of unexpected system shifts in recreational fisheries. Such patterns are to be expected as a result of strongly species-selective and size-selective exploitation of top predators in complex food webs (e.g. Brock and Carpenter, 2007; Persson *et al*., 2007; Biggs, Carpenter and Brock, 2009). In particular, when such exploitation of top predators merges with recreational-fishing-induced alterations of critical slow habitat variables such as dead woody debris in lakes, sudden system shifts between states with and without abundant large-sized top predators may occur. Carpenter *et al.* (2011) found that the addition of top predators to a lake via stocking, with stocking rates being the critical slow variable of interest, may similarly yield a shift in the fish community composition and the size structure of stocked top predators, potentially leading to a regime shift towards a loss of prey fish and a dominance of top predators. Another example is the critical slow variable spawning habitat, which when eroded may not substantially affect adult population size until a certain threshold is reached after which impacts are severe (Minns *et al*., 1996). Finally, the slowly changing variable of the relative fitness of stocked non-native genotypes versus wild recruits might effect a sudden replacement of the wild stock by the non-native genotypes. For example, a stocking model by van Poorten *et al.* (2011) showed that, once a certain relative fitness threshold of stocked fish has been crossed, continuous stocking may result in the loss of wild gene pools in light of the potential for existence of two alternative states – one with and one without the existence of wild genotypes. Overall, paying attention to thresholds and regime shifts and the underlying critical slow variables and feedbacks inducing such shifts is important in the aquatic stewardship norm, in turn motivating recreational fisheries management to adopt precautionary approaches and an ecosystem perspective.

be unresponsive to changes in critical slow variables until it is too late and the system has flipped into a potentially stable alternative state. Such abrupt but often stable changes include loss of top predators, the establishment of stocked genotypes and replacement of wild fish, the spread of an undesired non-native fish or the stable change in a regulatory environment (Arlinghaus, 2007; Brock and Carpenter, 2007, Biggs, Carpenter and Brock, 2009; Horan *et al*., 2011).

Another critical aspect of the framework is the focus on managing (positive or negative) feedbacks between recreational fishers and fish stocks in addition to more traditional metrics such as optimal social yield (Johnston, Arlinghaus and Dieckmann, 2010) or other objectives. Negative (amplifying) feedbacks may, for example, result in ever-increasing stocking levels to meet every-increasing angler expectations (Johnson and Staggs, 1992) that may in turn prove catastrophic for recreationally exploited fish stocks (van Poorten *et al*., 2011). Aquatic stewardship would then call upon the management of the feedback loop rather than MSY or other management objectives *per se*, e.g. by education of anglers in realistic expectations, by reducing the responsiveness of managers to angler dissatisfaction or by altered incentives. Positive (stabilizing) feedback loops are also possible, e.g. when anglers remain attracted to poor-catch fisheries because of desirable aspects other than catch. However, while these stabilizing feedback loops might increase stability, they are not necessarily desirable and need to be managed. For example, inverse density-dependent catchability – a depensatory mechanism (Post *et al*., 2002, 2008) – may interact with unresponsive recreational fishing effort to cause widespread collapse of recreationally exploited fish stocks across a landscape (Hunt *et al*., 2011).

To conclude, the ethical framework of aquatic stewardship strives towards sustainable and responsible recreational fisheries, acknowledging multiple objectives that may be region-specific or locality-specific contingent on implementation of actions and strategies that maintain and improve the biotic communities and the aquatic ecosystems of which humans are a part (*sensu* Leopold [1949]). To facilitate this, the action-oriented framework has the following core areas and principles:

- a focus on adaptation and flexibility in management processes and the building of adaptive management capacity (Chapter 3);
- avoidance of narrowly focused management objectives and reference points such as MSY (Figure 2.1);
- a focus on the management of resiliency of the coupled social-ecological system and its critical feedbacks and variables while maintaining the full range of biological, stakeholder and institutional diversity;
- incorporation of the interests of multiple stakeholders and their knowledge in the planning of management interventions and fisheries-management decision-making;

- emphasis on each individual's fisher and actor contribution to ecological sustainability by adhering to pro-environmental behaviours.

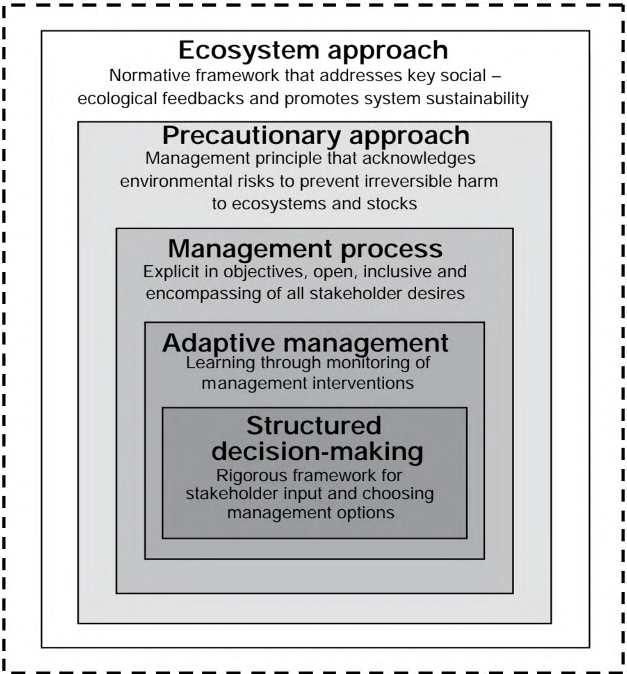
In this context, the aquatic stewardship framework embraces both the precautionary and the ecosystem approaches (Chapter 3) and targets actions that foster the diversity of future options by conserving biotic integrity rather than a single presumed, usually unrealistic optimum (e.g. MSY). Managing the diversity at all levels will provide system resilience in the face of unknown futures and possible sudden disturbances to the recreational fisheries system (Chapin, Kofina and Folke, 2009). Therefore, uncertainty and change become expected features of aquatic ecosystem stewardship rather than impediments to management actions (Chapin *et al.*, 2010).

3. MANAGEMENT FRAMEWORK FOR SUSTAINABLE RECREATIONAL FISHERIES

With aquatic stewardship for sustainability as the key normative framework governing recreational fisheries (Chapter 2), a guiding framework is now needed for "day-to-day" management as developed in more detail in Chapters 5 and 6. Given pervasive uncertainties stemming from a range of non-linear interactions between recreational fishers and fish stocks (Carpenter and Brock, 2004; Biggs, Carpenter and Brock, 2009; Hunt *et al.*, 2011), the focus is on adaptive management (AM) and structured decision-making as the core rigorous management process. This is in turn a nested element of, and affected by, overarching key fisheries management principles such as the ecosystem approach and the precautionary approach (PA; Figure 5). Uncertainty in recreational fisheries is pervasive, including productivity and size of stocks, importance of genetic diversity, impacts of alien species, behaviour of recreational fishers, expectations of various fisher types, stock condition in relation to management objectives and reference points, levels and distribution of fishing mortality, future climate and species invasions, and a range of social and economic drivers. The following process and principles tackle this uncertainty and enable robust decisions to help implement the overarching normative framework of aquatic stewardship. Because one source of pervasive uncertainty is the biological impact of recreational fishing or fisheries management (e.g. release of hatchery fish) on the ecosystem and biodiversity, an AM approach also constitutes a means to respond to the demands of the risk-averse ecosystem approach (FAO, 2003; Arlinghaus and Cowx, 2008) to fisheries and the PA (FAO, 1996). Moreover, AM is at the core of the normative framework of aquatic stewardship by acknowledging multiple objectives and sources of knowledge, multiple ecological services of interest, the critical importance of feedback and key system variables, and the need for continuous learning and adaptation to change to iteratively approach an "optimal" management solution in the long term.

Figure 5 visualizes the nested structure of management principles affecting the core management process of AM and is unfolded from the inside (i.e. AM and structured decision-making) and can then be modified by ecosystem and precautionary approaches to match local and regional conditions.

Figure 5
The nested structure of management principles affecting the core management process of adaptive management

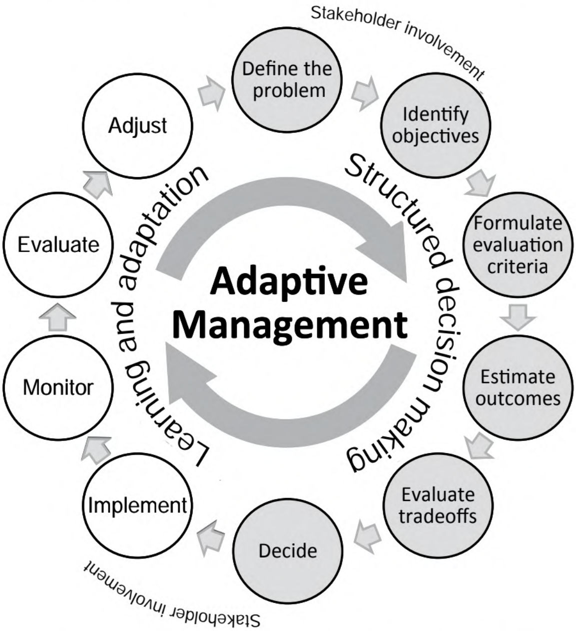


Notes: The core management process of adaptive management (AM) in recreational fisheries management is perceived as nested in, and being affected by, overarching management principles (PA), which are in turn derived from the guiding normative frameworks of the ecosystem approach and aquatic stewardship. Core elements of each component are given inside each box. The dotted line visualizes the flexibility and context-dependence of the prevailing normative. By contrast, the suggested management process of decision-making is less open to change, and, similarly, the underlying risk-averse approach to avoid irreversible loss to ecosystem structure and function will prevail in the light of pervasive data uncertainties that characterize many of today's recreational fisheries. Note that AM can mean either passive or active AM.

3.1 OVERVIEW ON ADAPTIVE MANAGEMENT

Adaptive management constitutes a strategic management approach to sustainable fisheries management, which is designed to confront pervasive uncertainties and social and ecological risks associated either with exploitation

Figure 6
Adaptive management of recreational fisheries



Notes: Adaptive management of renewable natural resources such as fish is a formalized iterative process that acknowledges uncertainty and achieves management objectives by increasing system knowledge through monitoring, feedback and revision of objectives and means to achieve objectives. Integral to it are both a decision component and an opportunity to learn. Structured decision-making (grey circles) is an organized and transparent approach to the decision process for identifying and evaluating alternatives and justifying complex decisions. However, structured decision-making does not necessitate the iteration and consequential higher-order learning (white circles) inherent in adaptive management.

Source: Modified from Allen *et al.* (2011).

or management actions supporting recreational fisheries (and other natural resource use) (Figure 6). The conceptual underpinnings for AM are simple although practical implementation may be challenging in terms of financial and human resources and the time needed to secure a successful project (Walters, 2007). However, it is not advocated to engage in rigorous, experimental active AM in all recreational fisheries. Instead, there are many less-demanding forms of passive AM that seem suitable for recreational fisheries management worldwide. In particular, the circular, rigorous, open and inclusive management process that AM advocates is of core importance for successful fisheries management, and this process may be implemented with a range of data sources, often qualitative, and is therefore much less resource-heavy than first appears.

The reason why engagement in some form of AM is advocated for recreational fisheries is simple. There will always be inherent uncertainty and unpredictability in the dynamics and behaviour of complex social-ecological systems such as recreational fisheries, e.g. as a result of non-linear interactions among mobile, heterogeneous recreational fishers and spatially structured fish populations in light of natural stochasticity in fish recruitment, yet management decisions must still be made. However, precisely because of the context dependence, complexity and unpredictability of many ecological and social-ecological processes in fisheries, the outcome of any management action can rarely be predicted with certainty, motivating variants of AM for natural resource management (Williams, 2011a, 2011b). The strength of AM is in the recognition and confrontation of uncertainties by emphasizing learning through management intervention and observing the reaction of the fishery (i.e. system) to any intervention (Walters and Hilborn, 1978; Walters, 1986).

Adaptive management has thus been characterized as "learning by doing", informed "trial-and-error" management or "experimental management". It is proposed here simply as a cyclic process-oriented approach to recreational fisheries management that follows a rigorous procedure of objective setting in dialogue with relevant stakeholders, initial policy and/or management action choice, evaluation of likely effects of these management choices in light of risk aversion to ecological or socio-economic impacts, decision on a policy or tool, subsequent management action implementation and, most importantly, monitoring of social and ecological outcomes, which then may lead to modified objectives in the future (Figure 6).

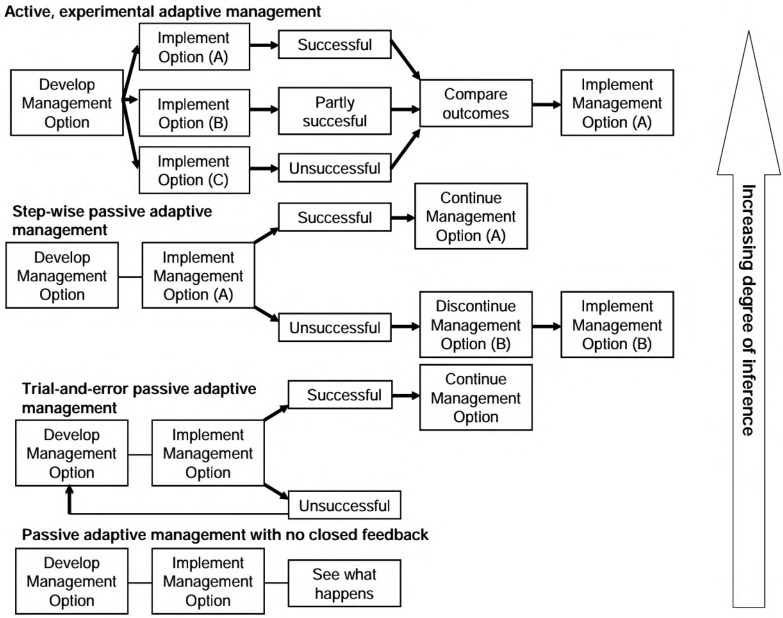
While quantitative monitoring data are desirable in the evaluation feedback loop, it is advocated to use all available data and experiences in the adaptive process, which can involve qualitative data in data-poor situations or in recreational fisheries that are too small in scope or value to justify a major stock-assessment exercise. Any data source and experience may be helpful in AM as a tool to evaluate responses and successes, so the lack of quantitative data or experts should not devalue the process itself. The important point for all recreational fisheries is that good fisheries management practice necessitates a cyclic, open, inclusive process to management in light of previously agreed, explicit and operational fisheries objectives that are derived based on the overarching normative frameworks of the ecosystem approach and aquatic stewardship, and ideally in consultation with stakeholders (Chapter 5). However, in many recreational fisheries, no such rigorous process of planning is followed, which increases the likelihood of mismanagement. Therefore, it is proposed that some variant of AM should be implemented in all recreational fisheries management systems, ranging from the small angling club exploiting an urban fishery to the coastal marine fisheries for large top predators that operate jointly with commercial fisheries. Although there will be differences in data quality and quantity, number of stakeholders to be considered, resources, time investment in the process, frequency and periods of updates, and the procedures and funding needed to put AM into practice, the general philosophy will be similar – management actions are decided upon following a cyclic, open, inclusive approach in light of objectives and considering overarching management principles (e.g. ecosystem approach). This will ultimately improve both the understanding of how the system works and the quality of the fishery, to in turn improve future management actions in the light of potentially revised goals and objectives.

The core idea of AM is thus to identify iteratively and over time an "optimal" management portfolio in the light of objectives, because *a priori* identification of this mix is usually impossible or confronted by scientific uncertainty, stakeholder distrust or disagreement about proper actions and their effects. Where this is the case, only a whole-system "experiment" can provide an answer. In essence, what is tested or explored in AM is the effect of management intervention on recreational fisheries and adjacent system components by monitoring outcomes on system variables (e.g. fish, angler welfare) and evaluating results in terms of objectives.

It is important to realize that AM comes in many variants and need not be strictly experimental in the sense of a replicated scientific experiment where one would treat, for example, entire fisheries as sampling units and assign treatments (e.g. harvest regulations or stocking rates of varying degree) to test their effects in the social, economic and biological domains. In fact, most applications of AM are much less rigorous and less controlled and replicated for practical reasons (e.g. lack of funding of subsequent monitoring activities, lack of time to invest into the process, or political inability of managers to push systems to extremes; Walters, 2007). However, even non-replicated case studies are preferred to unmonitored and unplanned actions because such so-called passive AM still helps to understand the impact of actions and to learn how the system "works" (Figure 7; Williams, 2011a, 2011b).

Active AM (Walters, 1986) is more advanced and involves deliberate testing of alternative methods and management interventions at the scale of replicated whole-system experiments. Such an approach involves hypotheses about the system in response to some management intervention and the subsequent testing of its effects at field levels. Owing to its experimental focus, active AM is more rigorous than passive AM, which is a "try something, and if it does not work try something else" approach with ad hoc revision of strategy through time (Figure 7; Williams, 2011a, 2011b). Where funding and human-resource

Figure 7
Types of adaptive management



Note: The learning and degree of information gain (inference) possible among approaches to recreational fisheries management varies, increasing from little or none in passive adaptive management to much in the active adaptive management approach.

Source: Modified from Allen *et al.* (2011).

limitations constrain experimental AM, the most commonly applied strategy for recreational fisheries will probably be some variant of passive AM.

The time, financial and political limitations and challenges of AM need to be recognized. Any AM that involves time-consuming stakeholder processes, contested management decisions, computer model building/analyses, and field testing of alternatives will not be a viable option for understaffed recreational fisheries management systems. For example, for small recreational fisheries governed by clubs and associations, the monitoring needs and expertise for active AM would be prohibitive. However, passive AM may still be possible, e.g. in water-rich landscapes where hundreds or thousands of lakes are to be managed in light of uncertainties. Here, a region-based or space-based monitoring scheme could still be preferred to a lack of monitoring, in particular when wanting to manage fisheries from a "landscape" perspective where lakes and rivers are connected by mobile recreational fishers. Under these conditions, the management of individual lakes and rivers may not be advisable (Lester *et al.*, 2003; Post *et al.*, 2008; Hunt *et al.*, 2011) and some form of "regional monitoring" is needed to identify optimal management solutions tailored to the landscape (usually based on geoclimactic features that underlie biological processes, e.g. an ecoregion) or management unit. Such an approach may not be experimental in the spirit of active AM, but instead be a version of passive AM by testing a range of previously agreed strategies in a more ad hoc version.

Passive AM comes in three variants, as outlined in Figure 7. Similar to active AM, passive AM focuses on predefined, mutually agreed fishery objectives and envisages learning about the system dynamics as a useful but unintended by-product of decision-making (Walters, 1986). What is learned from passive AM will be less than from active AM, but similarly lower are the needs for expertise and resource, which increases its suitability for recreational fisheries and means that it can be implemented by the smallest angling club.

Active AM differs from passive AM based on trial and error by the structure used in decision-making, which involves the articulation of quantifiable objectives, identification of management alternatives, predictions of management consequences based on explicit recognition of key uncertainties, implementation of the most probable actions and monitoring of field data to determine what worked best in reality at the scale of entire fisheries or ecosystems (Walters, 1986). Based on the outcome, the best management approach can then be identified and pursued further (Figure 7). Thus, in active AM, learning through ad hoc trial and error is replaced by learning by careful design and testing (Walters, 1997). For example, discussion among stakeholders about the best way to manage a range of lakes for a given target species might lead to conflict. Active AM would use a model-based analysis to build several hypothesis about how the system would probably react to certain management variants, and, after identifying the most successful alternative (given previously defined objectives), allocate treatments (e.g. variants of stocking or size limits) to sampling units (e.g. lakes) to test effects under real conditions. Then, intensive monitoring of system variables (e.g. catches, relative abundance) would be used to test which variant performed best and what other expected or unexpected impacts occurred (e.g. biodiversity impacts). Monitoring of the response of the system to the various actions would then provide insights for revising the quantitative or qualitative models of the system (learning) and subsequent decision-making (adaptation) (Figures 6 and 7).

Such active AM increases the ability of managers and stakeholders to learn about the outcomes of various management regimes, but there are daunting tasks involved with successful projects (e.g. financial resources for long-term monitoring on large spatial scales). Moreover, active AM projects require a range of types of expertise (e.g. modelling, experimental design, statistics, field research), which usually limits its applicability in fisheries practice (Walters, 1997, 2007). Nevertheless, engaging in some sort of flexible, adaptive strategy, including variants of the passive trial-and-error approaches in Figure 7, is always advisable as this will promote locality-specific approaches that work "pretty well" in the long term (analogously to the "pretty good yield" perspective by Hilborn [2010] for commercial fisheries).

3.2 ADAPTIVE MANAGEMENT WITH STRUCTURED DECISION-MAKING

Ideally, AM, no matter which variant, should be combined with structured decision-making (SDM; Box 3). Central to the success of the SDM process in recreational fisheries management (Irwin *et al.*, 2011) is the requirement to articulate fundamental (long-term desired outcomes) and operational (i.e., quantifiable) objectives clearly, acknowledge uncertainty explicitly, and respond transparently to all stakeholder interests in the decision process, even if this delays decision-making – the process thus also helps consensus building and conflict management. Structured decision-making can be conducted using quantitative tools (e.g. models of fish populations and the interaction with recreational fishers) as exemplified by the case study of Irwin *et al.* (2011) or by qualitative means (e.g. conceptual maps of how the system variables interact with each other) to identify plausible management alternatives in light of objectives.

Box 3
Adaptive management with structured decision-making

Management options are usually multifaceted, and any given action will probably have environmental, social and economic implications. Stakeholders may have conflicting views about goals for the fishery and the means to achieve them. Thus, choosing a course of action can be a daunting task. Adaptive management with structured decision-making (SDM) is a process well suited to complex environmental problems (Kendall, 2001; Irwin *et al.*, 2011). This process can help policy-makers, managers and stakeholders think clearly about the system, entertain multiple objectives, evaluate trade-offs between actions, and decide what action to implement. When the process is combined with modelling and multiple sources of uncertainty, a management strategy evaluation framework can follow, which outlines a set of plausible management tools with their associated costs and benefits resulting in trade-offs. Irwin *et al.* (2011) outline an SDM approach applied to various inland and marine recreational fisheries in the United States of America.

In most fishery management situations, decisions are made with considerable uncertainty. Adaptive management explicitly captures uncertainty and allows for multiple working hypotheses (e.g. alternative models for the system and its response to management). Management strategies should evolve as knowledge and experience are gained. Thus, actions need to be adjusted as new information becomes available. Adaptive management is an iterative form of SDM that promotes learning to reduce uncertainty and improve management outcomes.

Structured decision-making:

- is a rigorous framework for identifying and evaluating alternatives, and then making choices in complex situations (Hammond, Keeney and Raifa, 1999);
- can transform command and control structures from top-down designation of problems and imposition of management solutions to a more pluralistic approach in which stakeholders play a formal role;
- requires explicit, objective quantification of the problem and solutions but also provides a rigorous means to incorporate subjective information (e.g. stakeholder values, expert opinion);
- increases transparency of management knowledge and decision-making, recognizes alternative views of problems and solutions, and provides for accountability and learning when decisions do not produce desired outcomes;
- is a suitable procedural approach to fisheries management decision-making in recreational fisheries and can ideally be combined with adaptive management.

A structured approach to decision-making in recreational fisheries is suitable for the implementation of AM by promoting stakeholder involvement in the setting of objectives, discussion of plausible alternative tools and evaluation criteria, and evaluation of alternatives. The goal is careful identification of agreed management alternatives. These may then be tested in the virtual world of a computer (management strategy evaluation, e.g. Mapstone *et al.* [2008]) or be tested in real recreational fisheries using some variants of AM (Figures 6 and 7). The progress can be combined and a subset of tools be implemented in reality as a proof of the modelling predictions. Generally, AM is enhanced where SDM is done in collaboration with the full spectrum of stakeholders, whereupon the suite of potential management actions becomes richer and stakeholders may be more supportive of management actions when they were part of their choice and development (Irwin *et al.*, 2011).

3.3 ADAPTIVE MANAGEMENT AND THE PRECAUTIONARY AND ECOSYSTEM APPROACHES

Adaptive management with SDM depends on the identification of various potentially suitable management directions and tools to be considered and possibly tested for their effects. This involves difficult decisions as to which management tools to consider in principle and which evaluative criteria to use to prescreen suitable tools. Here, some general principles of risk-averse environmental management, in particular the PA and the ecosystem approach to fisheries (EAF; Figure 5), are to be considered as important principles framing management decision-making in recreational fisheries. These principles have been found useful in fisheries management in general, and are similarly relevant to recreational fisheries in the light of potential negative consequences of exploitation and selected management tools (e.g. release of unsuitable fish via stocking) for aquatic biodiversity and ecosystems (see Chapter 1).

The explicit consideration of precautionary approaches and the ecosystem approach in AM in this context is ultimately motivated by the normative framework of the ecosystem approach and aquatic stewardship as elaborated above and summarized in Figure 5. In this context, the EAF is characterized as "to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by ecosystems" (FAO, 2003). Thus, it is conceptually equivalent to the aquatic stewardship norm in Chapter 2. According to FAO (2003), the EAF shall:

- manage fisheries so as to limit their impact on the ecosystems, as measured by indicators of environmental quality and system status;
- minimize the risk of irreversible change to natural assemblages of species and ecosystem processes as a result of fisheries;
- avoid changes that are not potentially reversible within 2–3 decades or correct them promptly without delay if technically feasible.

To move forward specifically in the AM of recreational fisheries, the first step is to accept that ecosystem-level impacts are possible through recreational fishing, rather than discounting such effects as has happened in the past (Arlinghaus, 2006a). Then, rather than focus on target species only, a broader ecosystem outlook is needed, and this ecosystem perspective should then be used in the routine assessment and evaluation of alternative management options, including risk analysis in the cycle of AM prior to initiating action (Chapter 5). The EAF principle thus supplements the narrow, "piscicentric" perspective on a single target species or a single fishery that is still prevalent in places (Arlinghaus and Cowx, 2008). In some situations, however, a purely target-species-directed perspective may be needed for practical reasons and to meet stakeholder demands, and this will not be an issue as long as planned interventions have no wider ecosystem-level effects. Overall, the EAF is to be viewed as a principle to account for ecosystem processes in the formulation of fisheries management measures (Sissenwine and Murawaski, 2004). Thus, the EAF emphasizes an evolution of fisheries management rather than a revolution as is sometimes perceived (Mace, 2004; Rice, 2011).

Where knowledge about system dynamics is insufficient, as is often the case in small inland recreational fisheries scattered over hundreds of lakes and rivers (Post *et al*., 2002; Arlinghaus, 2006a), the EAF also calls for precautionary recreational fishery management measures that minimize ecological risks in light of recreational fisher responses that are dynamic and difficult to predict (Arlinghaus and Cowx, 2008). Thus, the so-called precautionary approach[1]

[1] The precautionary approach is not to be confused with the precautionary principle originally emanating from environmental law and policy. The latter emphasizes that any risk is "too much" and often results in delay or even constraint on any fisheries management decisions. The precautionary approach argues in favour of taking environmental risk into account and basing decisions with risks in mind (Peterman, 2004). Relatedly, the absence of data should not be a reason for postponing actions provided these actions have a reasonable likelihood of success. These actions are to be chosen precautionarily and commensurate with the potential for ecological impact. Thus the precautionary approach should not be misused as a tool against management.

(PA) is proposed as a final guiding principle of AM processes in recreational fisheries; it will affect the management tools considered in structured decision-making (Figure 5). The PA "exercises prudent foresight to avoid unacceptable or undesirable situations, taking into account that changes in fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to change in the environment and human values" (FAO, 1996). A key point to understand is that, if faced with considerable uncertainty and risks, and if it is not clear which action to choose, actions should be chosen to give priority to conserving the biological productivity over the long term rather than satisfying short-term economic or social demands (Peterman, 2004). This can involve setting safety margins in relation to clearly articulated limit or target reference points in terms of, say, how much fishing mortality or effort to tolerate or how strong a decline in fish biomass to accept (e.g. spawning biomass in relation to virgin stock size). All activities that strongly modify food webs, e.g. by selectively removing keystone species and therefore predation control, by strongly altering the size and age structure of stocks (which alters predation pressure and enhances variability in recruitment [van Kooten *et al*., 2010; Hsieh *et al*., 2010]) or by altering nutrient cycling or predation pressure through bottom-up or top-down processes (Lathrop *et al*., 2002), are to be thoroughly reviewed and the risks and costs and benefits properly valued (Francis *et al*., 2007) in the SDM process in the AM cycle. Usually, in the face of trade-offs between social and economic benefits, the EAF and the PA will thus affect the AM planning process by determining "risk-averse" objectives and the choice and evaluation of principally useful management strategies (Garcia, 1994; Fenichel *et al*., 2008), in turn motivating the carefully evaluated choice of actions that promise no strong effect or modification of the ecosystem (e.g. release of non-native genotypes).

3.4 CONCLUSIONS

Adaptive management constitutes a suitable management process for recreational fisheries. It is particularly useful where the system to be managed exhibits high controllability (e.g. the management body can determine management actions for all relevant fisheries, and the systems are reasonably closed, e.g. lakes) but uncertainty about outcomes of particular management actions is high (e.g. whether stocking really enhances fisheries) (Allen and Gunderson, 2011). There are some situations where recreational fisheries is either not important enough socio-economically or politically and the system to be managed is open (e.g. ocean). Still, the core idea of the proposed adaptive, iterative management process is valid even under these situations (although its implementation will be more difficult) by forcing decision-makers to express objectives, plausible management tools and evaluate their effects after implementation.

Thus, with few exceptions, it seems that, for every recreational fishery, appreciation of the general management philosophy of AM using an SDM framework could be helpful and may indeed be implemented with a range of simple participatory (to identify objectives and strategy decisions) and monitoring (assessment of outcomes) tools in light of principles of the EAF and the PA. For example, in smaller angling clubs in central Europe that lack the scientific expertise or human resources to engage in sophisticated fishery-independent monitoring of fisheries management actions, passive AM may well be conducted using recreational fisher diaries, as long as people provide sound data about catches and sizes of catch. This can be promoted by good interpersonal communication skills and an inclusive management process based on mutual understanding about the need to monitor key variables of the fishery (Chapter 5). This helps managers and stakeholders collaborate and choose risk-averse management actions despite uncertainties about the system, with a view to agreement on actions that reduce future uncertainties while maximizing learning, system knowledge and benefits to the recreational fishers.

4. POLICY AND INSTITUTIONAL FRAMEWORKS

Coherent and effective fishery management requires an appropriate policy and institutional framework that usually involves fisheries laws and regulations as well as organizations or community-derived alternative structures that fulfil important roles in the governance and management of fisheries. Because recreational fisheries are complex social-ecological systems, the purview of "management organizations" (those persons or organizations with the authority to make management decisions about the fishery) includes oversight of the ecological system and a variety of human interactions with the biota and the environment, with a view to avoiding undesirable ecological impacts and optimizing socio-economic benefits. "Managers" are broadly defined and, depending on property rights, may be: (i) the State (e.g. government fisheries agencies); (ii) organizations such as fishing clubs; or (iii) communities with strong ties to the fishery. In many economically developed nations, pure community-based management systems are rare, and management organizations of the latter two types cooperate with government managers to some degree, although there is large variance across the world (Daedlow, Beard and Arlinghaus, 2011). Stakeholders are diverse and may have conflicting interests, so policy should provide the means for development of a framework of fishing-rights and management institutions. Moreover, appropriate mechanisms for gathering input and managing conflicts within and among user groups are needed if recreational fisheries management is to succeed (Chapter 5). Management organizations must have sufficient authority to enact regulations for the development, management and conservation of recreational fishery resources under their stewardship.

To encourage compliance with regulations, management organizations must not only enforce them but also educate stakeholders, and there must be adequate network links to the various managers of the ecosystem, e.g. water managers and fisheries managers. Sufficient funding is required to execute management, outreach, monitoring and enforcement responsibilities. Because recreational fishery management has societal benefits (e.g. economic value, environmental conservation), such funding is often provided by both user groups and the general public. However, many management bodies are understaffed and can only fulfil their most rudimentary obligations related to monitoring of recreational fish stocks and rule compliance (Arlinghaus, 2006a).

4.1 GOVERNANCE STRUCTURES

Structure and function of the governance framework must be clearly delineated to ensure transparency and to promote among stakeholders both trust in decisions and respect for authority. Three common approaches to governance of natural resources affect authority, access, and privileges or rights to catch or manage fish: (i) State control; (ii) private control; and (iii) community-based control (e.g. control by a group of people) (Table 1). Historically, inland recreational fisheries in many countries (e.g. the United States of America, Canada, Australia) and most coastal and marine fisheries have been managed under the first model, with government assuming full management authority over the fish and fisheries in the public's trust. Governmental organizations may use independent boards or commissions to review agency policy and act as arbiters of disputes between agencies and stakeholders. Many small-scale commercial, artisanal and subsistence fisheries worldwide and some recreational fisheries in countries such as Germany (Daedlow, Beard and Arlinghaus, 2011), Austria and the Netherlands (Arlinghaus, Mehner and Cowx, 2002) are managed under the second model, whereby a subset of users holds access and management rights to the resource, sometimes assisted by governmental agencies enforcing fisheries laws. In these situations, private fisheries user groups (e.g. fishing clubs) are responsible for managing their waterbodies provided that actions agree with a general legal framework designed by the state fisheries agencies that in turn enforce legal regulations. In Finland, statutory fishery associations represent the actual owners of waters, i.e. shareholders associations for areas held in common by a registered village (Sipponen and Valkeajärvi, 2002). This joint possession of private waters is also found in Sweden.

Community-based management (Ostrom, 1990), in which resource-based communities have primary responsibility for management, has been advocated in recent years as one means to improve fisheries management (Gutierrez, Hilborn and Defeo, 2011). Organizational structure varies greatly across communities, and many members and subgroups may play a role in management, hence, identifying "the manager" may be difficult. Regardless of the governance structure and the fishing rights in place, some roles of state control may still be needed, such as setting overall environmental policy and regulations that apply to recreational fishers and the rest of society. For this reason, private control and community-based management arrangements are often forms of comanagement, wherein the resource is managed cooperatively with the government.

TABLE 1
Three common forms of governance of natural resources and some features of each

	State control	Community-based	Private control
Manager	Government agencies and their employees	Community or tribal members, paid staff, councils, fishers, fishing and tourism business representatives	Rights holder
		Sometimes in conjunction with State that protects public interests and enforces laws ("comanagement")	
Access and withdrawal	Open or provision of fishing rights (may require licensing)	Dictated by community	Dictated by rights holder
Features	Prevents conflicts of interest in management decisions	Captures local knowledge	Thought to promote stewardship of resource, but science-based management difficult
	Management and monitoring can be coordinated across management units	Costs dispersed from agency to local communities	May be better tailored to local conditions than broad-scale government control, potentially more economically efficient
	"Blueprint approach" fails to tailor management to local context	Can prioritize stakeholder opinions over objective data	Has not always resulted in better stewardship of resource
	Users may become disenfranchised	Delayed decision-making	Conservation of biodiversity or other societal goals potentially de-emphasized

Note: In many cases, the governance system possesses attributes of more than one form of governance.

Source: Derived from Daedlow, Beard and Arlinghaus (2011).

4.2 ACCESS, RULES, COMPLIANCE AND ENFORCEMENT

A legal framework for recreational fisheries is usually needed in order to vest rights, identify parties holding rights, determine agents responsible for management, set fees and licensing requirements, and develop regulations governing the protection, promotion, management and use of the resource.

The authorities responsible for enforcement of regulations and penalties for non-compliance must also be established. In the case of transboundary stocks, straddling stocks and highly migratory stocks that are fished by two or more management organizations, the authorities should cooperate to develop consistent and effective policies for conservation and for management of the stocks and fishers.

Fisheries management organizations require sufficient funding and authority to enact policy in order to ensure that the fundamental goals of fishery management are achieved: (i) conservation of biodiversity; (ii) biologically sustainable use of its components; and (iii) equitable sharing of benefits among diverse stakeholders (Chapter 2; Welcomme, 2001). More specifically, management organizations should adopt policies to protect and promote access to recreational fisheries, and for the sustainable development, conservation and management of recreational fishing and fishery resources (EIFAC, 2008, Article 6). Actions on the land (e.g. development, grazing, mining, agriculture) usually have direct impacts on aquatic ecosystems, yet fisheries management organizations in many countries have very limited power to control terrestrial factors. Moreover, other water interests (e.g. hydropower, irrigation, navigation) and commercial fisheries may possess higher use priority than do recreational fisheries. Therefore, it is essential that recreational fishery managers cooperate with other authorities, and vice versa, to ensure that environmental regulations provide adequate protection for fished ecosystems and that fishery management practices are compatible with other uses of the environment. Such cooperation also reduces conflict and duplication of regulations. Policies must be regularly reviewed and updated with input from recreational fishers and other stakeholders.

Fishing regulations should be developed with active participation of stakeholders to improve compliance and integrate traditional ecological knowledge. While stakeholder input is essential for setting goals and objectives for the fishery, it is usually the management organization that has the system knowledge and technical capability to determine the appropriate strategy to achieve the stated goals, and to identify the regulatory options to implement the strategy. Once managers have identified potential options for management, stakeholders can and should provide input on their preferences, or alternatively the management authority can decide on the best strategy to meet multiple stakeholder preferences. The management organization should provide a mechanism for managing any resulting conflicts between fishery or environmental policy and the interests of recreational fishers and other stakeholders. Independent review boards and government officials can provide recourse when stakeholders believe that their interests are not being considered fairly or management organizations believe that their mandate is compromised by other governmental action.

Ideally, recreational fisheries would be managed on an individualized basis with the regulatory scheme tailored to system characteristics derived from creel surveys and stock assessments (Chapter 5). However, government management organizations often lack the monitoring resources or the rationale to obtain detailed information on all the fisheries within their jurisdictions (Pereira and Hansen, 2003), and, in many situations, fishers move among many fisheries. Therefore, individual fisheries are connected to other fisheries, and an action in one system will have consequences elsewhere, for example, owing to effort shifts with regulatory changes (Hunt *et al*., 2011). Thus, regulations may be applied categorically, with classes of waters in a fisheries "landscape" or management area receiving a given management regime based on shared fishing and ecological characteristics (Chapter 5; Lester *et al*., 2003). Because fishing regulations by their nature involve users, regulatory schemes must be a compromise of ecological, economic and social objectives; ideally, meeting social objectives also preserves the fish stock biologically (Johnston, Arlinghaus and Dieckmann, 2010). Overly complex rules that change frequently and are too system-specific are difficult to justify and to communicate, and they may thus be disregarded. The management organization should promote compliance with fisheries and environmental regulations by involving stakeholders in rule development and by making them aware of rules, their justification, and sanctions for violations (EIFAC, 2008, Article 7). Management organizations should provide the mechanisms and the means for monitoring compliance and for enforcing regulations, but, regardless of the governance system, recreational fishers must share the responsibility for compliance by informing themselves and their fellows, and by self-policing (Ostrom, 1990, 2005).

4.3 INTERNAL POLICIES AND PROCEDURES

Management should develop internal policies and procedures to ensure the safety, efficiency, effectiveness and integrity of its members and the organization. Policies and procedures are needed to: establish roles and responsibilities of members; promote ethical behaviour, e.g. fiscal responsibility, ethical treatment of animals, responsible conduct of research; provide for safety and welfare of employees; provide stakeholder involvement and conflict management procedures; establish employment and supervisory practices;

recommend and standardize sampling methods; establish data collection and archival procedures; establish procedures for fishing rule development and promulgation; provide outreach and education policies; and establish best practices for stocking, habitat and other management approaches. The management organization should provide training to ensure that members understand policies and procedures. The organization should regularly review and update policies and procedures to remain consistent with laws, regulations and prevailing public and professional attitudes.

4.4 FUNDING AND LICENSING

The management organization should base decisions not only on stakeholder input but also on the best available scientific information. Hence, the manager must have adequate funding or networks with researchers to gather this information. In the United States of America, where fishery management is a function of the government, funding for fish and wildlife management has come from a combination of licence sales and user fees, sometimes supplemented by excise taxes on fishing-related and hunting-related purchases and general fund revenue (Prukop and Regan, 2005; Ballweber and Schramm, 2010). Funding for management in private control systems could come from membership dues, user fees; and in community-based systems, from local taxes and user fees. Because fishery management can have societal benefits, the use of some general tax revenue can probably be justified in all management systems.

Licensing of recreational fishers may be contested by the fisher public but has three important advantages: (i) a potential funding stream to support management activities; (ii) a mechanism for limiting access or use of a fishery if needed to ensure biological sustainability; and (iii) the means to account for, characterize and study the primary users of recreational fishery resources. Licensing need not be fee-based in order to be useful. In most jurisdictions, recreational fishing is considered a privilege and the licence for which may be revoked for violation of fishing or other environmental regulations. For these reasons, it can be advantageous to require licensing through the management body in all types of management systems, with the potential fee being commensurate with functions provided by the management. Fees for licences can also vary according to social considerations, with reduced costs for residents, children, elderly, and military personnel. Licences are often available for daily, weekly and annual durations. Many state agencies have optional surcharges on licences in the form of fees or stamps that allow special privileges, e.g. for harvest of restricted species, use of special gear, or access to limited-entry fisheries. In the absence of licensing, in private control and community-based management systems, user fees could be developed with similar considerations to support the costs of management.

4.5 DESIGN PRINCIPLES FOR SUSTAINABLE MANAGEMENT

Regardless of the governance system, adherence to some fundamental organizational principles has been shown to promote effective institutions, both formal (e.g. fisheries law) and informal (based on voluntary behaviour), and overall sustainable resource management. Ostrom (1990) identifies principles for the design of management institutions and governance of common pool resources, including fisheries, that facilitate sustainable use (Daedlow, Beard and Arlinghaus, 2011). These include:

Clearly defined boundaries – the resource, users and their access rights are explicitly defined.

Right to self-determination – the rights of stakeholders to organize and establish institutions (including regulations) for long-term sustainability are recognized by higher authorities.

Collective choice arrangements –- stakeholders are involved in the decision-making process, promoting development of locally relevant policy that enhances legitimacy of the management authority and compliance by stakeholders.

Effective monitoring – the resource and its users are monitored, preferably by monitors that are stakeholders of the resource being monitored.

Graduated sanctions – sanctions are needed to encourage stakeholders to follow the rules. Users who violate rules and risk the sustainability of the system should receive sanctions that are proportional to the severity of the offence.

Mechanisms for conflict management – conflict is inevitable in fisheries, within management organizations, among stakeholders and between management organizations and stakeholders. The means to manage conflict effectively and rapidly is required.

Ostrom's typology was initially developed for community-based governance systems, but the message is more general. Thus, incorporating these principles increases the likelihood that the policy and institutional framework facilitates sustainable recreational fisheries, whether they are under state control, under private control, or community-based management systems.

4.6 CONCLUSIONS

A well-defined institutional framework that meets the design principles outlined above is needed for sustainable management of recreational fisheries to identify the resource, its users and their rights, and the manner in which the system will be managed. A variety of governance structures have been employed (state control, private control, and community-based management). All management organizations need to solicit stakeholder input in decision-making, adopt adequate policies and regulations to conserve the resource, protect and regulate users' rights, and effectively monitor and enforce policies and regulations. Funding mechanisms must be in place to support these and other duties of the management organization. Regardless of the exact governance system in place, sustainability of resource management should be enhanced if fundamental design principles are recognized and incorporated into the structure of the system.

5. RECREATIONAL FISHERIES MANAGEMENT

5.1 BACKGROUND

This chapter presents concepts, issues and approaches relevant to the management of recreational fisheries, regardless of the habitat (inland or marine) or geographic region. This chapter is directed at the fisheries manager and fisheries management in its broadest sense, in contrast to Chapter 6, which is tailored to the individual recreational fisher. One objective of Chapter 5 is to assist developing nations and economies in transition that may lack a history of recreational fisheries management. Recreational fishery management shares some fundamental tenets with commercial and subsistence fishery management so the reader should also consult other FAO guidance summarized in Box 1, and *A Fishery Manager's Guidebook* (Cochrane and Garcia, 2009).

Fisheries management is the process by which sound information is used to achieve management goals by directing actions at the three components of the fishery system: (i) the habitat, which usually transcends the aquatic–terrestrial interface; (ii) the biota, including but not limited to the target fish population; and (iii) the humans directly and indirectly involved in the fishery (Nielsen, 1993). The primary goals of fisheries management should be consistent with those in the Convention on Biological Diversity (CBD, 2011): (i) conservation of biodiversity; (ii) biologically sustainable use of its components; and (iii) equitable sharing of benefits among diverse stakeholders (Welcomme, 2001) Details on the normative framework used here are in Chapter 2. Commercial, subsistence and recreational fisheries management share these fundamental goals, but those associated with recreational fisheries can be more diverse and difficult to quantify. For example, benefits to be gained from recreational fisheries may include food but this is secondary to other outputs from the fishery such as psychological and physiological aspects of the fishing experience (Fedler and Ditton, 1994; Weithman, 1999). Thus, the first challenge for the recreational fishery manager is to understand stakeholder attitudes and values.

While overfishing of commercial fish stocks has been widely publicized (FAO, 2010; Worm *et al.*, 2009), recreational fishing also has the potential for detrimental impacts (Chapter 1). Recreational fishing itself is becoming widely recognized as a potent ecological force, capable of having significant impacts on fish populations (Post *et al.*, 2002; Cooke and Cowx, 2006; Lewin, Arlinghaus and Mehner, 2006), trophic interactions (Walters and Kitchell, 2001), and ecosystem services (Eby *et al.*, 2006; Jørgensen *et al.*, 2007; Crowder *et al.*, 2008). 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 at large.

Management authorities in developing countries should anticipate that with industrialization and agricultural modernization the relative importance and value of recreational fishing is likely to increase compared with other uses of aquatic ecosystems such as aquaculture and commercial fishing (Arlinghaus, Mehner and Cowx, 2002). Much of the advice in this chapter derives from experience in developed nations. Developing nations may have different management goals and stakeholder desires, particular to their own social and cultural context (Chapter 9; Sanderson, 1995). However, the natural science that underlies assessment and management is universal.

An important challenge to recreational fisheries management 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. Because humans vary greatly in how they value recreational fisheries and the benefits they obtain from them, involving stakeholders in goal-setting and decision-making is necessary order to ensure legitimacy of management. The entire process of recreational fishery management should employ an objective, transparent, science-based approach to achieving management goals, as outlined in Chapter 3 and below.

5.2 THE MANAGEMENT PURVIEW

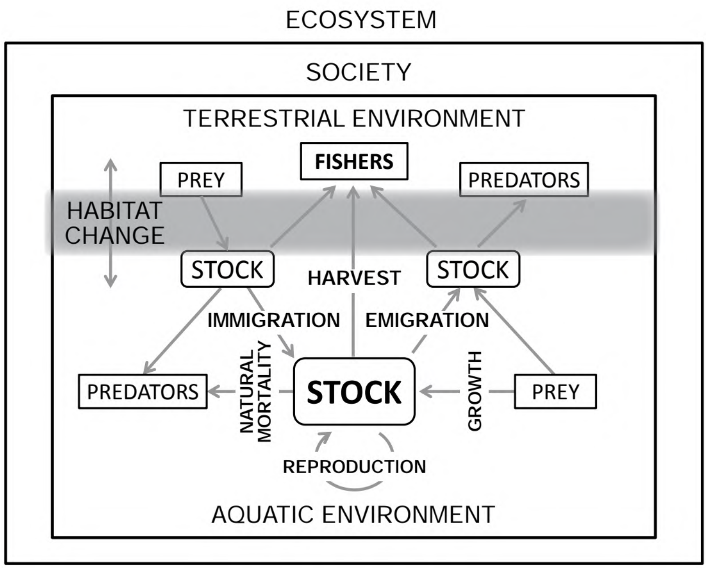
Historically, fishery management has used a “single-species” approach in which stakeholder desires and management objectives are focused on a single, economically and recreationally valuable species. In this approach, management actions may be directed at other species (e.g. predators or competitors) because of their influence on the focus species, or on the habitat, but the indicators of success are defined in terms of desirable change in the focus species. Because recreational fishers are selective in the species that they exploit and these species are often top predators (Donaldson *et al.*, 2011), fishing and fishery management can have cascading effects on other species and ecosystem processes (e.g. herbivory, nutrient cycling) (Roth *et al.*, 2007, 2010). Managers must be aware of the roles of recreational species and the interdependences that link them to other members of the ecosystem. For example, management that seeks to enhance the abundance of a recreationally important species needs to do so within the constraints of the system (e.g. productivity, sustainability of prey populations). Growing imperilment of species, global environmental change, and the need to conduct fishing and fishery management in a sustainable fashion dictate a broader ecosystem-oriented purview of recreational fishery management, which includes the social and economic components of the coupled social-ecological system (Arlinghaus, Johnson and Wolter, 2008).

Increasingly, the need to consider other species, the structure and function of the entire ecosystem, and the relationships among fish and fishers on the landscape (Hunt *et al.*, 2011) is being recognized. This "ecosystem approach" to fisheries management (Chapter 3; FAO, 2003) provides guideposts for managers (and fishers) to conduct their activities in a way that minimizes environmental impacts and sustains socio-economic benefits without compromising ecosystem integrity. It is clear that recreational fishers will continue to favour particular species, and managers will continue to need a deep understanding of the dynamics of exploited populations. The long tradition of the single-species approach in renewable resource management provides managers with theory and tools for understanding and manipulating vital rates of recreationally valuable species. However, this expertise must be tempered by a keen awareness of the species and processes that sustain the focus species and affect the outcomes of management (Figure 8). This chapter considers the single-species approach a "necessary but insufficient" purview that should be complemented with a more ecologically realistic system view and a more environmentally responsible perspective for management objectives in the light of social and economic drivers (e.g. fishing effort) that affect objectives and fishing impacts.

5.3 THE FISHERY MANAGEMENT PROCESS

Fishery management is challenging because managers operate at the intersection of ecological and social-psychological, sociological, economic and political realms. Diverse human desires for the resource and uncertainty about the ecological and social systems, both of which are dynamic and interact with each other (Fulton *et al.*, 2011), can make choosing a course of action difficult. Traditionally, agencies have used a variety of approaches to make management decisions, emphasizing politics, conventional wisdom, or best available data (Johnson, 1999). Managers of recreational fisheries need better tools for coping with diverse objectives, complexity and uncertainty in the decision-making

Figure 8
Concept diagram showing relationships between the single-species approach to stock assessment and a more ecosystem-oriented perspective



Notes: In this view, population dynamics of the target stock and other species in the ecosystem are interpretable from an understanding of functional linkages in the system, including interactions that span the soft boundary between the terrestrial and aquatic realms. This view also recognizes that fisheries are social-ecological systems, with the social system being a nested component of the overarching life-supporting ecological system. In this context, the way that population status and management actions are judged in light of objectives is socially constructed and affected by societal preferences.

process, and strongly coupled interactions of recreational fishers and fish stocks (e.g. Hunt *et al*., 2011). Structured decision-making (Chapter 3) in an adaptive management framework is a systematic process developed for finding optimal solutions in complex situations (Hammond, Keeney and Raifa, 1999; Kendall, 2001). As such, SDM can be a very useful underlying framework for the fishery management process. The method provides a pluralistic approach in which stakeholders play a formal role, subjective information (values, opinions) is rigorously incorporated, and knowledge and decisions are transparent to all. While management provides an opportunity to learn about the system and how it responds to humans, many problems persist despite years of attention. Learning and improving management can be facilitated by following SDM with explicit evaluation of outcomes and adjustment of the management in a cyclic fashion, in an AM process (Chapter 3).

As shown in Figure 9, the process of recreational fishery management involves:

1. characterizing the system;
2. assessing the fishery;
3. setting goals and objectives;
4. choosing and implementing a course of action;
5. monitoring, evaluation and adjustment.

Explicit specification and documentation is required at each step. The development of a fishery management plan (Table 2) can provide a framework for identifying problems, stakeholder desires, goals and objectives; and for

Figure 9
The recreational fishery management process formulated for structured decision-making and adaptive management

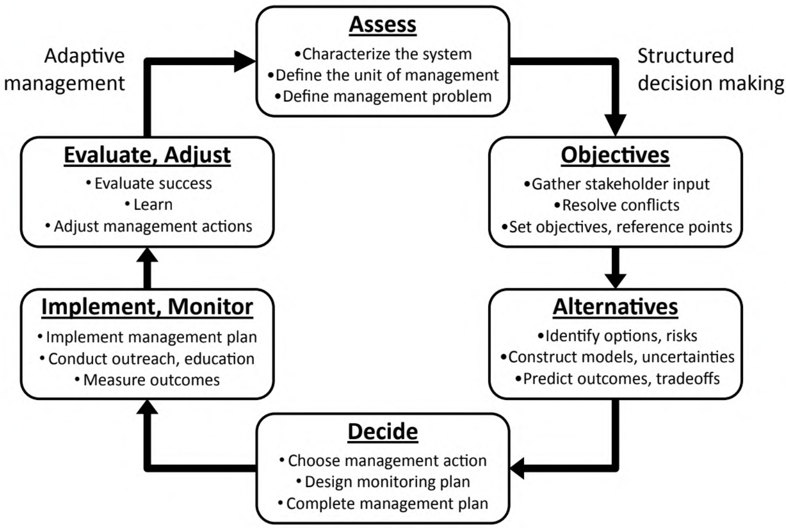


Table 2
General elements of a recreational fishery management plan

Plan element	Description
1. Characterize the system	Characterize: (i) the fishery: background, history, status, types of fishers and their preferences; (ii) the geographic and legal setting: environmental characteristics, socio-economic and political factors, laws; and (iii) the ecosystem – food web, sensitive species, system productivity. Identify threats to fishery and potential for habitat modification that has impacts on stocks. Identify potential limiting factors (biological, physicochemical).
2. Goals and objectives	Gather stakeholder input, resolve conflicts, and set measurable objectives, including establishment of reference points and performance indicators, and indicators of ecosystem status.
3. Strategies	Define the management actions necessary to achieve goals and objectives and set a timeline for implementation. Predict outcomes for the fishery and indirect effects on the ecosystem.
4. Monitoring	Monitoring required and reference points, performance indicators. Enforcement and outreach plan.
5. Financial responsibilities	The cost of implementing the plan, including monitoring and enforcement. Methods for having users and beneficiaries pay a portion of management costs.

proposing management remedies and expected outcomes. The plan should be as short and simple as possible (Hindson *et al.*, 2005), updated regularly, and well publicized in order to promote transparency of decisions and trust among stakeholders.

5.3.1 Characterizing the system

Characterizing the system involves understanding the type of fishery, the setting, the types of users and the stocks to be managed (Table 2). The impact of fishing on a species cannot be determined without knowledge of stock (population) structure. Thus, explicitly defining the stock (Ihssen *et al.*, 1981; Dizon *et al.*, 1992; Hilborn and Walters, 1992) or evolutionarily significant unit (Vogler and DeSalle, 1994) that is the target of the fishery and of management actions is an essential first step. In fisheries sustained by natural reproduction, the management unit should usually be the population of interbreeding individuals. When ambiguous, as in mixed stock fisheries, tagging or marking can be used to discriminate stocks, or an eclectic approach to stock delineation employing genetic, morphomeristic, behavioural, and ecological information may be employed (Behnke, 1992; Vogler and DeSalle, 1994).

Stock delineation can be challenging when the species being managed is highly migratory or has a transjurisdictional range, as is the case for many marine fisheries. In such cases, stocks are often defined by pragmatic criteria (spatial distribution relative to jurisdictional boundaries). However, an eco-evolutionary (Carroll *et al.*, 2007) perspective is required in order to ensure that fishing and its management preserve the integrity of the population and sustain benefits to humans. Protecting the genetic and functional diversity of fish populations, akin to a financial portfolio (Schindler *et al.*, 2010), can stabilize their response to environmental change and thereby protect future yields to recreational fisheries. Maintaining such a portfolio may require that some stocks are managed at lower exploitation rates than others and that no stocks are viewed as expendable as their loss may reduce the overall viability of the species.

5.3.2 Assessing the fishery

Knowledge of the current status of a fishery is necessary before management goals and objectives can be chosen (Hilborn and Walters, 1992; King, 2007). 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. Managers can be informed about the state of a fishery by recreational fisher opinions and through their own sampling and observations. While local knowledge of recreational fishers is essential to a complete understanding of the system and current stakeholder satisfaction, attitudes and preferences, choosing and evaluating management actions also requires information obtained from scientifically valid sampling programmes (Mackinson and Nottestad, 1998).

Assessment methods will depend on the environment and species of interest, but in general: (i) stock assessment seeks information on vital rates of populations and their eco-evolutionary characteristics (FAO, 2006; King, 2007; Guy and Brown, 2007); (ii) creel surveys seek information about recreational fisher catch, harvest and effort, which should be supplemented by human-dimension information on satisfaction and preferences (Pollock, Jones and Brown, 1994; NRC, 2006); and (iii) ecosystem surveillance monitors the status of the ecosystem.

The ultimate goal of stock assessment is to understand the processes that drive the stock's dynamics and its current state in relation to reference points and performance metrics. 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 population vital rates (e.g. growth, mortality, 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. Even where assessment capacity is not limiting, the manager may need to rely on inference or back-calculation approaches (e.g. modelling, virtual population analysis; Hilborn and Walters, 1992). Creel surveys (Pollock, Jones and Brown, 1994) are primarily directed at quantifying recreational fisher-related factors and human dimensions (e.g. information on preferences and satisfaction) but the manager may also generate data for economic impact analysis (e.g. Ditton and Hunt, 2001) and obtain samples from the fishers' catch that contribute to stock assessment. For example, fish caught by recreational fishers can be sampled for growth and diet information, and fishers may be asked about expenditure or willingness to pay as a measure of social importance. In fisheries subject to recreational, subsistence and commercial fishing, catch and harvest data must be available from each to account fully for fishing mortality. Monitoring ecosystem status is an enormous task, so managers may wish to develop indicators that can inform them about condition of the ecosystem and sustainability of their management actions (Rice, 2003; Cury and Christensen, 2005; Kwak and Freeman, 2010). The Trophic State Index for lakes (Carlson, 1977), the Index of Biotic Integrity for streams (Karr, 1981), biomass ratios (Medley *et al.*, 2009), and abundance of sentinel species (Beeby, 2001) are examples of useful metrics for ecosystem surveillance. Despite the importance of monitoring, it is unrealistic to assume that such information will be available for all recreational fisheries as many smaller systems may not justify routine stock assessments (Table 3). A broad-based survey sampling approach may then be the best strategy based on suitable stratification of fisheries in space and time (Lester *et al.*, 2003).

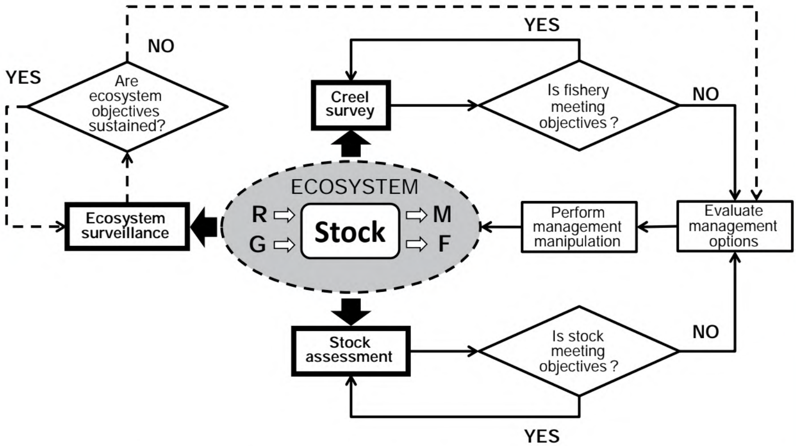
Together, the various information sources allow the manager to assess present status both biologically and socially, and identify problems, constraints and opportunities for improvement through a management manipulation (Figure 10). By definition, stock assessment is a single-species approach, but there is widespread agreement that the indirect effects of manipulating the fisher–fish relationship should be considered in both inland and marine ecosystems (Cooke and Cowx, 2004; Coleman *et al.*, 2004; Crowder *et al.*, 2008).

Table 3
Fishery assessment procedures, graduated for the amount of sampling and analysis capacity available

Sampling resources			Recommended assessment procedures
Equipment	**Labour**	**Expertise**	
Minimal	Minimal	Minimal	Mandatory self-reporting: effort, catch, harvest and size of each species caught (time series of fishery characteristics)
Minimal	Adequate	Minimal	Conduct creel survey of catch, harvest, effort, fisher preferences and values; sample recreational catch: count, measure, weigh. Compute mean size, plot size distribution of catch and body condition vs size. Compute satisfaction scores for user satisfaction and study expectations for future developments.
Minimal	Adequate	Adequate	Conduct creel survey (statistically based estimates of catch, harvest, effort; fisher preferences etc.); sample stock and recreational catch: count, measure, weigh (body condition); extract ageing structures (age/growth); compute age composition of population, infer recruitment and mortality. Compute satisfaction of users. Ecosystem: track simple indicators of system structure and function.
Adequate	Adequate	Adequate	Thorough stock assessment and ecosystem surveillance. The stock and fishery: scientific sampling, creel survey, complete description of demographics of target population and fisher population; population modelling of management scenarios. Ecosystem: track multiple indicators of ecosystem structure and function, status of sensitive species, indirect effects of fishery management on non-target organisms (e.g. trophic analysis with bioenergetics modelling).

Managers should be prepared for indirect effects of changes in recreational fisher effort and harvest or discard mortality (catch-and-release) brought about through altered regulations (Beard *et al.*, 2011; Johnston, Arlinghaus and Dieckmann, 2010). Because of eco-evolutionary feedback and trophic

Figure 10
How fish and recreational fisher survey data are used



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

relationships, any alteration of the target population's biomass or size structure can have implications for other trophic levels and even water quality in extreme situations (e.g. Lathrop *et al.*, 2002). Understanding how fishing regulations might affect trophic relations can be evaluated using projections from a population model combined with a bioenergetics model to translate expected changes in the target population into predictions of consumptive demand and potential impacts on prey populations by the target population (Johnson *et al.*, 1992; Johnson and Martinez, 1995). More generally, Ecopath with Ecosim (Christensen and Walters, 2004) can be used to explore the ecosystem effects of fishing and fishery management.

Managers should also recognize that recreational fishers are likely to respond to changes in fishing conditions within a system (Johnson and Carpenter, 1994) but also to alternative fisheries across the landscape (Lester *et al.*, 2003; Post *et al.*, 2008). This behavioural response of fishers to alterations in the ecosystem or the management component should be considered in regulation planning to avoid misguided management advice and "surprise" (Johnston, Arlinghaus and Dieckmann, 2010). Integrated modelling that links biological and human dimensions models (e.g. Carpenter and Brock 2004; Hunt *et al.*, 2011) may prove useful for predicting performance of a fishery under alternative management regimes, and is particularly relevant when expanding the purview beyond the target species and to include socio-economic dimensions. Addressing the heterogeneity of recreational fisher preferences is a challenge but is necessary in order to understand the trade-offs that will differentially affect various fisher types (Dorow *et al.*, 2010). For example, it is usually impossible to please harvest-oriented fishers (by maximizing yield of a stock) and trophy-fish-oriented fishers (by maximizing the number of large fish) of a given species jointly in one fishery, and a diversity of fisheries may be needed in a fisheries "landscape".

Integrating information from fish stocks, ecosystems and recreational fishers provides for a more holistic and realistic conceptual model for fisheries and fishery management. Management actions are never final, and recreational fishery management is a continuous process requiring periodic re-evaluation, adjusted objectives (Chapter 3) and regular assessment of outcomes. The frequency of repeat surveys needed to inform fisheries is correlated with the intensity of management (+), value or importance of the resource (+), lifespan of fishes (-), time scale of environmental variation (-), and intensity of stakeholder conflicts surrounding a given fishery (+).

5.3.3 Setting goals and objectives

Clear and explicit goals and objectives are essential for effective management and are required in order to evaluate management outcomes. Goals are central to the overarching normative framework to guide the long-term development of the fishery (Chapter 2). Appropriate goals may include: (i) maintaining ecological integrity and protecting natural systems for present and future generations in the face of exploitation; and (ii) 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 (Chapter 2). Specific objectives should be operationally defined as part of the adaptive management process (Chapter 3).

While managers may believe that they know what is best for the fishery, choosing from among competing objectives requires that any value judgment be based on a societal, consensus-based choice in the light of ecological constraints and possibilities. The recreational fishery manager should always consider sociological, biological and ecological aspects:

What do stakeholders want?
What can the target population provide?
What can the ecosystem sustain?

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 strongly influence the direction of management (Johnston, Arlinghaus and Dieckmann, 2010). Thus, open discussion and disclosure of objectives is fundamental for fisheries management if a transparent and accepted process is to be achieved.

Unlike commercial fisheries, where yield (profit) optimization is a common objective of fisheries management, recreational fisheries generally strive to optimize relatively intangible benefits such as recreational fisher satisfaction and its multidimensional catch and non-catch components (Fedler and Ditton, 1994). Opinions about what constitutes a satisfying fishing experience also vary widely in recreational fishers (Arlinghaus, 2006b; Beardmore *et al.*, 2011), creating heterogeneity in expectations that complicates establishment of objectives. Collectively, recreational fishers may wish to maximize catch rate, harvest, number and size of trophy fish, or ease and convenience of fishing (Hunt, 2005) while perhaps minimizing their exposure to contaminants in the fish they catch to eat. They may also desire a diversity of recreational fishing opportunities, including the chance to catch wild or unusual fish, use more challenging methods, or enjoy a relatively natural setting. Some fishers may be purely non-catch oriented (Beardmore *et al.*, 2011). Serving the heterogeneity of fisher types may only be possible by managing for a diversity of fishing experience over broad spatial scales (Johnston, Arlinghaus and Dieckmann,. 2010). In addition to meeting recreational fisher desires while avoiding undesirable impacts on ecosystems, managers can also manipulate fisheries in a fashion that affects water quality through food web effects (e.g. biomanipulation; Lathrop *et al.*, 2002) or otherwise emphasizes ecosystem services (e.g. increase predation on exotic species).

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. However, there will always be potential for disagreement. Fisheries managers must recognize that: (i) some activities may be of higher social priority than recreational fishing; (ii) values of recreational anglers and managers may differ from those of other stakeholders; and (iii) the sector should respect values, customs and objectives of other stakeholders (EIFAC, 2008, Article 10). If necessary, conflict management techniques (Daniels and Walker, 2001; FAO, 2005b) should be applied to reach a mutually acceptable solution.

5.3.4 Choosing and implementing a course of action

Equipped with knowledge and objectives, the next task is to choose a course of action to achieve the specified desires for the fishery. In some instances, no management actions will occur, but this is also a legitimate management choice (Arlinghaus, 2006a). However, given increasing human domination of the biosphere, this choice can carry potentially irreversible consequences for the fish stock, ecosystem, and human welfare, so some form of management action will be implemented in most fisheries.

Whereas in most commercial capture fisheries the stock is maintained through regulation of harvest, recreational fishery managers have a diverse array of tools and approaches to manipulate fisheries (Welcomme, 2001; Hubert and Quist, 2010). In general, these tools have clearly defined purposes and target the three primary components of the fishery system, namely, habitat, biota, and recreational fishers (Nielsen, 1993; Cowx, 2002), and a thorough understanding of their scientific basis is needed before an appropriate course of action can be chosen. In many countries, e.g. the United States of America, recreational fishery managers have university training, even college degrees in fishery biology and management. Where higher education is not practical, short courses and workshops can assist 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 with a university degree that for example many fisheries managers hold in the United States of America (Daedlow, Beard and Arlinghaus, 2011).

Choice of a management action must be justifiable on technical grounds but, also, it must be sensible from economic and social standpoints. For example, what are the costs of a change in management for the agency and for the resource users in terms of potential welfare loss? Who must bear these costs, are they justified, what are the financial trade-offs, and are the benefits shared equitably among stakeholders? Socio-economic evaluation of recreational fishing is usually more challenging than for commercial fishing (see Parkkila *et al*. [2010] for a methods overview). Whereas the benefits of commercial fishing can be readily valued by society's willingness to purchase the fish product, the benefits experienced by each individual recreational fisher (e.g. satisfaction while fishing) are not revealed by market mechanisms. However, modern economic evaluation tools such as contingent valuation (Loomis and Walsh, 1997) or discrete choice modelling (Dorow *et al*., 2010) are available 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, Newbold and Gentner, 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).

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). At this stage, the fishery management plan can be disseminated to stakeholders for their feedback and be modified accordingly.

5.3.5 Monitoring and evaluation

Monitoring is an essential component of the AM cycle to enable learning from individual management actions whether active or passive AM is employed (Chapter 3). Managers should always thoroughly document their actions and results whatever the level of activity. Statistically valid sampling designs are required in order to obtain reliable information on fish population responses (Hansen, Beard and Hayes, 2007; Noble, Austen and Pegg, 2007), recreational fisher catch and effort (Pollock, Jones and Brown, 1994; NRC, 2006), and recreational fisher attitudes, preferences and values (Ditton and 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. However, where 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 and Hubert, 2002;

Kubečka *et al*., 2009). Fisheries may take years to respond to some management actions, necessitating consistent sampling methods over time to allow for a full evaluation of the action. In developing nations where a historical record of fisheries investigations is not available, managers must rely on contemporary surveys as their knowledge base. Standardization of sampling methods allows managers to begin building a foundation of comparable data immediately.

Globalization dictates that managers share data increasingly widely. Standardization of routinely used sampling gear (e.g. gillnets, electrofishing) at a continental or global scale would improve communication among nations (Bonar, Hubert and Willis, 2009) and would be useful for addressing management questions at large geographic scales (e.g. effects of climate change, invasive species). To assess the global impact of the recreational fishing sector and to elevate recreational fishing as a conservation concern, fundamental information on fishing participation, compliance and harvest rates are needed. However, these data are currently scarce or unavailable for most recreational fisheries (Cooke and Cowx, 2004) and the situation needs to be improved.

Evaluation of the outcome of a fishery management action is necessary in order to determine whether goals and objectives have been achieved. However, enforcement of regulations must accompany any change in management if outcomes are to be properly interpreted. Evaluation of effectiveness is required to learn about system behaviour and to allow managers to refine management strategies (AM, Chapter 3).

Because recreational fishers can have significant ecological impacts (Chapter 1; Cooke and Cowx, 2004; Lewin, Arlinghaus and Mehner, 2006), it follows that fishery management actions that regulate effects of recreational fishers are powerful ecological tools and it is important to assess effects of management action on the host ecosystem. Tracking ecosystem indicators provides a means to detect and understand the broader implications of management actions targeting a particular fisher–fish interaction (Kwak and Freeman, 2010). However, in order to avoid unintended ecosystem impacts monitoring methods should be chosen that minimize adverse effects on the environment and the stock, and the bycatch of non-target organisms.

5.4 MATCHING MANAGEMENT TO OBJECTIVES

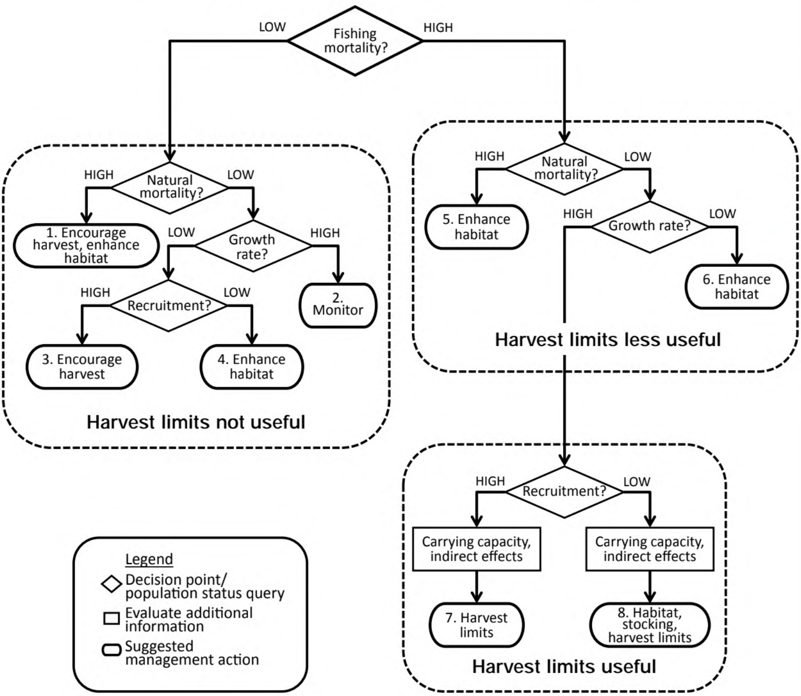
Collectively, recreational fishers may desire conflicting, inappropriate or unattainable fishery attributes. For example, some recreational fishers would like to maximize harvest of a desirable food fish, others would like to maximize the size structure of a piscivorous trophy fish that preys upon the other species (Johnson and Martinez, 2000) and yet others desire species that are not native or not suited to local environmental conditions. The responsible manager must understand stakeholder desires, optimize where possible and educate where not. Thus, an appropriate compromise for the first scenario could be to increase overall harvest of the piscivorous species to sustain the prey population but to protect the largest, trophy-size class of the predator with slot regulations (Arlinghaus, Matsumura and Dieckmann, 2010; García-Asorey *et al.*, 2011). Recreational-fisher wishes might also be accommodated by managing across systems, emphasizing trophy fish in some and food fish in others. Where recreational-fisher desires cannot be granted owing to environmental or eco-evolutionary considerations the manager needs to educate the fishers and provide a more sustainable alternative by enhancing the fishery by other means (Figure 11 and Table 4).

Recreational fishers commonly desire improvements in the catch rate, size of catch, and opportunity for harvest in a fishery. The manager must investigate reported inadequacies and implement an appropriate course of action (Table 4). Figure 11 presents a simple decision tree to identify which general management strategy may prove useful given the biological properties of the target population. While deciding on an appropriate regulation depends on the natural mortality and growth rate of the fish, final decisions will also depend on the recreational fishers' expectations and values. In some cases, there may be several approaches to achieve an end and others that would be contraindicated. Overall, the recreational fishery manager should accept and espouse three general principles: (i) recreational fishers are a multifaceted group with diverse expectations and motivations; (ii) ecological constraints can dictate what management strategies can or should be applied; and (iii) regardless of stakeholder desires, economic, social or biological constraints preclude some management strategies. The final decision will depend on socio-economic trade-offs within the biological realities.

5.4.1 Habitat management

Habitat management focuses on protecting, modifying, mitigating and restoring aspects of the biological, chemical and physical environment. Goals range from enhancement of habitat to increase the abundance of a particular recreational species to actions aimed at protecting or restoring ecological integrity of the system (Table 5). Managers should be alert to potential environmental problems created or aggravated by recreational fishing (Table 6; Chapter 6). Fostering environmentally responsible behaviour among recreational fishers complies with the aquatic stewardship principle (Chapter 2).

Figure 11
Generalized decision tree for recreational fishery managers



Notes: An implicit assumption is that the management objective is to increase size and abundance of the target species within ecological limits of the system. When fishing mortality is low (1–4), harvest regulations would not be useful, rather, it may be advantageous to encourage harvest to alleviate problems with density-dependent growth or natural mortality (1, 3). When fishing mortality is high but natural mortality is also high (5) or growth is low (6), habitat improvements rather than harvest restrictions would be indicated. The manager stands to make the greatest improvements to the fishery with harvest regulations when fishing mortality is high, natural mortality is low, and growth is high (7, 8). Under these conditions, harvest limits can increase biomass and size structure of the target population; hence, an assessment of system carrying capacity and potential indirect effects of the change on non-target species should be performed.

Table 4
Common complaints of recreational fishers about the fish stock and suggested management actions to remedy the situation

Complaint	Evidence	Diagnosis	Suggested remedies (Tables)
Not enough fish	Creel survey: low CPUE[1]	Low catchability: temporary boom in prey of fished species	Educate anglers: catch rate not always indicative of fish abundance
		Low catchability: fish dispersed	Install fish aggregating devices
	Sampling: low CPUE, abundance	Low abundance: insufficient recruitment	Improve habitat (5) Protect spawners Stock target species (8)
		Low abundance: excessive natural mortality	Improve habitat (4) Suppress predators (6) Alternative target species (8)
		Low abundance: excessive fishing mortality/too many recreational fishers	Size, bag and effort limits (9, 10) Stock target species
Fish too small	Creel survey: size in catch Sampling: size in catch	Slow growth	Improve habitat (5) Enhance prey (7) Suppress competitors (7) Encourage harvest (9, 10)
		Excessive natural mortality	Improve habitat (5) Alternative target species (8)
		Growth overfishing	Size, bag and effort limits (9, 10) Stock target species
Fish too thin	Creel survey: body condition Sampling: body condition	Slow growth	Improve habitat (5) Enhance prey (7) Encourage harvest (9, 10)
		Unsuitable environment	Improve habitat (5) Alternative target species (8)
Any of the above	Historical record	Unrealistic expectations, inaccurate recollection of past fishing success	Educate recreational fishers: provide access to historical data

Table 4 (Cont.)

Complaint	Evidence	Diagnosis	Suggested remedies (Tables)
Not the right kind of fish	Species not present in catch	Species not native to locale	Educate recreational fishers, Alternative target species (8)
		Environmental constraints	Improve habitat (5) Stock target species (8) Alternative target species (8)

[1] CPUE = catch per unit of effort.

Notes: In some cases, there will be multiple complaints caused by interacting factors; in these situations, effective remedies may be more limited (Figure 11). It is possible that problems with a target species are such that the manager needs to emphasize other species and educate recreational fishers about ecological constraints that preclude catering to some recreational fisher desires. Numbers in parentheses refer to tables in these Guidelines with more detailed information about remedies.

Table 5
Examples of management actions targeting habitat that may benefit recreational fish populations and their ecosystems

Strategy/goal	Explanation
Protect habitat	Mitigation and restoration are costly; preventing habitat change by education, regulations and enforcement should be a high priority
Restore connectivity	Install fish passage structures or remove dams to alleviate barriers to fish movement and restore metapopulation dynamics
Nutrient abatement	Contain point and non-point sources of excess nutrients in the watershed (often phosphorus and nitrogen)
Nutrient supplementation	Phosphorus and nitrogen additions to enhance fish production or to compensate for cultural oligotrophication
Reduce contaminants	Contain point and non-point sources of contaminants in the watershed (e.g. nitrates, metals, pesticides)
Liming	Addition of calcium carbonate (limestone, calcite) to neutralize acidified waters
Aeration	Increase dissolved oxygen concentration through physical means to prevent die-offs and undesirable chemical dynamics in hypoxic waters (e.g. dissolution of phosphorus and manganese, and mercury methylation)
Mitigate thermal pollution	Cooling-water effluent from power plants can cause harmful abrupt temperature changes when discharged into waterbodies
Manage turbidity	Soil runoff from the watershed, mixing by boats, and bioturbation by fish can all increase turbidity, limiting photosynthesis and increasing surface temperature

Table 5 (Cont.)

Strategy/goal	Explanation
Manipulate flow/ water level	Mimic natural water level/flow fluctuations in regulated waters; reservoir drawdowns can reduce reproduction of undesirable species
Restore wetlands/ estuaries	Inland and coastal wetlands provide many ecosystem services including water purification and fish production
Restore shoreline/riparian zones	Fish benefit from large woody debris in littoral zones of lentic systems; excluding livestock protects riparian areas and reduces bank erosion of lotic systems
Improve spawning habitat	Spawning substrates, spawning channels, river channel modification for fish and shellfish reproduction
Supplement structure	Fish aggregating devices, artificial reefs

Note: As with other management tools the effectiveness of habitat management will vary by site, ecosystem and scope of the habitat improvement scheme.

Table 6
Examples of regulations that managers can use to target environmental problems that may be aggravated by recreational fishers and their activities

Target	Regulation purpose
Anchoring	Prohibit anchoring over sensitive substrata (e.g. coral reefs); provide permanent mooring buoys for recreational fishers
Baiting	Regulate use of chum, groundbait and other recreational fish attractants with potential to pollute waterbodies
Biosecurity rules	Implement regulations and protocols to prevent the intentional and accidental introduction of invasive, pathogenic or parasitic organisms including from the release of bait
Boat noise and wake	Engine horsepower and speed limits to minimize conflicts with other water users
Boat discharge	Regulate emissions from boat motors, release of grey and black water into waterways
Boat strike	Restrict boat operations when collisions may have significant effects on fish and wildlife populations
Bycatch and discards	Regulate fishing to minimize incidental catch and mortality of non-target species, undersized fish, and sensitive species
Disposal of fish waste	Prohibit in waterways to reduce aesthetic concerns and disease transmission

Table 6 (Cont.)

Target	Regulation purpose
Disposal of garbage, tackle	Prohibit littering and provide trash collection receptacles; encourage recycling of fishing line and other fishing-related materials
Disturbance to wildlife	Restrict shore and boat fishing when there is potential for disturbance of breeding, nesting or rearing of wildlife
Habitat disturbance	Regulate recreational use of disruptive fishing gear (e.g. shellfish dredges, rakes; trawls) to protect benthic habitats
Harvest of bait	Regulate to prevent depletion of bait organism populations, habitat damage
Stocking	Require permits for importation, transportation and stocking of aquatic organisms
Introduction of non-natives	Prohibit introduction of invasive species; conduct risk analysis and thorough review before considering any introduction
Tackle and methods	Mitigate for tackle that is potentially damaging to fish or other wildlife (e.g. by use of non-toxic weights and barbless hooks)
Transport of live fish	Prohibit transport without a permit to discourage illegal transfer of fish and aquatic hitch-hikers among waters
Trophic cascades	Prevent overharvest of keystone species, apical predators to prevent undesirable food web consequences

Habitat protection is a powerful tool for promoting healthy fisheries but it is not always practical. Notwithstanding widespread benefits for fished populations and the ecosystem, complete restoration of human-altered habitats (e.g. engineered rivers in more developed nations) is not often feasible. Human impacts to watersheds, and hence to inland and coastal waters, are often pervasive and irreversible. The fishery manager rarely has authority to control potentially harmful activities on the land such as unsustainable logging, mining, agriculture and development. The manager's task is then to be an advocate for the aquatic environment, protect to the extent possible and then find ways to mitigate or compensate for habitat alteration, such as direct manipulation as described below.

5.4.2 Biotic manipulations

Manipulations of biota often involve the enhancement of desirable fishes and the suppression of undesirable ones (Table 7). Managers may conduct the manipulations themselves, through stocking or physical removal (e.g. Rose and Moen, 1953) or enlist the aid of recreational fishers by implementing mandatory

Table 7
Examples of management actions targeting biota

Biotic manipulation	Purpose
Stocking	Release of cultured or translocated fish to create or supplement populations of desirable fishes (see Table 8)
Biomanipulation	Stock, protect fishes as agents of biomanipulation to improve water clarity; compromises between recreational fishing and water quality goals are required
Enhance prey	Release of aquatic organisms or otherwise supplement prey resources and enhance growth of fishes
Suppress detrimental fishes	Physical removal by managers (e.g. netting, electrofishing) or recreational fishers (e.g. with liberal harvest regulations, bounties, contests); targets may or may not be recreational species
Selective removal	Reduce biomass of overabundant cohorts of recreational species to reduce interspecific and intraspecific competition
Renovation/ reclamation	Chemical piscicides to remove all fish from a waterbody when undesirable species cannot be removed by other means
Manage aquatic plants	Physical removal, biological control (e.g. grass carp, milfoil weevil), herbicides; often directed at invasive species; introduce beneficial plants, e.g. kelp

kill regulations to suppress undesirable fish. In North America and elsewhere, the desirability of species has evolved from a highly utilitarian position of favouring species that have pure recreational value and gastronomic appeal to one related to the maintenance of biodiversity and ecosystem function (Eby *et al*., 2006). Regardless, fishery management practices must be ecologically sustainable and derive socio-economic benefits from the fishery.

Stocking plays a prominent role in recreational fishery management worldwide (Cowx, 1998; Nickum *et al*., 2004). The practice has many objectives (Table 8) and includes the transfer of wild fish between waterbodies, the release of cultured fishes, and the introduction of non-native species. Managers may wish to stock cultured fish to restore a wild population decimated by an environmental catastrophe (restoration), to maintain or supplement a population to mitigate for an unresolved limitation on natural recruitment (maintenance/mitigation), or to increase the fishable stock above natural levels (enhancement). Where still legally allowed, non-native fish (or genotypes) might be introduced to diversify and enhance the socio-economic value of a fishery. Although such action may attract fishers as advocates for protecting aquatic

Table 8
Major types of stocking programmes used in recreational fishery management

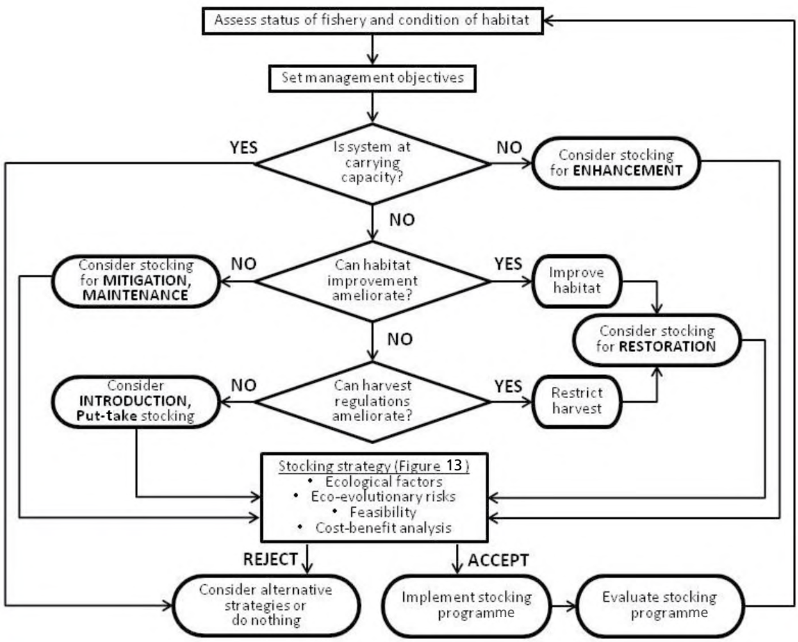
Type	Definition/objectives	Duration	Origin of stocking material
1. Restoration	Release of cultured fish to restore a population after a limiting factor has been ameliorated	Temporary	Indigenous
2. Mitigation	Release of cultured fish to compensate for reductions in wild stock caused by unresolved environmental inadequacy and overfishing (includes maintenance)	Permanent	Indigenous
3. Enhancement	Release of cultured fish to augment a population's natural supply of recruits	Temporary, permanent	Indigenous
4. Introduction	Release of non-native fish to create a new, self-sustaining fishery (the release of non-native genotypes of a native species across catchments could also be considered an introduction)	Temporary	Non-indigenous
5. Put-take	Release of cultured juveniles for immediate catch or catch at a larger size (includes sea ranching, put–grow–take)	Permanent	Indigenous, non-indigenous
6. Trophic	Release of predators or prey to manipulate food web for the benefit of recreational fish stocks	Temporary, permanent	Indigenous, non-indigenous

Note: The first three types involve stocking cultured fish on top of a natural (indigenous) population of the same species.

Sources: Cowx (1998), Bell *et al.* (2008).

habitat (e.g. Trout Unlimited in North America, trout anglers in New Zealand), it can be harmful to the ecosystem and other organisms (Goldschmidt, Witte and Wanink, 1993; Eby *et al.*, 2006;). In some cases, cultured fish, either native or non-native, are stocked for the express purpose of contributing to the catch and are not expected to be self-sustaining (e.g. put-and-take or put–grow–take type stocking, sea ranching; stocked fish may be sterile or otherwise unlikely

Figure 12
Decision tree for selecting an appropriate stocking strategy

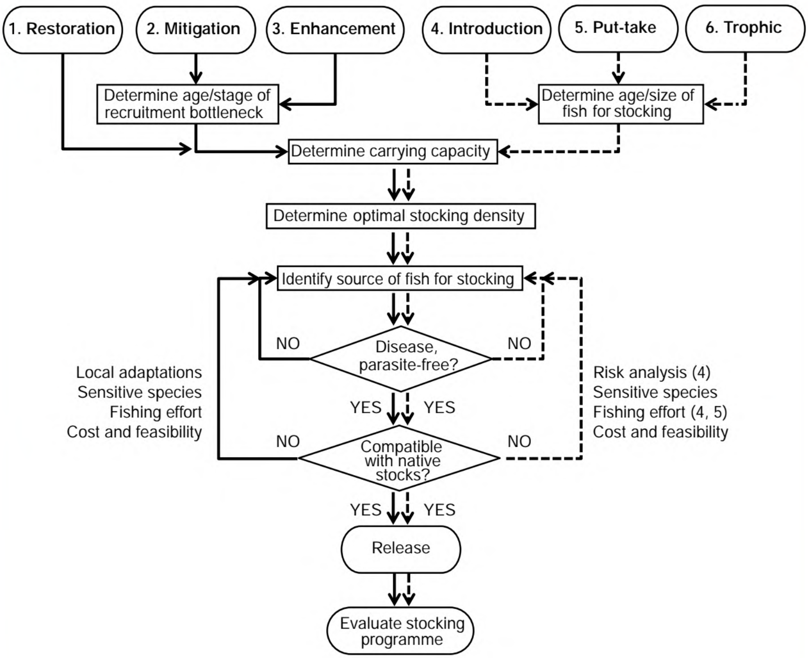


Note: See Figure 13 for procedures for planning and implementing a stocking programme.
Source: Modified from Cowx (1994).

to reproduce). Finally, managers may stock piscivores or prey to manipulate a food web for the benefit of the recreational fishery or other stakeholders (e.g. biomanipulation; Mehner *et al*. [2004]).

Managers considering a stocking programme should first evaluate whether stocking is actually an option (Figure 12), and then decide whether it is feasible and appropriate on eco-evolutionary and fiscal grounds (Figure 13). Given that stocking does not alleviate biological limits on the productivity of the ecosystem, habitat improvement or harvest regulations could be more cost-effective and less risky to ecological integrity (Rogers *et al*., 2010). Where these approaches fail, stocking may be a suitable alternative for improving the

Figure 13
Procedures for planning and implementing a stocking programme once objectives have been identified



Notes: Procedures for planning and implementing a stocking programme once objectives (1–6) have been identified. Solid arrows represent considerations relevant to stocking cultured fish on top of a natural population of the same species (restoration, mitigation, or enhancement). Dashed arrows represent considerations for stocking that may involve non-native species (after risk analysis) and does not involve rehabilitation of a native fish population, *per se*. The manager should anticipate recreational fisher response to stocking and its potential collateral effects on native fish populations.

fishery. However, in order for stocking to be successful, it is essential that the manager:

1. understands the status of the fishery and the condition of the habitat;
2. has clear management objectives;
3. selects a stocking strategy appropriate to the objectives;
4. considers ecological factors controlling survival of stocked fish;

5. evaluates eco-evolutionary risks to resident species;
6. anticipates recreational-fisher response to stocking and its potential collateral effects on native fish populations,
7. predicts the benefit–cost ratio and feasibility of the programme;
8. evaluates outcomes of the stocking programme.

Historically, items 3–5 and 8 have proved to be the most neglected and problematic. Stocking unquestionably supports substantial recreational fishing opportunity worldwide. However, the practice is commonly seen as a panacea for a multitude of fishery inadequacies, it is often unsuccessful (or its additive effects on top of natural recruits unknown), and it can be ecologically and genetically harmful (van Poorten *et al.*, 2011). In addition, advances in fish culture, providing the means to produce vast numbers of fish for stocking, provide further incentives to stock. Understanding, and preventing, the deleterious effects of stocking on fisheries and ecosystems while exploiting its potential for positive outcomes is becoming increasingly important (Lorenzen, Leber and Blankenship, 2011).

Stocking hatchery-reared fish is often viewed as an efficient means of restoring extirpated populations. A common management response to large-scale environmental damage that impairs or prevents recruitment of wild populations is to build hatcheries (e.g. 2010 Gulf of Mexico oil spill). When the stocking objective is restoration, managers should consider very carefully the genetic implications of using cultured fish as founders of populations. Even where cultured progeny of wild broodstock are used, the genetic composition and fitness of hatchery-reared juveniles can be quite different than that of wild juveniles. Managers should ensure that best practices (FAO, 2008a) are adhered to when hatchery reared fish are produced for restoration stocking.

Stocking to supplement a wild population (enhancement or mitigation) has some particular risks and challenges. Where natural reproduction is present, but deemed inadequate, stocking may be harmful to the wild population. For example, large-scale hatchery supplementation of Pacific salmon on the west coast of North America attracted fishing effort that increased exploitation rate on natural stocks and compromised local adaptations (Hilborn, 1992). Stocked fish may compete with wild fish, reducing growth and size structure of the population as a whole, diminishing the benefits of stocking. The cumulative effect of stocked and wild fish could also be harmful to sensitive species in the ecosystem (e.g. excessive predation; Eby *et al.* [2006]). Similarly, managers stocking piscivorous recreational fish to reduce abundance of undesirable prey species should consider collateral predation on desirable recreational species or sensitive species.

Practically speaking, stocked fish could be constrained by the same life-history bottleneck that may be limiting the wild population. Unless this aspect of the ecosystem is understood and the stocked fish are raised to a size that is beyond this bottleneck, the manager should not expect stocking to be effective (e.g. Donovan, Stein and White, 1997), but raising hatchery fish to an appropriate size can be very expensive (Johnson and Martinez, 2000). Maintaining a population entirely with stocking (maintenance, put–take) should be viewed as a long-term commitment because recreational fishers will expect such a fishery to be perpetuated. Similarly, when stocking to manipulate food webs, benefits may be transitory unless stocking is continued.

Introducing non-native fishes or prey has a long history in recreational fishery management, but these practices are now widely recognized as environmentally risky and have been discontinued by most management agencies in many industrialized countries (Rahel, 2004). In some countries, such as the United States of America, fishery managers today are devoting considerable time and resources to the removal, containment and suppression of non-native fishes stocked to create new recreational fisheries (Johnson, Arlinghaus and Martinez, 2009). In some other countries (e.g. some in Latin America and South America), socio-economically important fisheries for non-native salmonids exemplify the trade-offs between changing natural ecosystems via non-natives and economic benefits stemming from them. However, to some degree, non-native introductions are a legacy from when such introductions were perceived as generally positive. Today, managers contemplating the deployment of a non-native species should take into account the potentially catastrophic effects (Eby *et al*. 2006) and that any subsequent eradication may be unfeasible or too costly (Vander Zanden *et al*., 2010). Managers should thus adhere to professional codes of practice for introductions (AFS, 1986; Turner, 1988; Bartley, 2005; ICES, 2005). Where under pressure from recreational fishers to introduce new species and this is found to be inadvisable, the manager should educate the fishers about environmental sustainability of management practices, and provide more sustainable options with existing species wherever possible. Deterring unauthorized stocking should be a management priority (Johnson, Arlinghaus and Martinez, 2009).

Managers should evaluate success of stocking programmes whenever technically possible. However, given the pervasiveness and costs of the tool, there is a paucity of studies carefully evaluating the outcomes of stocking projects (but see Stroud, 1986; Schramm and Piper, 1995; Nickum *et al*. 2004), and there are very few controlled, replicated studies analysing additive effects of stocking (Hilborn, 1992). Therefore, the success of many stocking strategies cannot be predicted. As a minimum, managers should know whether stocking objectives are being achieved and, therefore, whether continued stocking is justified. A critical need for such evaluations is the ability to distinguish stocked fish from wild ones. Managers may believe that stocking is enhancing a fishery, but in cases where wild fish are present this is not an obvious conclusion. However, there is an array of methods to distinguish hatchery fish from wild fish, including fin-clipping, tagging, chemical marking, stable isotope ratios, and genetic analysis.

5.4.3 Harvest regulations

Many techniques are used to manage recreational fishers and the fish–angler interaction (Table 9). Regulations are often categorized as either input controls (regulating the amount and manner of fishing) or output controls (regulating the fate of the catch), but can also be indirect, using information and outreach to influence human behaviour. While effort restrictions (e.g. limited entry) are relatively rare in recreational fisheries as compared with commercial fisheries (Cox and Walters, 2002), recreational fishery managers can still manipulate the intensity of fishing by, for example, requiring licences and fees or avoiding the development of access roads and boat ramps to constrain participation. Moreover, gear restrictions are frequently used to reduce the efficiency of recreational fishing without controlling the amount of effort. While the provision of user conveniences such as boat landings and fish-cleaning stations may please recreational fishers, managers should anticipate any impacts that increased use of the fishery might bring.

An understanding of the life history of recreational fish and the effort response by fishers to altered regulations is necessary if harvest regulations are to be effective and achieve their objectives. Regulations applied to one life stage or at a particular locale may be ineffective if the target species is migratory. For example, anadromous fishes and adfluvial fishes may be targeted by different groups of fishers and at different intensities across the species' home range. Inadequate regulations at any location may jeopardize fishery sustainability for all anglers.

Bag and size limits and annual quotas have several purposes but, generally, they are used to limit fishing mortality. Daily bag limits are the most common output control in recreational fisheries (Isermann and Paukert, 2010). These

Table 9
Management actions and regulations targeting recreational fishers and interactions between fish and recreational fishers

Control type	Explanation and examples
Input controls	
Licensing, fees	Fees based on duration of licence, species, recreational fisher residency, recreational fisher status (e.g. youth, elderly, military, student, native, tourist)
Gear restrictions	Hook and line, hook type, artificial vs bait
Method restrictions	Motor trolling; attractants: ground baiting, artificial light, scents
Closed times, seasons	Spawning period, aggregations, stressful environmental conditions
Closed areas	Spawning areas, aggregations, refuges, marine protected areas
Fishing contests	Minimize conflicts with other users; can be employed to encourage harvest of overabundant or undesirable species
User conveniences	Provision of boat landings, fishing piers, fish-cleaning stations may attract recreational fishers
Effort restrictions	Limited entry, number of rods/lures/lines
Output controls	
Length limits	Limit size of fish retained (minimum, maximum, open or closed slot limits, 'one over X' limits)
Bag limits	Limit number of fish retained; daily or annually, and in possession with tags and stamps as variants for particular sizes
Sale of fish	Prohibit commercialization of recreational fish species
Harvest restrictions	Restrict based on wild vs hatchery, conservation status
Fish holding	Prohibit to reduce sorting, stress, translocation
Harvest mandates, bounties	Encourage harvest of overabundant or undesirable species

Note: In general, input controls regulate the amount and manner of fishing and output controls regulate the fate of the catch.

rules affect the per capita (recreational fisher) harvest rate, but because access to many recreational fisheries is unlimited, not necessarily the total harvest from the fishery (Radomski *et al.*, 2001). Daily bag limits affect harvest expectations and thus fisher behaviour (Beard *et al.*, 2011). However, unless bag limits are very restrictive, potentially displacing effort or severely limiting the take, they will not reduce harvest mortality sustainably because few recreational fishers actually catch the daily limit. Effort controls and size limits on harvesting may be more effective for reducing fishing mortality, and bag limits would then allow more recreational fishers to participate and "share the benefits". Effort can be controlled by limiting licence sales, and harvest quotas can be implemented with season-long bag limits (e.g. punch cards or harvest tags). Catch-and-release rules can increase recreational fisher use without depleting the fish population, unless hooking mortality becomes excessive (Chapter 6; Coggins *et al.*, 2007), in which case method restrictions might be needed to maximize survival of released fish.

Length-based harvest limits are another common form of output control in recreational fisheries (Table 10). By tailoring size restrictions to match fish population characteristics and level of fishing effort in the light of objectives, the manager can use fishing as a means to manipulate fish population structure. Individual growth rates can increase and productivity can be enhanced by targeting fishing mortality on overabundant size-classes, and recruitment can be improved by protecting age- and size-classes with the most successful progeny (Venturelli, Shuter and Murphy, 2009; Arlinghaus, Matsumura and Dieckmann, 2010). In order for a minimum-size limit to be effective, it is necessary that protected fish have rapid growth and low natural mortality to allow them to recruit to the vulnerable population. Minimum-size limits can also be set above the size at maturation to allow fish to spawn prior to being vulnerable to harvest. Although many fisheries are routinely managed based on minimum-size limits, there is a range of other tools (e.g. harvest slot length limits) that may offer better results under certain conditions (Table 10). Particularly when trophy fish are to be maintained, minimum-size limits will not perform well at high fishing effort intensities (Pierce, 2010; Garcia-Asorey *et al.*, 2011). Generally, size limits that disregard fish population demographics and ecosystem characteristics can be counterproductive (Johnson and Martinez, 1995).

Many recreational fishers are unclear about the applicability of harvest regulations. Under the implicit assumption that recreational fishers would like more fish and larger fish, the regulations that can best achieve these goals are not only constrained by the characteristics of the fish population and the fishery but by angler preferences that can affect the range of socially optimal regulations (Johnston, Arlinghaus and Dieckmann, 2010). Usually, the level of size-specific fishing mortality interacts with the natural mortality, growth

Table 10
Five common size-based harvest regulations for managing recreational fisheries, and the associated vulnerability to harvest, management objectives and demographic conditions necessary for the tool to be effective

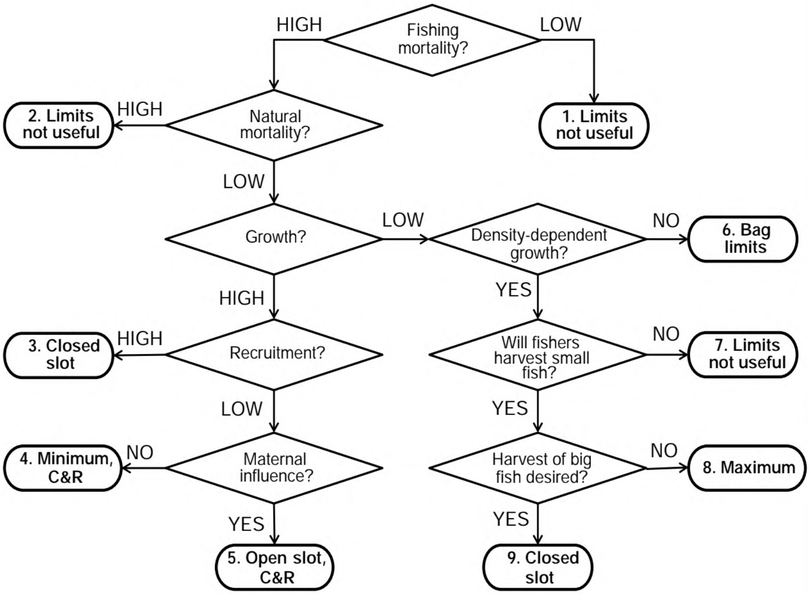
Size (total length) limit type	Fish that must be released	Management objectives	Demographic conditions
Minimum	Fish smaller than the size limit	Conserve recruits; produce larger fish for reproduction and harvest	Low recruitment, rapid growth, low M
Maximum	Fish larger than the size limit	Reduce abundance and competition among small fish; maintain trophies and fecund large spawners	High recruitment, slow growth, moderate M
Open slot	Fish above and below an intermediate size class (combination of minimum-size and maximum-size limits)	Protect young recruits and spawners; maintain yield and CPUE; protect large, fecund spawners, maintain trophies	Low recruitment, rapid growth, low M; particularly useful when size-dependent maternal influences affect recruitment and when fishing could deplete the spawning stock
Closed slot	Fish within an intermediate size class	Reduce abundance and competition; allow harvest of large fish	High recruitment, slow growth, high M
Total catch-and-release	All fish	Improve CPUE and size, maintain stock in "natural" condition, consumption prohibitions	Little interest in harvest by fishers, high F; sensitive stock; high contamination

Note: F = fishing mortality; M = natural mortality; CPUE = catch per unit of effort.

rate and recruitment rate of the fished population to determine a regulatory regime that achieves predefined management objectives. In the light of diverse objectives, the choice of optimal harvest regulations for recreational fisheries or for a combined exploitation of commercial and recreational fisheries will thus be fishery-specific and site-specific and may only be generalized in relation to the decision trees presented in these Guidelines document (Figure 14, Tables 9 and 10).

Figure 14

Decision tree for selecting appropriate size and bag limits based on the intensity of fishing, target fish population's demographic characteristics and recreational fisher desires



Notes: When fishing mortality is low (1), harvest restrictions would not provide any benefit. If natural mortality is high (2), then deferring harvest will not result in more large fish. The manager can expect size and bag limits to have the greatest impact on the number of large fish when fishing pressure is high, fish grow quickly and experience low natural mortality (3, 4, 5). When growth is slow, size limits may be useful for reducing density-dependent growth depression by channelling harvest onto overabundant size classes (8, 9). In cases where demographics of the stock are completely unknown, bag limits (6) should be established as a precaution against overharvest. Maternal influence means size-dependent influences of females on recruitment stemming from fecundity or egg quality influences. C&R = total mandatory catch-and-release.

Basic recommendations can still be given assuming that a fishery is solely exploited by recreational fisheries (Figure 14, Tables 9 and 10). Where the fishing mortality rate is low, limiting it further will not be beneficial. Protective size limits that defer harvest will also have little benefit if growth is slow and natural mortality is high, because few fish will survive to reach the harvestable size. When growth is slow, specifically tailored size-based harvest limits may be useful for reducing density-dependent growth depression by channelling harvest onto overabundant size classes. In general, the manager can expect size and daily bag limits to have the greatest impact on the number of large fish to be conserved in the stock when fishing pressure is high, fish grow quickly and experience low natural mortality. Thus, under these conditions, when regulations defer harvest to a larger size, the abundance of fish in that size class will be higher than if natural mortality and growth were less favourable. When fishing pressure is great enough to truncate size and age structure severely, open slot length limits may be superior for conservation and enhancing fishery quality in fast-growing top predator species that may be recruitment limited at low spawning stock sizes (Arlinghaus, Matsumura and Dieckmann, 2010). When natural mortality and growth favour deferred harvest strategies, the recruitment dynamics of the stock and the objectives of the fishery will ultimately dictate the particular size regulation to apply. For example, where recruitment is high, a closed slot limit would be appropriate, but where recruitment is low and size-dependent, maternal influences (fecundity and egg quality) are important for securing future recruitment; then, an open slot limit or total catch-and-release might be called for to protect the most influential spawners. Open slot limits may be a good compromise for maintaining a high harvest (in numbers) as well as protecting trophy-sized fish in populations with fast growth, low natural mortality and limited recruitment at low spawner abundance (Venturelli, Shuter and Murphy, 2009; García-Asorey *et al*., 2011). Simulation modelling can predict how a given population will respond to various harvest limits and suggest the optimal choice before testing it in real life.

There are also opportunities for recreational fishers to adopt conservation-minded measures voluntarily to help support regulations, perhaps even making regulations superfluous. For example, in some fisheries, people voluntarily release all the fish captured (Arlinghaus, 2007), obviating the need for a very restrictive harvest policy. Alternatively, "unexpected" behaviour may render some regulations ineffective, for example, where people refrain from harvesting small fish under a protected slot regulation aimed at reducing density-dependent competition (Pierce and Tomcko, 1998).

In order to reduce the information burden and increase ease of communication and acceptability by fishers, regulations should not be too complex or too system-specific. Usually, more novel regulations are initially resisted unless the benefits become obvious. Therefore, regulatory planning must involve a thorough understanding of the human dimensions of the fishery.

Managers should be aware of voluntary behaviour that arises from proper education and outreach thereby sustaining fisheries using a "softer approach" to resource stewardship. Such an approach could be particularly effective in developing countries where formal management capacity and enforcement are lacking. Where voluntary behaviour is not enough, Walker, Foote and Sullivan (2007) provide examples of enforcement needs to ensure rule compliance in recreational fisheries.

Application of harvest regulations provides the means to improve the fishery for recreational fishers. However, it is also an opportunity to learn about the system and improve management in the future. In some cases, regulations may not produce the desired effects so it is important for managers to follow up regulation changes with fishery evaluation (Figures 9 and 10).

6. RECREATIONAL FISHING PRACTICES

This chapter considers recreational fishing practices of the individual recreational fisher. The focus is on the activities and behaviour of individuals as affecting their safety, gear selection, use of aquatic resources and the impacts that their fishing has on the environment and on individual aquatic animals, particularly fish. In some cases, behavioural choice is voluntary and it is for the recreational fisher to decide whether or not to act in a way to minimize impacts on habitats or individual fish. In other cases, policies or laws exist but the recreational fishers still have to decide the extent to which they will comply with such regulations. There can be consequences of recreational fishing, including direct impacts on fish populations and both aquatic and terrestrial ecosystems (Chapter 1), and the issue of fish welfare is receiving increasing public attention (Arlinghaus *et al*., 2009a). However, by following simple guidelines, these potential negative consequences can be minimized and often eliminated. The following sections provide details on the issues, scientific basis and context for guidance and the guidelines themselves. Although the guidelines are related to the individual behaviour of the recreational fisher, there are various channels for their promotion. Examples include formal regulation and informally based voluntary behaviour, which may be stimulated by guidance, outreach and education from NGOs, recreational fishing clubs and associations or fisheries management bodies and agencies.

6.1 SAFETY

The safety of recreational fishers, other stakeholders and their property is of paramount importance and, consequently, many jurisdictions have developed a suite of safety regulations, most of which pertain to boat safety. Regulations can dictate the need for certain pieces of safety gear including signalling devices, paddles, anchor, buoyant heaving lines, first-aid kit, fire extinguisher, and life jackets. There is also a growing trend towards the licensing of pleasure-craft operators.

Commercial fishing is regarded as one of the most dangerous occupations in the world, and there is a large body of literature detailing aspects of occupational health and safety (e.g. , Kite-Powell and Talley, 2001). A similar body of literature does not exist for recreational fishing, possibly because of its leisure-time focus that reduces governmental and industry-based safety input.

However, each year, many hundreds of recreational fishers die, with almost all deaths directly attributable to drowning. Following appropriate fishing industry regulations and best practice for boat safety and for working on or around water would reduce safety concerns in recreational fisheries. The single largest factor that could minimize deaths is the use of life jackets. Recreational fishers can injure themselves and others by careless use of gear (e.g. hooks penetrating parts of the body). Wearing sunglasses can help to shield the eyes from hook injuries, and a pair of sidecutters sharp enough to cut through a hook can be useful for removing embedded hooks. Learning how to handle aquatic animals that are likely to be encountered can also help with fisher safety (while also helping to maintain the welfare status of the fish). A well-stocked first-aid kit should always be carried.

With recreational fishing being an outdoor activity, there is potential for exposure to harmful ultraviolet radiation, and cover by clothing, hat and/or sunscreen is essential to reduce risk of skin cancer. In some regions, the correct choice of clothing is critical to either stay warm (e.g. ice fishing) or to minimize exposure to biting insects. Consumption of aquatic animals can also be a safety concern in some locations. For example, biotoxins such as ciguatera exist in some coastal marine regions in recreationally harvested species, which can cause gastrointestinal and neurological issues (Ting and Brown, 2001). Other toxic substances (heavy metals, polychlorinated biphenyls, etc.) can enter the aquatic food chain, so aquatic animal consumption advisories exist in some regions (Fiore *et al*., 1989). Research has revealed that many recreational fishers are unaware of fish consumption advisories or tend to ignore them, which is a significant concern (Ramos and Crain, 2001), particularly in urban fisheries. Of concern is the fact that such advisories do not exist in some countries, which does not mean that aquatic animals are safe to eat, but simply that research or monitoring are lacking.

6.2 SALE AND TRADE OF AQUATIC ANIMALS, PARTICULARLY FISH

A tenet of recreational fishing by definition is that fisheries protein is generally not sold or otherwise traded on domestic, export or black markets (Chapter 1; EIFAC, 2008; Arlinghaus and Cooke, 2009). Doing so bridges the divide between commercial, subsistence and recreational fishing. In many jurisdictions, it is thus illegal for recreational fishers to catch fish and then sell them following capture. In commercial fisheries, the selling of fish product is usually subjected to a variety of inspections and rules intended to protect consumer health or fisheries management, including stock assessment. Such a situation does not exist for fish that are captured by recreational fishers and then sold or traded. There is no general scientific issue questioning trade in recreational fish, e.g. to offset costs (e.g. Mike and Cowx, 1986), other than if allowed it could lead to the "industrialization" of recreational fishing and thus to overharvest. However, in many countries, there are legal and tax-based regulations supporting a clear demarcation between recreational and commercial, sale-oriented fishing. Moreover, any sale by recreational fishing will compete with commercial fisheries and thus disadvantage those fishers who are generating resources for livelihood. Therefore, the sale and trade of fish in recreational fisheries should be confined to those rare exceptions where national law on fisheries is still in development. Currently, there is no simple means of identifying whether a fish appearing in the market place was captured by the recreational sector or the commercial sector, which limits the ability to determine compliance with regulations in countries where the sale of fish by recreational fishers is already formally banned.

6.3 USE OF HARVESTED AQUATIC ANIMALS, PARTICULARLY FISH

When fishing, recreational fishers have the potential to voluntarily either release or harvest the aquatic animals that they capture. Only a few jurisdictions entirely ban the release of legal-sized fish (Arlinghaus, 2007). Although there is emphasis on voluntary total catch-and-release among a large segment of the more avid recreational fishing community in some countries such as the United States of America and the United Kingdom of Great Britain and Northern Ireland (Arlinghaus *et al*., 2007a), most recreational fishers worldwide, even the most specialized ones, practice selective harvest, evaluating their catch based on a variety of factors (e.g. fish size, species, food value, amount of food at home, conservation concerns, management regulations) to decide whether they will release or harvest an individual fish. Cultural and legal norms vary widely, such that in some regions voluntary release rates are very low while in other regions release rates are high and many approach 100 percent of captured fish in some specialized fisheries (Arlinghaus and Cooke, 2009). Recreational fishers, as commercial fishers, do have the potential to overharvest fish, leading to population declines (Post *et al*., 2002). As such, independent of whether harvest regulations exist, recreational fishers should harvest only as many aquatic animals are immediately needed. This is particularly sensible for a practice conducted during leisure time that supplements household diets with fish protein but is not essential for survival. Similarly, for ethical reasons, when a fish is harvested, it should be used efficiently and not wasted. Some jurisdictions have regulations to this effect. Similarly, for ethical and fisheries-conservation reasons, everything possible should be done to minimize bycatch mortality (Coggins *et al*., 2007). Fish that are to be kept should be handled and stored in such a way that preserves the quality of the flesh. When fish are cleaned, this should be done at a proper fish-cleaning station, and entrails or whole dead fish should not be left in the environment to cause odours, disease and attraction of potentially problematic wildlife.

6.4 TACKLE, GEAR AND FISHING TECHNIQUES

Recreational fishers have a large array of fishing gear and techniques to choose from. Indeed, although most people think of rod and line as the primary tool of recreational fishers, others use a spear, bow, rifle, trap, or gillnet (Arlinghaus and Cooke, 2009). Whatever gear and method is used, it is important to ensure that it is consistent with various regulatory requirements and also minimizes welfare impacts on individual fish (see below). Moreover, it is expected that in most recreational fisheries gear will be tended (e.g. checking nets and traps frequently, not using too many rods) in order to minimize its impact on non-target species. Indeed, in some developed countries, these concepts are incorporated into various regulatory instruments by for example limiting the number of rods an individual angler can use at a given time. Also relevant to fishing tackle is the potential for environmental pollution (see Section 6.5).

6.5 LITTER AND POLLUTION

Although issues of litter and pollution are relevant to managers (Table 6), these guidelines are directed mostly towards the fishers and the industry.

Similar to commercial fisheries, the recreational sector can generate litter and pollution, and many non-fishers associate recreational fishing with unpleasant littering of shorelines in heavily used fisheries. Litter from bait containers, tackle packaging, etc. has the potential to harm animals and is generally not compatible with natural environments and their aesthetic appeal. Areas frequented by recreational fishers can have more litter compared with low-intensity sites (e.g. O'Toole, Hanson and Cooke, 2009). Human-created waste that has deliberately or accidentally become afloat in a lake, sea, ocean or waterway is now an increasing global issue. Garbage in the ocean accumulates in swirling seas of debris, mainly because of an increase in non-biodegradable plastic. The largest of these garbage swills is in the North Pacific Ocean and is known as the Pacific Gyre, or The Great Garbage Patch. While this large accumulation is not much of an issue of recreational fisheries, fishers should be aware that bringing unnecessary plastic containers that are easily lost or washed away by water can contribute to this global issue. Anthropogenic debris along shorelines and in adjacent waterbodies can have a negative impact on the environment (Cryer, Corbett and Winterbotham, 1987; Radomski *et al*., 2006). Loss of fishing gear (e.g. line, lures, hooks, lead weights) can affect both the substratum in which it is deposited and the wildlife present in the area (Forbes, 1986; Lewin, Arlinghaus and Mehner, 2006). The ability of abandoned, lost or otherwise discarded fishing gear to continue to fish (often referred to as "ghost fishing") has detrimental impacts on fish stocks and potential impacts on endangered species and benthic environments (Macfadyen, Huntington and Cappell, 2009), although this issue is mainly confined to large-scale commercial fishing operations.

Although rarely quantified, fishing line and hooks can become entangled in a variety of wildlife species including birds, marine mammals, and turtles (e.g. Nemoz, Cadi and Thienpont, 2004). When line is ingested or when animals become entangled, it can result in injury or mortality (e.g. Franson *et al*., 2003). Cryer, Corbett and Winterbotham (1987) estimated that up to 13.7 m of fishing line was lost per recreational fisher on an annual basis, and Forbes (1986) found that the average length of line discarded around a small, coarse fishery lake was 56 cm. While most research on the effects of lost fishing gear has occurred in freshwater systems, fishing hooks and line also can damage sensitive sessile marine invertebrates (i.e. coral habitats) although the proportion of hook-and-line gear attributable to commercial versus recreational fishing is unknown. In the Florida Keys National Marine Sanctuary, lost hook-and-line fishing gear accounted for 87 percent of all fishing debris encountered and was responsible for 84 percent of impacts (i.e. tissue abrasion, partial individual mortality, colony mortality) to sponges and benthic cnidarians, albeit the overall damage caused by lost gear being minor at < 0.5 percent of total invertebrate density (Chiappone *et al*., 2005). In Asia, coral colonies entangled with fishing line were consistently in poorer condition, had higher rates of mortality, and larger proportions of dead or damaged coral (Yoshikawa and Asoh, 2004). Similar recreational fishing impacts were reported for cauliflower coral (*Pocillopora meandrina*) by Asoh *et al*. (2004).

Lead deposition can also pose a hazard to wildlife, especially to birds that ingest small stones and grit in order to aid digestion, although the effects tend to be quite localized. Lost lead fishing tackle is not readily released into aquatic and terrestrial systems under most environmental conditions, although under some circumstances pieces of lead can weather and erode, yielding free dissolved lead, precipitates, and chemical species that complex with inorganic and organic matter (reviewed in Rattner *et al.* [2008]). Lead has a very slow dissolution rate and a high stability in sediment, leading to ingestion by waterfowl, which subsequently suffer the effects of lead poisoning (Cryer *et al.*, 1987; Donaldson *et al.*, 2003; Scheuhammer *et al.*, 2003). Jacks, Bystroem and Johansson (2001) estimated that in Swedish Atlantic salmon (*Salmo salar*) fisheries, up to 200 tonnes of lead fishing sinkers are lost in river mouths. In littoral regions of the waters of South Wales, the United Kingdom of Great Britain and Northern Ireland, 24–190 sinkers/m^2 were found (Cryer, Corbett and Winterbotham, 1987). Lead poisoning in birds may result in lethal and sublethal effects, including decreases in body weight, reproductive stress, and anaemia (Scheuhammer and Norris, 1995; Kendall *et al.*, 1996). Educational efforts by governments and environmental organizations have been successful in promoting the use of alternatives to lead weights. In the long term, it is desirable to move away from lead fishing tackle, although it has been suggested that this should be driven by consumer demand and the industry rather than regulatory agencies (Rattner *et al.*, 2008).

An emerging issue is related to the accidental loss or intentional discarding of soft plastic lures into waterbodies. Research has revealed that soft plastic lures often swell in water and can be consumed by fish. The fish are unable to digest the lures, and these block the digestive tract and can lead to starvation (Danner, Chacko and Brautigam, 2009).

Any efforts to minimize the accidental or intentional deposition of litter would be beneficial both for the environment and for the public image of recreational fisheries. In some jurisdictions, angling clubs are highly active in cleaning up the environment and have regular meetings to remove voluntarily waste and litter left by others, both fishers and non-fishery users. In addition, there is a need for the development of more biodegradable and environmentally friendly products and packaging. Provision of refuse containers at popular fishing sites or access points could also assist with reducing the deposition of litter.

Combustion engines of boat traffic in rivers, lakes, and along the coastline, emit inorganic and organic compounds (mostly hydrocarbons) into the water and into the air near the surface, which can be toxic to aquatic animals. In marine ecosystems, such emissions can contribute to the surface microlayer, and the toxic substances on the air–water interface can significantly affect the survival and development of early life-history stages of marine fishes and other surface-dwelling organisms (Kocan *et al.*, 1987). Although it is not possible to quantify the effects of boat traffic linked exclusively to recreational fishing, it is likely to be substantial, and Lewin, Arlinghaus and Mehner (2006) conclude that there could be negative effects on the aquatic environment or fish stocks, with the effect dependent upon motor type, travelling speed, bottom structure of the ecosystem, and slope of the shoreline.

6.6 ENVIRONMENTAL AND WILDLIFE DISTURBANCE

Areas that experience high fishing effort may also be subjected to considerable shoreline changes as a result of human activity, which can lead to a cascade of deleterious changes in both the terrestrial and aquatic environments. Increased foot traffic from recreational fishers reaching access points could potentially lead to removal of vegetation (Mueller *et al*., 2003), loss of plant diversity (Ros *et al*., 2004), soil compaction (Andrés-Abellán *et al*., 2005), and erosion; factors that have rarely been studied in the context of recreational fishing (Cooke and Cowx, 2006; Lewin, Arlinghaus and Mehner, 2006) but are known in terms of hiking and camping impacts (Cole, 2004). In turn, as riparian vegetation is important in providing overhead cover and shade for fish, and also for anchoring soil, riparian disturbance may lead to increased shoreline erosion as well as decreased habitat complexity (Delong and Brusven, 1991; Schindler and Scheuerell, 2002). Soil compaction increases soil density and reduces its porosity (Lei, 2004), further contributing to erosional processes, surface runoff into nearby watersheds, and water quality degradation (Kozlowski, 1999). O'Toole, Hanson and Cooke (2009) found that the percentage of barren area and soil compaction were greater in areas of high level of activities by recreational fishers compared with areas that experienced relatively low recreational fishing. In addition, terrestrial and aquatic macrophyte density, height and diversity were lower in areas with high levels of recreational fishing.

Recreational fishing, although essentially a quiet and often solitary activity, can disturb wildlife. Commonly, waterfowl and coastal and wetland birds, many of which are now rare, are liable to disturbance if access to waters or shoreline is uncontrolled (Cryer *et al*., 1987). Most damage is done at nesting time when birds are disrupted or prevented from gaining access to their nests (Maitland, 1995). There are also many mammals commonly found associated with the rivers and lakes, most of which are shy and sensitive to disturbance, e.g. otters (*Lutra lutra*), and prefer secure places to rear their young (Jefferies, 1987). Closed seasons or protected areas are designed to minimize these impacts, but problems still persist, although it is clear that also other recreationists will induce similar impacts and that wildlife can also become accustomed to disturbances by humans without any measurable long-term impact. Recreational fishers wading in streams can also damage aquatic habitats. For example, Roberts and White (1992) reported that anglers wading on trout eggs and pre-emergent fry resulted in mortality as high as 96 percent. In addition, recreational-fisher activity can also affect the production of invertebrates that can serve as important food sources for fish. For example, Mueller *et al.* (2003) reported that dragonfly fauna were negatively affected by bank trampling caused by recreational fishing activity in a Hungarian river. This problem is exacerbated where recreational fishers modify bankside and littoral zone vegetation to gain access to fishing sites because its removal in lakes is known to affect predator–prey relationships, food webs and fish growth (Roth *et al.*, 2007). Intertidal fauna and turtle nests are probably also affected by recreational fishers driving to their fishing spots by the beach. Smith and Murray (2005) reported that recreational fisher foot traffic combined with the collection of mussels (*Mytilus californianus*) for bait may reduce cover for mussels and create mussel-free gaps.

The intense, but spatially restricted, nature of recreational fisheries can result in alteration of localized habitats from increased boat traffic, particularly in near-shore and inland environments (Bellan and Bellan-Santini, 2001). Sargent *et al.* (1995) documented that more than 6 percent of seagrass beds in Florida exhibited damage caused by propellers, representing some 70 000 ha. Although both commercial and recreational fishery boats can scar seagrass, 95 percent of boats registered in Florida are recreational (not that all engage in recreational fishing), and it is these boats that typically operate in shallow, near-shore environments. In addition to damage from propellers, anchors also have the potential to damage sensitive habitats such as reefs. Noise from recreational fishing vessels can, but ought not to (Klefoth, Kobler and Arlinghaus, 2011), disturb fish and affect their distribution and energy budget. In the Adriatic Sea, noise from the passage of outboard boat engines resulted in behavioural alterations in gobies (Gobiidae; Costantini and Spoto, 2002). In small inland waterways or near-shore areas, vessels can also generate waves that erode shorelines, suspend sediment, and may disturb fish, especially where movements are excessive and uncontrolled (Pygott, O'Hara and Eaton, 1990; Mosisch and Arthington, 1998; Wolter and Arlinghaus, 2003). This can lead to collapse of banks, loss of riparian vegetation, and, on a more subtle level, change in littoral water temperatures, which directly affects juvenile growth and recruitment (Hodgson and Eaton, 2000). When boats are trailered and moved between catchments or systems, there is also the potential for the introduction of non-native organisms such as invertebrates (e.g. zebra mussels) and aquatic macrophytes. Overall, however, these impacts will be localized and regionally confined and, thus, can be addressed through regulation or education.

6.7 ENVIRONMENTAL MONITORING AND REPORTING

Most natural-resource agencies lack sufficient staff to be able to provide the level of monitoring and surveillance needed to identify "real-time" problems with aquatic ecosystems. Given the number of recreational fishers, they serve as an important group of frontline observers when it comes to documenting aquatic animal kills, instances of pollution, and the presence of non-native species. Indeed, this is regarded as one of the benefits of recreational fishing. However, recreational fishers must not only observe but also report their findings to relevant authorities in a timely manner. A common limitation is that fishers or other members of the public are unsure as to how such information should be reported, thus there is a need for clear mechanisms to facilitate reporting. As key resource stakeholders, recreational fishers are well positioned to benefit from participation in environmental monitoring and reporting, and they do so effectively in many areas (Bate, 2001; Granek *et al*., 2008).

6.8 BAITING AND COLLECTION AND TRANSFER OF LIVE BAIT ORGANISMS

Use of live and organic baits in recreational fishing has the potential to generate a number of environmental problems. These range from the intentional deposition of various organic materials in the water to attract fish (which releases nutrient and potentially toxic substances [Rapp *et al*., 2008]) to the harvest of various vertebrates and invertebrates that are used for bait, as well as potential consequences induced by the animals being introduced into a new environment. In some recreational fisheries, ground-baiting (with cereals, maggots or other baits) or chumming, the process of distributing bait in water to attract fish, is common in both freshwater and marine environments. Where used excessively, it can lead to deterioration in water quality (Cryer and Edwards, 1987), increased phosphorus loading (Edwards and Fouracre, 1983; Niesar *et al*., 2004), and substantial reduction in benthic fauna (Cryer and Edwards, 1987). Comparatively, there is much more known about ground-baiting in freshwater systems than chumming in marine systems.

Collection of bait can also cause problems, and as the absolute number of recreational fishers worldwide increases, so will the demand for live bait. Some studies on marine coastal habitats have shown that digging for bait can influence the littoral fauna (Beukema, 1995) as well as the abundance and size structure of harvested benthic organisms (e.g. Cryer *et al.*, 1987). Some of the harvested bait species play an important role in structuring the bottom communities, such that there can be systems-level consequences (Wynberg and Branch, 1997; Shepherd and Boates, 1999). The bait digging or pumping and the associated trampling can cause considerable disturbance to the sediment and affect sensitive taxa (Skilleter *et al.*, 2005). Litvak and Mandrak (1993) reviewed the baitfish industry in Canada and the United States of America and conservatively estimated it to be worth US$1 billion annually. The authors identified a number of problems experienced by the systems where baitfish harvest occurred. In Ontario, Canada, they revealed that 15 baitfish species were listed as vulnerable or threatened. Also of concern can be the disturbance of habitats and interaction with non-target species during collection of baitfish. Some jurisdictions restrict gear types and seasons in order to minimize impacts of bait collection on aquatic ecosystems.

A significant concern associated with use of live bait is the potential for the introduction of non-native species (Johnson, Arlinghaus and Martinez, 2009). A survey of the characteristics of the bait industry in 1992 in six north-central states in the United States of America revealed that all retail dealers purchased bait, and 16 percent reported harvesting some bait (Meroneka, Copesa and Coble, 1997). Most bait came from within the state of sale, but 15 percent of retail dealers and 34 percent of wholesale dealers reported purchasing bait outside the state. In another study (Ludwig and Leitch, 1996), a survey of bait vendors, bait samples from retail locations, vendor interviews, a creel survey, and a literature review, were used to estimate the potential for recreational fishers in North Dakota and Minnesota (in the United States of America) to contribute to the dispersal of non-indigenous fish from the Mississippi River basin into the Hudson Bay basin. They estimated that the probability of a single recreational fisher on a single fishing day in the Hudson Bay basin releasing live bait from the Mississippi River basin to be 1.2/100. The authors suggest that drastic policy measures would have to be undertaken to reduce recreational fishers' potential for contributing to the dispersal of aquatic species. Litvak and Mandrak (1993) examined bait dealer tanks in Ontario, Canada, and found that 18 of the 28 fish species found in the tanks were potentially used outside their known ranges. Freshwater crayfish are also believed to be introduced by recreational fishers. In a 2008 survey of United States and Canadian fisheries agencies, 49 percent of respondents reported aquatic resource problems that were believed to have been caused by bait-bucket introductions of alien crayfishes (DiStefano, Litvan and Horner, 2009). Visits to bait shops revealed sales of illegal and invasive alien crayfishes by bait shop proprietors who could not identify the species they were selling. Non-native earthworm populations are often found near lakes, and it has been suggested that recreational fishers discarding unwanted bait are a vector for the establishment of new populations. It was determined that all the bait stores surveyed sold known invasive species, and 44 percent of recreational fishers who purchase bait dispose of unwanted bait on land or in trash, thus suggesting that the bait trade and disposal of worms is a major source of earthworm introductions (Keller *et al*., 2007). Font and Lloret (2011) studied recreational shore fishing along the coast of the marine reserve of Cap de Creus (northwest Mediterranean) and determined that 43 percent of the baits used by the shore recreational fishers were live, non-native species (mostly polychaetes), emphasizing the increasing environmental risks arising from the use of exotic marine baits, which constitute a potential and unregulated vector of introduction of non-native species in the Mediterranean. Other introductions occur indirectly through recreational fisher activities, for example, the transfer of aquatic zooplankton through attachment to fishing lines (Jacobs and MacIsaac, 2007), the transfer of algae through attachment to waders, or fishes when released from bait buckets (see below for details).

In recognition of the problems identified above, particularly with respect to bait-bucket transfers, regulatory agencies, particularly in North America, have enacted regulations to limit the season and quantity of baitfish harvest more effectively, to limit species that can be harvested, to minimize interstate and interwatershed transport, and to require that recreational fishers do not release bait alive. These regulatory actions have been coupled with outreach and education activities that have targeted bait harvesters, dealers and recreational fishers in order to maximize compliance.

6.9 ILLEGAL RELEASE AND TRANSFER OF FISH

Similar to the above undesirable transfer of non-teleost organisms, the introduction or transfer of non-native fish species or genotypes and associated pathogens by recreational fishers has the potential to alter fundamentally the structure and function of recipient fish populations, and potentially entire aquatic ecosystems (Cowx, 1994; Lewin, McPhee and Arlinghaus, 2008; Johnson, Arlinghaus and Martinez, 2009). While the issue of management-decided introductions has been covered in Chapter 5, the issue extends to each individual recreational fisher who transfers fish among waterbodies in the process of fishing, as bait or intentionally, but usually illegally, to establish populations of desired species. This can have devastating impacts on local fish communities, e.g. the establishment of European wels catfish (*Silurus glanis*) in Spain was driven by an angler introducing the species to establish it for recreational exploitation. Many more examples of illegal transfer of fish by recreational fishers exist worldwide (Cambray, 2003). Although authorized stocking of sport and forage fishes is a common reason for fish introductions, the unauthorized illegal introduction by individual fishers is now a major reason for the spread of non-native fishes (Rahel, 2004). Mechanisms to prevent illegal transfer and introductions of fish include a combination of education as well as the development and strict enforcement of regulations (with large penalties in keeping with the severity of the offence).

6.10 FISH WELFARE IN RELATION TO CAPTURE, RETENTION, KILL AND CATCH-AND-RELEASE

A contentious issue in some countries is the well-being (or welfare) of individual fish and how this welfare might be compromised in the process of recreational fishing with various types of gear (Huntingford *et al*., 2006; Arlinghaus *et al*., 2007b). The concept of fish welfare is relevant independent of the question of whether fish can suffer or feel pain in the process of being captured by recreational fishers because fish will experience a stress reaction to any form of capture, fight and handling (Rose, 2007). Therefore, from a pragmatic fish welfare perspective that considers recreational fishing to be a legitimate human activity (Arlinghaus *et al*., 2009a), 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 and Sneddon, 2007).

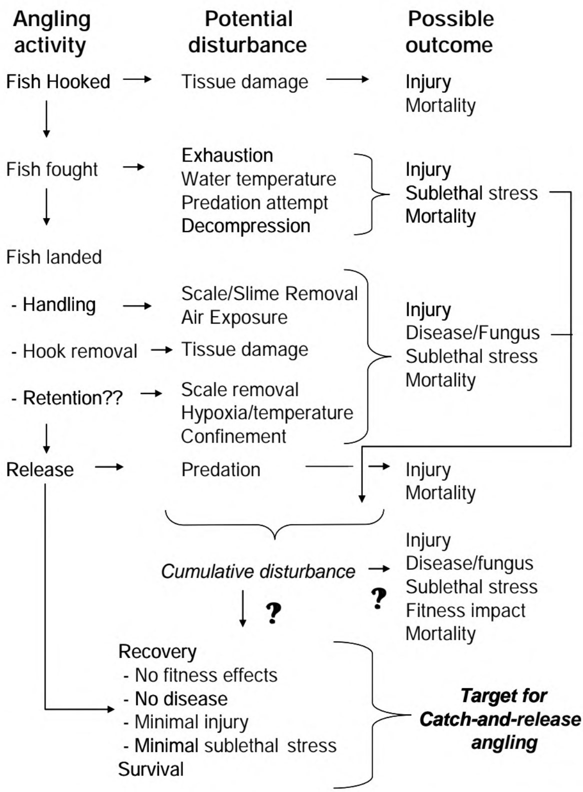
Fish welfare issues always deal with the individual fish, not with population impacts (Arlinghaus *et al*., 2007b, 2009a), and attempts should be made to maximize chances of survival if fish are released, or to minimize discomfort prior to and during slaughtering of the fish. The subsequent discussion focuses on fish captured by rod and line (i.e. angled) because angling is the most common form of recreational fishing. Although angling is often the least stressful form of catching a fish compared with other gear types, there are still fish welfare issues that demand consideration. Other gear types used by recreational fishers offer little scope for improvement in fish welfare because the fish is usually mortally wounded (e.g. spear fishing) or dead at harvest (e.g. gillnetting) and thus are unlikely to be released. Best practices for non-angling gear types relate primarily to when it is appropriate to use them, the need to abide by local regulations, and how to kill fish in a responsible manner.

Guidelines related to these aspects thus apply generally, while all others are confined to angling.

By its nature, hooking or otherwise catching a fish with recreational fishing gear necessarily causes some level of stress response by, and some injury to, an individual fish that cannot be avoided (Cooke and Sneddon, 2007). Although most stress induced by angling can be compensated for by the fish during its recovery, the entire process from hooking to when the fish is released offers opportunities for angler behaviour to increase the chance that a released fish recovers quickly with no fitness impairment (Figure 15). Any judgement as to how strongly fishing practices, including holding fish in keepnets or similar, influence the welfare of individual fish is contingent on how fish welfare is defined and what a given stakeholder group tolerates. Appropriate behaviour of recreational fishers in all areas of a catch event (Figure 15) is critical for all because it reflects a high moral standard of recreational fishers towards their quarry. This benefits the image of recreational fishers, increases fish flesh quality (e.g. when fish are rapidly killed after capture), and increases recovery and survival of fish that are released, helping maintain fish populations by fish being unharmed and resuming normal behaviour with no fitness impacts. Thus, although consideration of fish welfare is sometimes perceived as a threat by some recreational fishers and fisheries managers, accounting for it is common sense, ultimately benefiting individual fish, fishers and potentially the entire fish population and fishery (Cooke and Sneddon, 2007). There is little argument against engaging in behaviour that minimizes the stress response of fish to fishing provided that fish welfare arguments are not misused as moral arguments against fishing, as happens in certain arenas (Arlinghaus *et al.*, 2009a).

Defining fish welfare in a manner that is objective, useful and not threatening to recreational fisheries on moral grounds has proved elusive and has generated considerable debate. In the EIFAC Code of Practice for Recreational Fisheries (EIFAC, 2008) a feelings-based approach to fish welfare that focuses on currently immeasurable "unpleasant mental states" of fish (Huntingford *et al.*, 2006) was found to be unsuitable based on arguments presented in detail in Arlinghaus *et al.* (2007b, 2009a). As a consequence, a function-based definition of fish welfare based on objectively measurable indicators of impaired fish welfare (e.g. physiology, behaviour) is preferred (Arlinghaus *et al.* 2007b, 2009a) and is thus adopted in this document. Consequently, "good welfare means an individual fish is in good health, with its biological systems functioning properly and with no impairment of fitness" (EIFAC, 2008). Against this, it can be judged how recreational fishing may improve fish welfare, acknowledging that some impacts need to be accepted (e.g. hooking a fish).

Figure 15
Overview of various sources of impacts on fish in the context of catch-and-release angling



Notes: Welfare is not explicitly listed as an impact as all of the potential impacts listed can be considered to be related to fish welfare. In the context of "potential disturbance", factors such as temperature and hypoxia are moderating factors. Although the focus is on fish caught using rod and line, this framework is also generally relevant to fish caught by other recreational gear types.

Source: From Arlinghaus *et al.* (2007a).

A number of techniques and handling practices promote improved welfare of recreationally captured fish (Arlinghaus *et al.*, 2007a, 2007b), whereas others potentially impair fish welfare. Accordingly, the recommendations for best practices that follow address fisher behaviour and techniques for minimizing fish welfare impairment. Most recreational fishers are interested in adopting gear choices and behaviour that facilitate survival of fish that are to be released or that maintain flesh quality in fish that are to be harvested, thus, there is ample scope to combine outreach, education and formal regulation. An inherent challenge in attempting to generate best practices for maintaining the welfare status of caught fish is the fact that there is substantial variation in how different species and even stocks respond to capture and handling.

Cooke and Suski (2005) provided an extensive overview of this challenge in the context of catch-and-release (mandatory or voluntary) and essentially asked the question as to the extent to which generalizations can be developed that apply across a broad range of recreational fisheries. Substantial interspecific variation in behaviour, physiology, ecology and morphology exist within fish and other aquatic organisms. Similarly, species of fish vary in terms of sensitivity to different stressors, including those associated with catch-and-release (Muoneke and Childress, 1994). Interestingly, similar levels of variation in response to catch-and-release are also evident among congenerics. Finally, within species, some researchers have revealed that fish respond differently to stressors (and experience differential release mortality) at different life-history stages (Brobbel *et al.*, 1995), among stocks (Nelson, Tang and Boutilier, 1994), by fish size (within the same species [Meals and Miranda, 1994]) and by sex (Hanson *et al.*, 2008). These examples illustrate how a guideline that is appropriate for one species will not always be appropriate for others and, indeed, what is appropriate for an individual species in one location or at a particular life stage, may also be inappropriate for the same species at other locations/times. The generalities that are provided in this document represent the extent to which reliance can be placed on deriving generic information from the catch-and-release studies conducted to date and applying it to other fish and fisheries. The ultimate goal for research-based recommendation, tailored locally and regionally, is to develop and refine the general guidelines presented below for the successful release of most fish, and then develop a suite of specific guidelines for individual species or types of fisheries (e.g. tournaments, deep-water fishes). Those interested in this topic are directed to a number of syntheses including Muoneke and Childress (1991), Bartholomew and Bohnsack (2005), Cooke and Suski (2005), Cooke and Sneddon (2007), Cooke and Wilde (2007), Arlinghaus *et al.* (2007a), and Hühn and Arlinghaus (2011).

Table 11 summarizes the scientific basis and context for the generic guidelines. It focuses on catch-and-release as this is a standard practice in most recreational fisheries, either being a by-product of harvest regulations or due to

Table 11
Factors influencing fish welfare (including stress, injury and survival) during catch-and-release recreational fishing

Factors	Summary of scientific literature	Generalization
Gear		
Barbed vs barbless hook	– Use of barbless hooks may reduce the amount of time required to remove the hook (Cooke *et al.*, 2001; Meka, 2004), which may reduce mortality (Bartholomew and Bohnsack, 2005; see Schill and Scarpella [1997] for a study where the higher survival was not reported) – Use of barbless hooks reduces tissue damage at the point of hook entry (e.g. Cooke *et al.*, 2001; Meka, 2004)	– Barbless hooks preferred over barbed hooks in some situations
J hook vs circle hook	– For J hooks, the point is parallel to the shank whereas for circle hooks the point is typically at least at a 45° angle to the shank – Circle hooks favour shallow hooking and relatively few instances of deep hooking, and mortality rates are on average 50 percent less when circle hooks are used (Cooke and Suski, 2004) – Small differences in circle hook configuration (e.g. degree of offset) can obfuscate the benefits of circle hooks (Prince, Ortiz and Venizelos, 2002)	– When fishing passively with organic baits, circle hooks are favourable because of the reduced instances of deep hooking, but landing rates might be negatively affected
Single vs treble hook	– Muoneke and Childress (1994) reported that single hooks tend to be more deeply ingested than treble hooks; deep hooking is the single most important factor of mortality after release – In a meta-analysis of salmonids, Taylor and White (1992) failed to demonstrate a difference in mortality between these two hook types, and Hühn and Arlinghaus (2011) did not find a relationship between hook type and mortality – Effects will finally depend on how mouth morphology, fishing technique and hook size interact to determine shallow hooking	– No general recommendation possible – Does not appear to be an important factor aside from the fact that one hook point theoretically should be easier to remove and result in less injury

Table 11 (Cont.)

Factors	**Summary of scientific literature**	**Generalization**
Hook size	– Among conventional hook types, the relationship between hook size, fish size, and hook performance has varied widely among studies (Muoneke and Childress, 1994) – Larger hooks catch larger fish (Alós *et al.*, 2008) – The larger the hook, the greater the injury (Rapp, Cooke and Arlinghaus, 2008)	– Smaller hook sizes preferred, unless they result in deep hooking – Very fishery-specific
Bait/lure type	– Artificial lures or flies tend to hook shallower with less opportunity for damage to vital organs (Muoneke and Childress, 1994) – Organic baits, including live bait, are typically ingested deeper than artificial lures, resulting in more time required to remove hooks and a greater potential for mortality (Siewert and Cave, 1990; Cooke *et al.*, 2001; Arlinghaus *et al.*, 2008) – Studies of flies vs lures and baits have been consistent in that flies tend to be less injurious and have a lower chance of causing mortality (Meka, 2004)	– Lures and flies tend to have less likelihood than organic baits of deep hooking
Practices		
Fighting time	– The duration of an actual angling event experienced by a fish correlates positively with the magnitude of physiological disturbance (Gustaveson, Wydowski and Wedemeyer, 1991; Kieffer *et al.*, 1995) – Meka (2004) determined that experienced anglers took longer to land fish than novices because they tended to capture larger individuals and thus factors such as fish size and angler experience can affect the duration of angling and subsequent physiological responses (Meka and McCormick, 2005)	– Anglers should attempt to land fish as rapidly as possible to minimize the duration of exercise and the concomitant physiological disturbances; in addition, fishing gear (e.g. line, rods) should match the size of targeted fish
Landing methods	– Use of landing nets can cause scale loss and other injuries, but this seems to depend on the species and this issue has been poorly studied – In general, more abrasive net materials tend to cause more damage than softer knotless or rubber materials (Barthel *et al.*, 2003) – Anything that reduces slime loss or injury to the fish is useful such as using wet hands – Lip-gripping devices work well on some species but on others they can cause severe injury (Danylchuk *et al.*, 2008)	– When landing fish it is preferable to minimize dermal injury by using wet hands and if a net is required, it should be made of a fish-friendly material (e.g. rubber nets)

Table 11 (Cont.)

Factors	Summary of scientific literature	Generalization
Air exposure	– Air exposure occurs after capture when anglers remove hooks, weigh and measure fish, and/or hold fish for photographs – During exposure to air, gill lamellae collapse leading to adhesion of the gill filaments (Boutilier, 1990), which causes several major physiological changes – Fish exposed to air typically experience greater acid/base disturbance than those fish that were exercised but not exposed to air (Ferguson and Tufts, 1992) – Extended exposure to air eventually results in permanent tissue damage beyond some timing threshold – Mortality rates can also be increased by exposing fish to air (Ferguson and Tufts, 1992), but many species are resilient to even extended air exposure (Arlinghaus *et al.*, 2009b)	– Whenever possible, anglers should eliminate air exposure by handling fish that are to be released in the water
Hook removal	– Survival rates are higher for deeply hooked fish when the line is cut and the hook left in place than when the hook is removed (e.g. Jordan and Woodward, 1994) – There are still negative consequences of leaving hooks in place (Borucinska, Martin and Skomal, 2001; Borucinska *et al.*, 2002), so the optimal strategy is to avoid deep hooking	– It is usually better to cut the line on deeply hooked fish
Retention	– Catch-and-release angling sometimes involves the retention of fish for a period (usually hours) prior to release as anglers assess whether they will harvest individuals or in competitive events when fish are retained for later enumeration at a weigh-in – Studies suggest that retention is stressful to fish, but if provided with adequate water quality, mortality and sublethal disturbances are minimized (reviewed in Cooke and Wilde, 2007) – Artificially cooling water or supersaturating holding environments with oxygen is counterproductive (Suski *et al.*, 2006) – Some forms of retention including wire fish baskets and stringers cause severe injuries and should not be used (Cooke and Hogle, 2000) – Nylon keepnets seem to cause little injury and fish tend to recover during retention (Pottinger, 1997, 1998)	– If fish are to be retained it should be for as short a period as possible and should be in sufficient water that is similar to ambient conditions – Retention gear should not be abrasive to mucus

Table 11 (Cont.)

Factors	Summary of scientific literature	Generalization
Environment		
Water temperature	– In species for which data exist across a gradient of water temperatures, angling at extreme water temperatures (especially high) is correlated with increased physiological disturbances and the probability of mortality (reviewed in Cooke and Suski, 2005) – Catch-and-release angling at extremely cold water temperatures has also been suggested as potentially challenging to fish but there is little research on this topic	– Caution should be exercised when angling for fish during very warm water conditions – Where possible, other stressors (e.g. air exposure, fight duration) should then be minimized
Depth and barotrauma	– When brought to the surface rapidly, the gasses in swimbladders particularly of physoclistous fish rapidly expand to the point that the fish are unable to achieve neutral buoyancy, maintain equilibrium, and may even have their stomachs protruding from their mouths or anus (because of the expanded swimbladder pushing out the viscera; Burns and Restrepo, 2002) – Different species respond to capture at depth differently and each also has its own threshold regarding which depths are problematic. Water depth of several metres may cause problems in some species (e.g. walleye) – One obvious, but draconian, option for anglers to avoid these problems is to not fish in deep waters – An alternative solution can involve anglers venting the swimbladder with a needle to release the gas and enable the fish to swim back to depth (Keniry *et al.*, 1996; Collins *et al.*, 1999; Kerr, 2001, Burns and Restrepo, 2002); however, some research has revealed that venting does not reduce mortality (Wilde, 2009)	– When fish are observed to be exhibiting barotraumas, it is prudent to relocate to shallower habitats and not release fish – There are a number of tools available to anglers to recompress fish with barotraumas although they should only be used after training in proper techniques and if legally allowed
Predators	– The habitat where fish are released influences exposure to predators and can result in mortality during the fight and after release (e.g. Cooke and Philipp, 2004) – Attempts to release fish closer to cover failed to reduce mortality in one study (Danylchuk *et al.*, 2007) – Fish that lose equilibrium have been shown to be more likely to be attacked by predators post-release (Danylchuk *et al.*, 2007)	– If predators are abundant it may be prudent to relocate to other locations and release the fish there

Notes: The factors presented in terms of gear, practices and environment focus largely on fish captured by rod and line (i.e. angled). Release may involve undersized (mandatory release) or voluntarily released fish.

voluntary choice. In addition, some information on holding effects is included as this practice is also common in many recreational fisheries, either in keep-nets, live-wells or other devices. Figure 16 shows a "how to" schematic for a fish-friendly catch-and-release event.

In many situations, the fish is not released but harvested, especially when using gear such as nets or spears. For angled fish, flesh quality is improved if the fight time is kept to a minimum and the fish is rapidly killed after capture, if possible prior to dehooking. Davie and Kopf (2006) summarized the most important aspects related to killing fish rapidly, which is a legal norm in some countries, e.g. Germany. In particular, a fish that is to be retained should be killed rapidly, e.g. by a sharp blow on the head (percussive stunning) or with a sharpened object such as a pick (i.e. called Iki jime in Japan), and then bleed out the fish. Such a rapid kill will also reduce the stress level of the fish and increase flesh quality (Arlinghaus *et al.*, 2009a). The ability in recreational fishing to take care of individual captured fish, also in the process of rapid kill, represents a major difference to commercial fisheries (e.g. fish dying slowly due to hypoxia after trawling or in gillnets) and allows recreational fisheries to reduce the amount of harm induced to the absolute minimum. Therefore, recreational fishers should be educated in behaviour that makes people engage in rapid kill procedures rather than letting fish suffocate slowly. Globally, the best practices for killing fish may differ by region; hence, managers and policy-makers should take existing traditions into consideration while making country/regional guidelines, discussing the issues with local and/or regional stakeholders.

Figure 16
Overview of generalized best practices for catch-and-release of fish by rod and line

Selection of Gear

- Use hook and bait/lure types that encourage shallow hooking and facilitate easy hook removal
- Select gear (rods, line, drag settings) appropriate to the size of fish targeted
- Use gears that are legally required to conform with regulations

Angling Event and Landing

- Minimize fight duration
- When the fish is in a state where it can be handled, use wet hands or a fish-friendly net to land fish

Hook Removal and Handling

- Keep fish in water during hook removal and handling
- Use pliers, hemostats or other unhooking device to gently but rapidly remove hook(s)
- If fish is deeply hooked, cut the line
- The admiration period and photographs should be kept to a minimum and should avoid air exposure

Revival and Release

- Hold fish in the water and face it into the current or if no current move fish forward through the water in a figure-eight pattern
- Be alert for predators
- Evaluate condition of fish (e.g., was it exhausted and unable to maintain equilibrium) and adjust behaviour accordingly for subsequent captures to reduce stress
- Release fish when it is able to swim away with vigour

7. INFORMATION, KNOWLEDGE SHARING AND RESEARCH

Information, knowledge sharing and research are essential elements of fisheries management independent of fishing sector. Particularly relevant is the idea of education and capacity building within the recreational fishing community and among recreational fisheries managers so as to be prepared to solve past and future sustainability issues. This is particularly important given the many community-based management systems that exist worldwide in recreational fisheries, where expert assistance by trained personnel is limited (e.g. central Europe [Arlinghaus, 2006a]). Moving such systems towards sustainability depends on aquatic stewardship by stakeholders and solid networks of knowledge. This requires good information sharing within networks of fishing clubs and recreational fisheries, and between agencies and fishing bodies locally and regionally. This section deals first with information and knowledge sharing and then identifies research needs for recreational fisheries.

7.1 INFORMATION AND KNOWLEDGE SHARING

Information must be exchanged and shared among various actors internal and external to the recreational fishing sector in order to reduce conflict, promote sustainable fishing practices and obtain the interdisciplinary information needed to assess adequately the state of fisheries and implement strategies intended to maintain or rehabilitate them. Indeed, many of the problems facing fisheries are multisectoral and problem solving necessitates formal and informal alliances and coalitions. Moreover, it is becoming increasingly important for resource managers to involve most, if not all, stakeholders in discussions about management policies as a way to solicit constituency support, to facilitate rule compliance and to conserve and manage the resource base effectively (Krueger and Decker, 1999; Plummer and Fitzgibbon, 2004). Unlike in many fields of scientific endeavour, stakeholder and traditional knowledge (STK) is an essential source of information and regarded as relevant for both recreational fisheries research and management (Fraser *et al*., 2006). Nonetheless, there are still challenges with respect to how to balance different forms of information. In particular, fisheries managers face complex situations in which policy may be viewed and accepted differently by multiple stakeholder groups, such as recreational and commercial fishers, fisheries researchers, and the local community itself. Each group can have contrasting attitudes and opinions regarding the accepted future use and development of aquatic resources. The resulting disconnects among the stakeholder groups can lead to inappropriate implementation of management activities (Miranda and Frese, 1991) and lack of compliance with policy (and in some cases deceit [Sullivan, 2002]), and can be perceived as weaknesses within the sector, leaving it vulnerable to attack from outside groups (e.g. the animal rights movement, Arlinghaus *et al.*, 2007a, 2007b). Conversely, information sharing and communication within and among stakeholder groups has the potential to further understanding and alleviate conflict. In order to incorporate stakeholder information effectively, it is essential to understand the biases associated with different information sources and their reliability. 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 STK and local experiences.

Information and knowledge sharing among various stakeholders in fisheries is covered in detail in the FAO Technical Guidelines on Information and Knowledge Sharing (FAO, 2009) and the "Strategy for improving information on status and trends of capture fisheries" (approved by the FAO Committee on Fisheries). These technical guidelines were produced in response to the recognition that a lack of essential information is often major constraint to the implementation of responsible fisheries. Without the essential information upon which to pursue research, make informed decisions and benefit from the lessons learned by stakeholders in similar situations, implementation of the documents such as the Code or the present Guidelines will continue to be constrained. At the international level, the FAO guidelines (FAO, 2009) aim to foster a better understanding of the issues involved in all types of fisheries in order to ensure that stakeholders obtain the essential information they need. The focus is on six key components of information exchange that are highly relevant to the recreational fisheries sector, namely: sustainability of a fishery, best scientific evidence on current topics, participation and cooperation, objectivity and transparency, timeliness, and flexibility.

The technical guidelines on recreational fisheries presented here will help to ensure that stakeholders have access to the general information needed to achieve responsible and sustainable recreational fisheries. However, it is acknowledged that more specific local and regional advice is also needed, e.g. on species of interest in a given locality. When FAO developed the initial guidelines on information and knowledge sharing, they were not intended to be specific to the recreational sector but they are equally relevant here and include:

- Capacity building in economies in transition and developing countries – Recreational fisheries occur around the globe and there is a need for capacity building in developing countries to enable fisheries managers to ensure sustainable recreational fisheries and the interaction of subsistence, commercial and a growing recreational fishing sector. Moreover, as developing countries become more industrialized and/or recognize the importance of recreational fisheries, it is expected that recreational fishing activity will increase, further emphasizing the need for capacity within the management community. Non-governmental organizations, government agencies in developed countries and international bodies (e.g. FAO) have the potential to play a role in developing capacity for recreational fisheries assessment and management in the developing world.
- Development of long-term stable and peer-reviewed arrangements for the provision and exchange of information within and among countries – There are few formal mechanisms for the global dissemination and exchange of recreational fisheries information. Most information sharing from government and the scientific community is based on the scientific literature and is largely restricted to developed countries. Angling-related NGOs have the potential to play an important role in establishing mechanisms for the exchange of information and these arrangements exist in a number of countries (e.g. Lake Taupo, New Zealand, has a time series of angler-collected data on salmonids since the 1890s). The angling media is also a powerful mechanism and it already operates online, television and print sources, some of which are particularly good at generating dialogue between the recreational fishers and the scientific and management community.
- Sustaining data collection and global information systems – As with any data collection and information system, it is essential that mechanisms and safeguards exist to ensure that data are available and archived for use. There is a pertinent information need within countries to invest into routine data collection systems for recreational fisheries (Beard *et al*., 2011). However, there is not a culture or history of considering recreational fisheries data to be as important

as commercial fishing data. There is a need for greater emphasis on both the collection of recreational fisheries data and their sharing with bodies such as FAO, and appropriate strategies for collecting reliable data need to be explored.

- Expanding the scope of information on status and trends of regional or national fisheries, including the need to incorporate ecosystem considerations into fisheries management – There is scope for increasing the monitoring and reporting on the status and trends in recreational fisheries. Also needed are success stories illustrating how ecosystem management can be operationalized when most harvest regulations tend to focus on single species. One issue that needs to be resolved is how to address the language barriers that typically exist in local and regional case studies.
- Greater participation in working groups in assessing the status and trends of fisheries and greater international visibility of recreational fisheries – Working group models are used to address recreational fishing issues, and they can play a strong role by involving multiple stakeholders, particularly for larger systems adjacent to multiple countries or in marine environments. The International Union for Conservation of Nature has recently used a working group model to explore the status of several key recreational species (i.e. bonefish and tarpon) and, in some jurisdictions (particularly North America), regional fisheries management councils exist that are able to seek stakeholder perspectives on management priorities and strategies related to the recreational sector. In Ontario, Canada, the provincial natural resource agency operates more than 20 such councils (called Fisheries Management Zone Councils). They include 12–15 members of the community such as fishing guides, recreational fishers, tourist operators, bait fishers, commercial fishers and academics. The councils provide advice and input to the Government on management priorities and strategies. Although only initiated in 2007, the councils have already successfully addressed a number of controversial issues related to recreational fisheries. Also in North America, the Great Lakes Fishery Commission represents a similar entity where stakeholders play an important role but do not usurp the authority of the management agency. Similar multistakeholder advisory groups exist elsewhere (although not at that scale). Where they do not exist, their implementation would be a useful means of engaging

recreational fishers in fisheries management. It is important to accept the integration of recreational fisheries into commissions that are more traditionally oriented towards commercial fisheries and where coexploitation occurs (e.g. Regional Fisheries Management Councils of the European Union).

Another major challenge to be overcome is the exchange and translation of knowledge into action nationally or regionally. It is well documented that transitions in recreational fisher behaviour can often be facilitated through education, outreach and awareness (Arlinghaus *et al.*, 2007b). As such, effective communication is critical for regulatory agencies or NGOs to encourage behavioural change (Gray and Jordan, 2010). However, in many areas of the world, there is a disconnection between science, management and practitioners. In addition, there are different rewards systems, some of which reduce communication. For example, university-based scientists receive reward from peer-reviewed publications and may have little incentive or resources to communicate and share knowledge in other formats to be of use for management. Moreover, the science capacity in many areas is not enough to fulfil the information needs to tackle recreational fisheries management issues, not least because explosive development of recreational fisheries is relatively recent in some countries (Beard *et al*., 2011). However, even in this situation, recreational fisheries research results or other forms of knowledge (e.g. practical experiences) should be shared with stakeholders using clear language and concise communication approaches that match the needs of the stakeholders. Equally relevant is knowledge sharing among agencies within countries, among countries, among fishing clubs and among anglers because each local experience can be relevant in solving pertinent issues elsewhere. The fishing media and outreach by fisheries agencies or NGOs (e.g. angler associations) play a critical role in that they have the ability to disseminate information effectively to a variety of stakeholders, but new forms and formats of across-agency and country communication would be highly beneficial. Currently, there are major challenges even for the developed nations. For example, international travel is an issue for agency employees in many countries, such that information sharing on recreational fisheries in different countries or states is severely curtailed. This is a major impediment to progress.

Thus, determining the best way to use existing communication sources to disseminate information to recreational fishers remains a challenge in terms of infrastructure, unifying frameworks and language barriers. Some media outlets such as In-Fisherman Inc. in the United States of America employ editors with scientific training and also routinely solicit and/or co-author content from fisheries scientists and summarize findings from relevant peer-reviewed sources. Newer forms of knowledge dissemination are offered through the Internet and social networking sites. Angling-related websites are common and there are a variety of discussion boards, blogs and social network pages related to recreational fisheries and responsible fishing. Most such sites are operated independent of governments (either by individuals, NGOs or fishing clubs); hence, while the Internet is a solution it is also a problem because much information is no longer subjected to peer review and may cause confusion and conflict.

One mechanism for international exchange is attendance of the World Recreational Fishing Conferences, but these tend to be tailored towards science, and country-level managers often have issues with travel to international meetings. Generally, there is too little international exchange of knowledge in recreational fisheries, despite sometimes the same species being managed (e.g. pike, *Esox lucius*, in both North America and Europe), and the exchange is even smaller when it comes to management–science interfaces. A global communication platform on the Internet to improve information on recreational fisheries would be highly advisable, but it needs funding to be functional. In the long term, objective communication of both the socio-economic and ecological benefits, as well as the potentially negative impacts, of recreational fisheries practices would strengthen the sector and encourage critical debate to further benefit the fish, the environment and those that enjoy recreational fishing or are dependent on its associated commercial activities.

Some jurisdictions have developed recreational fisher education programmes that are institutionalized as part of the licensing process (Andrews, 2007). In others, such as Germany, anglers need to take a 30hour course in order to obtain a licence (Arlinghaus, 2007). However, more commonly, the education of recreational fishers (e.g. regarding fish welfare-friendly angling practices) is done via outreach by government agencies, recreational fishing associations and clubs (Siemer and Knuth, 2001), or by word of mouth within fisher groups. These programmes and practices also generate awareness of recreational fishing and help to recruit new fishers (particularly young people and women).

In some jurisdictions, there is increasing interest in promoting awareness and educating recreational fishers rather than imposing regulations, but how best to do this is a major research need. Recreational fishers have diverse preferences and attitudes (Arlinghaus, 2006b); hence, understanding how and where fishers and stakeholders acquire and use information about responsible recreational fishing will play a central role in crafting effective conservation and management strategies.

7.2 RESEARCH

Contemporary models of fisheries management require information from a variety of sources (e.g. STK, research, monitoring and stock assessment) to support decision-making (see Chapters 3 and 5). Effective management of recreational fisheries, whether or not jointly exploited by other sectors, requires an understanding of the features and dynamics of targeted fish stocks and the associated social-ecological system dynamics (Arlinghaus, Johnson and Wolter, 2008a). Currently, recreational fisheries research is either absent or underdeveloped, and existing approaches are mainly biological in orientation, somewhat limiting the usefulness of research. In some cases, research on recreational fisheries has adopted a multidisciplinary, interdisciplinary and transdisciplinary approach, recognizing that incorporation of the social and economic sciences is needed in order to embrace fully the dynamics and features characterizing recreational fisheries as social-ecological systems (e.g. Massey, Newbold and Gentner, 2006; Hunt *et al*., 2011). In short, if recreational fisheries research is 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). Nonetheless, studies of biological or social science phenomena in isolation can still provide essential building blocks for more integrated understanding (Chapter 5). A basis for rapid biological assessments of the sustainability of recreational fisheries is needed (Beard *et al*., 2011) because it is impossible for any country to have, or be willing to invest in, the necessary resources for a complete assessment of recreationally exploited stocks similar to that for high-profile marine fisheries such as for cod (*Gadus morhua*). Moreover, the research capacities in many countries are slim or only developing, partly because studies on recreational fisheries were often considered of low social priority (given its leisure focus). This needs to change if the sector wants to develop sustainably, and the call is for policy-makers and decision-makers to respond.

Specific research needs vary regionally and through time, but there are some research foci that seem relevant generally. These include descriptive information to judge the developments of fisheries, such as monitoring participation and landings using both fishery dependent and 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 parameters of exploited stocks, and recreational fisher behaviour in the light of social and economic objectives (also known as bioeconomics models [Johnston, Arlinghaus and Dieckmann, 2010]). In this context, a basic research need relates to better understanding human behavioural responses and the heterogeneous preferences and objectives of those involved in recreational fisheries alongside economic cost–benefit analyses (Parkkila *et al.*, 2010). An improved integrated understanding of the long-term benefits and costs of stocking and other traditional regulations compared with other policy options is also needed (Beard *et al.*, 2011), as is policy analysis of allocations across potentially competing fishing sectors. Generally, all recreational fisheries research should adhere to the standards of science and be able to withstand the scrutiny of peer review as the foundation for modern dissemination of scientific knowledge. However, it has to be accepted that some developing countries lack an appropriate research infrastructure. This, combined with a need to invest funds in combating hunger and poverty, will limit the implementation of this ideal situation.

In addition to novel management-oriented research, a basic first step in any fisheries assessment is descriptive work to characterize the scope and magnitude of recreational fisheries on a global and national scale in relation to other fisheries (Welcomme, 2001). Most jurisdictions do not adequately monitor or report recreational fisheries participation, catch and harvest, which impedes the ability to generate accurate fisheries statistics. The use of a landscape approach to estimate production using characteristics of waterbodies should be a priority as an important first step towards a broad indication of potential catches from each region (Beard *et al.*, 2011). In addition, longitudinal panel research may provide an improvement over expensive creel surveys in order to monitor catches, effort and harvest for the recreational sector. In general, successful implementation of fisheries management programmes relies on the development of broad-based monitoring schemes. These should collect pertinent data on the habitat, fishery and fish stocks to ensure that progress towards management goals and objectives can be documented (Chapters 3 and 5).

Because recreational fisheries do not operate in isolation, it is also necessary for each jurisdiction to have fisheries organizations and agencies that routinely monitor and assess stocks and stressors such as land-use change, climate change, habitat alteration, invasive species, and overexploitation by other forms of fishing. Indeed, managing recreational fisheries without understanding the wider aquatic ecosystem framework and its influence on fish population dynamics and community assemblages is problematic and could result in misguided management initiatives (Lester *et al.*, 2003) rather than the desired sustainable trajectory. At a more "fish-centric" level, important future research topics should relate to understanding more fully the impact of recreational fisheries exploitation, the interaction of fish and fishers, fish welfare, sustainable harvest regulations, stocking and habitat management. Cutting-edge research has to take a whole-lake or perspective and replicate "interventions" in space and time to analyse some of the outstanding questions, e.g. how fishers distribute in space, whether stocking provides additive effects, and whether regulations have any measurable impact in the long term. It is equally essential to improve knowledge about hooking mortality in the wild by tracking the fate of fish that are caught and released as well as to study the potential for evolutionary consequences of selective harvest. It is unreasonable to assume that catch-and-release studies can be conducted on every species. Hence, there is a need to develop generalized tools and strategies that are effective across a wide range of species and systems (Cooke and Suski, 2005). There are also opportunities for collaborative research with the commercial sector given that many of the stressors and injuries arising from fishing are similar in both sectors (Cooke and Cowx, 2006).

In terms of knowledge generation in academia, recreational fisheries research is, by definition, applied research, and therefore must not be conducted in isolation from the real world. Engagement of stakeholders in research is important but challenges are inherent where there are attempts to involve them in identifying research priorities, in executing partnership research and in transferring knowledge among members of the recreational fishing community. Engaging recreational fishers and other stakeholders in collaborative structured research, e.g. recreational fisher diary programmes, citizen science with respect to monitoring fish habitat (Granek *et al.*, 2008; Silvertown, 2009; Danylchuk *et al.*, 2011), is important provided that the data are collected in a standardized manner (Lester *et al.*, 2003) and stored in a database that is both accurate and accessible.

Only by interaction between managers, recreational fishers and researchers can research questions be adequately formulated (see Stein and Krueger [2006] for example; also see above for information on information and knowledge transfer) although a degree of independence from stakeholders does need to be maintained. Several studies have identified that typically there are inconsistencies with respect to research priorities, which reflects different perceived goals of different stakeholders (Hasler *et al.*, 2011). Connelly, Brown and Knuth (2000) reported that opinions of fisheries managers and recreational fishers were similar on a number of management-related issues, although differing attitudes among managers and recreational fishers were found for a range of issues, including agency performance, fish consumption advisories, necessity to protect endangered fish species, and access issues. Differences in opinions and attitudes also occur among fisheries researchers and among managers within an organization's staff (Knuth *et al*., 1995). Therefore, there is a need both to characterize the level of heterogeneity within and among user groups and to evaluate different strategies for incorporating different perspectives and building consensus where possible. Understanding how to "market" and implement different management scenarios, fishing opportunities or best practices and/or gear innovations could also benefit from structured research activity as would studies on effective enforcement.

For all research activities, completed studies should be published in a timely fashion and data made available, subject to intellectual property and confidentiality being respected. If possible, results should be published to allow dissemination of the information internationally, but local and regional research reports are equally important for the information needs of local end users. Fishery research results should be shared with stakeholders using clear language and concise communication approaches that match the needs of the stakeholders.

8. PARTICULARITIES OF DEVELOPING COUNTRIES AND ECONOMIES IN TRANSITION

As detailed in Chapter 1 and in line with the "life cycle of fisheries" (Smith, 1986), recreational fisheries growth is expected to be particularly strong in economies in transition owing to the increasing wealth of their societies This often will involve resident recreational fisheries that complement commercial and/or subsistence fisheries in marine and inland fisheries, and the challenge is to develop them sustainably. The situation is different in developing countries that have a traditionally strong focus on subsistence, artisanal and commercial fisheries. Here, the development of recreational fisheries may initially be based on foreign tourism. This creates different challenges to the "evolution" of resident recreational fisheries in economies in transition that "naturally" develop with prosperity, sometimes even replacing commercial fisheries, at least in freshwater fisheries. However, it is still important to provide the policy and governance structures that facilitate sustainable exploitation and recreational fisheries growth (Chapter 4). By contrast, in developing countries with few alternative employment opportunities, recreational fishing by residents may not be important or affordable, with people instead fishing for subsistence, but foreign tourism-based recreational fisheries may provide much needed incomes and support jobs locally (e.g. billfish recreational fishing in Kenya). Under these situations, the promotion of recreational fisheries at the expense of or in conjunction with commercial fisheries may be economically wise because recreational fisheries usually provide additional income and also indirectly facilitate resource-conservation activities (e.g. Mike and Cowx, 1986; Everard and Kataria, 2011). While the specifics differ, the general policy, licensing and regulation process for both resident and tourism-based recreational fisheries will share similarities. Similarly, whatever the type of fishery, all capture fisheries should aim for maximum and equitably distributed economic and social benefits for the entire capture fisheries sector, while minimizing cultural conflict and ecological impacts from, for example, the angling tourism industry, changed market demands, economic and social forces associated with industrialization, and the rise of alternative employment opportunities.

Under the particular conditions of developing countries and economies in transition, two types of conflict are possible: objectives and allocation.

Regarding objectives, while commercial and subsistence fisheries focus on maximized yield for food security and income, many recreational fisheries, especially tourism-based ones, might seek to provide trophy fish or other special fishing experiences. A fish stock cannot usually be jointly managed for both maximized physical yield and number of trophy fish (García-Asorey *et al.*, 2011). A possible solution might be allocation of various fishing grounds to different purposes, provided that employment and food security for local people are not compromised (Leslie *et al.*, 2009).

Regarding the emerging issue of allocation, any allocation decision is difficult and usually contested. There are multiple social, economic and cultural dimensions that the decision-maker has to include in trade-offs. In developing countries, it is especially important to consider issues of equity and food security from an ethical perspective. In industrialized countries, the issue of allocation can be resolved by maximizing the welfare of resource use for society as a whole independent of any particular sector. In this context, the utility (welfare) of a fish captured by recreational fisheries (as typically measured by the willingness of a recreational fisher to pay to fish, i.e. consumer surplus) is often higher than the utility generated by the same fish in commercial food markets (as measured by the willingness of consumers to purchase the product, and the subsequently generated producer surplus) (Parkkila *et al.*, 2010). Thus, economic arguments based on maximized welfare produced by fish may motivate the allocation of selected fish stocks to recreational fisheries or joint exploitation of stocks (Edwards, 1991). In countries where food security is at stake, a welfare-based allocation decision might not be preferred; instead, an allocation based on economic impact as modified by objectives based on equity and food security might be pursued. This economic analysis tool is not concerned with the well-being of recreational fisheries in the pursuit of fish relative to the value of fish when traded through "consumer lenses" in commercial markets. Rather, it is concerned with the economic effects of fishing expenditure in job markets (which is a cost to recreational fishers, and thus reduces their well-being or may be used a minimal estimate of value of fishing to recreational fishers, see Parkkila *et al.* [2010] for details). The result of such a perspective may usually favour joint exploitation by both resident and tourism-based recreational fisheries. In particular situations, development of a recreational fishing tourism-based subsector may be worthwhile for some developing countries and generate important economic resources, although these will usually accrue in sectors outside the traditional fisheries sectors (e.g. hotels, transport, bait industry).

From an ethical perspective, allocation of fish to recreational fisheries and the recreational use of selected fishing grounds or stocks in developing countries by tourist fishing should be promoted, provided that local and regional fishing communities become economically better placed than previously, and that access to resources by the poorest is not constrained. To support this, FAO has articulated to favour interests of subsistence and possibly commercial fisheries in developing countries over alternative uses of fish stocks, given the importance of fish in food security. For example, in the Code (FAO, 1995), it says "States should appropriately protect the rights of fishers and fishworkers, particularly those engaged in subsistence, small-scale and artisanal fisheries, to a secure and just livelihood, as well as preferential access, where appropriate, to traditional fishing grounds and resources in the waters under their national jurisdiction". Indeed a major component of ethical fisheries, according to FAO (2005a), is to acknowledge the meeting of essential human interests related to three main categories:

- Welfare – People need basic goods to survive and care for their offspring, and these are usually fish-protein-based in many developing countries.
- Freedom – People seek to regulate their own affairs and realize their life plans in accordance with their own or culturally defined values (and development of recreational fisheries may interfere with this desire).
- Justice – People need to find ways to share social benefits and burdens and facilitate peaceful coexistence (which may become important when fishing tourism operators are developed using investments and funds external to the developing country where the tourism is developed).

Thus, decision-makers are asked to value carefully the basic interests of subsistence fisheries with more prosperous resident and non-resident recreational fisheries, and maintain access to resources and work for equal distribution of economic benefits associated with local recreational fisheries.

In many situations, commercial and/or subsistence fisheries and recreational fisheries can work together to create mutual benefits, e.g. in marine fishing tournaments, fee-based inland fishing, and fishing in estuaries, bays and lagoons. Commercial fisheries may develop services and ecotourism, and teach the foreign fishing tourist aspects of culture and responsible, community-based fisheries management. Although not likely to be a large market everywhere, these activities may help realign developing countries with foreign cultures and improve mutual acceptance and understanding. It is then important to consider whether revenue will be accrued locally in the community or whether development will result in economic gains elsewhere, e.g. in the tourism sector abroad. Decisions should be taken that result in a net gain for a given region when fish resources are allocated towards recreational fisheries and taken away from subsistence and commercial fisheries. This may involve investments in infrastructure to host significant fishing tourism, and potential changes to fishing practices to meet the aspirations of foreign tourists (e.g. catch-and-release of large fish). In this context, commercial fishers in economies in transition may develop into service providers, e.g. accommodation and guiding. To facilitate a potential shift, developing nations and economies in transition should pay particular attention to developing institutions and governance structures that are able to deal with the variety of recreational fisheries, both in inland and marine waters, in particular in the light of potential for coexploitation. Such development necessitates training of fishers and the development of infrastructure and networks that promote international travel, accommodation, bait, local touristic goods and guiding, some of which can be taken over by subsistence fisheries. Fish stocks must be reasonable healthy to offer tourists an attractive fishing opportunity. In these situations, development of fishing tourism may also be highly beneficial for conservation of fish if fishing tourism development promotes incentives to reduce destructive fishing methods and overexploitation. To facilitate this development, education programmes are needed to familiarize the local people with the desires and demands of foreign tourists, and this might entail a careful communication strategy to prepare local fishers to engage in alternative income-generation activities that are more "service-oriented" than traditional ones that are oriented to catch, harvest and sale. This challenge to develop the infrastructure needed to transform a location into a popular tourist destination will not appeal to all. Because of the possible mismatch between recreational, subsistence and commercial target fish, differential regulations to protect the stock may be needed. However, many tourist recreational fisheries engage in catch-and-release fishing, and this practice may conflict with traditional perspectives on the legitimate use of fish; hence, such cultural aspects must be taken into account. This again demands education and information campaigns to develop sustainable angling tourism that results in net benefits for local communities and avoids conflicts.

Given the limited experience with recreational fisheries management in many developing countries, and also the societal priorities they face, creating appropriate institutions and governance might be difficult. Overcoming this challenge may demand close collaboration between actors and stakeholders, potentially aided by expertise from countries with greater experience in managing aquatic ecosystems and recreational fisheries. This expertise could be tapped through capacity building of fisheries managers elsewhere to then help establish and steer the organizational and institutional frameworks for managing these "evolving" fisheries, while taking account of local customs. Development of recreational fisheries may in turn provide environmental benefits by establishment of a political force interested in habitat and fish stock protection, reduction of destructive fishing practices, etc. However, the environmental risks associated with recreational fisheries development, e.g. spread of non-native fish introduced illegally, should be properly weighed. Ideally, before initiating action to increase recreational fisheries at the expense of other fishery types, an economic feasibility study should be conducted to look at their current status, growth potential, likely economic impacts and within-country sectoral effects as well as the social impacts on subsistence fisheries and their alternative employment opportunities.

There are other particular challenges that developing nations face when developing recreational fisheries. With a history of combating hunger and poverty, developing nations could experience potentially pervasive cultural and value conflicts between usually wealthier members of society who like to fish for recreation and those traditionally engaged in commercial or subsistence fisheries. Combating hunger and poverty should always be a priority and, thus, commercial and subsistence fishing might receive preferential allocation in the very poor countries where poverty and food security are dominant societal issues. However, what should drive decisions for fish stock allocation in the long term is the combined societal welfare created by decisions in the light of economic, social and environmental trade-offs. This might also favour the development of recreational fishing. For example, in some coastal areas of the United States of America, it has been realized that the economic gains from allocating stocks to recreational fisheries are higher than the economic benefits created by using the stocks commercially (Ihde *et al.*, 2011). States, nations and regions should therefore properly value the benefits and costs of various uses of fish stocks, such that economically and socially acceptable decisions can be taken that involve recreational fisheries interests in waters jointly exploited with other fishery types. However, if recreational fisheries development is uncertain, priority should remain with subsistence or artisanal fisheries as a food security "safety net" for developing nations (Berkes *et al.*, 2001). In turn, these fisheries may reduce harvest of particularly charismatic species that are then preferentially targeted by, for example, tourist fishers.

As emphasized above, economies in transition can be classified as intermediate between developing countries and the more industrialized world. It is these countries that are currently experiencing the greatest rise in resident recreational fisheries, as with increasing prosperity subsistence fisheries transform into more leisure-type fisheries, e.g. in South America and Asia. Decision-makers need to ensure that this development is sustainable, and, therefore, the TGRF should be followed. In particular, there is a need for development of appropriate governance frameworks that integrate recreational fisheries in the overall fisheries policy and carefully balance recreational, subsistence and commercial fisheries using an appropriate regulatory mix without over-regulating recreational fisheries unnecessarily.

9. IMPLEMENTATION OF THE GUIDELINES

These Technical Guidelines for responsible recreational fisheries are targeted at the entire recreational fisheries sector: policy-makers; representatives of angler associations, unions and clubs; recreational fishers; the recreational fishing industry at large; local and regional fisheries managers; and fisheries scientists. Because the Guidelines were not developed for a specific user group, the implementation strategies will vary. Moreover, given cultural, social, political, governance and economic differences around the globe, the implementation strategies will need to be cognizant of such diversity and flexible in their application. For example, some inland European fisheries are subject to private property rights whereas in the Americas and Australia fisheries tend to be public. It will be easier to reach most North American fisheries agencies than the thousands of independent management bodies (usually angling clubs) in central Europe. Transboundary fisheries issues, management structures, diverse organizations with vested interests and a diversity of instruments and funding streams in various countries further complicate the implementation of the technical guidelines.

Nonetheless, to be viable, the TGRF must be adopted by the international community and be further developed as new issues and conflicts arise. Failure to adopt at the international level would mean that the TGRF would probably be received and implemented only on a regional or local basis. In reality, the TGRF need to be adopted by a variety of bodies ranging from local to international. Beyond governments, the TGRF would ideally be used by regional and international angler and industry alliances such as the European Anglers Association, RecFish Australia, International Game Fish Association, and the American Sportfishing Association. This would give the TGRF the recognition they deserve and make them a focal point for governments, agencies and international policy-makers. In addition, there are some activities that can take place more immediately. For example, any stakeholder responsible for governance or management of recreational fishing could voluntarily endorse the TGRF and use and modify them to suit local or regional needs. To this end, the TGRF should be actively promoted to increase the extent and speed of uptake. In addition, translation of the TGRF into various languages would improve implementation.

The various stakeholder groups will probably implement the TGRF in different ways. Accordingly, an overview of the potential role of different bodies and stakeholder groups in implementation of the TGRF is provided below, as is a list of generic recommendations. The implementation list is not exhaustive but it is desired that all interested parties will collectively use a variety of creative means to implement and further the spirit of the TGRF.

9.1 THE ROLE OF DIFFERENT BODIES AND STAKEHOLDER GROUPS IN IMPLEMENTATION

9.1.1 National States and related state and provincial agencies

The primary fisheries management and regulatory agencies are a combination of national (e.g. Bahamas Division of Marine Resources, Fisheries and Oceans Canada, Environment Agency of England and Wales) and state and/or provincial governments (e.g. Illinois Department of Natural Resources). These types of agencies are typically responsible for enacting policy, ensuring compliance, managing fisheries, collecting data and conducting research in support of their missions. Given that in some regions such agencies are supported largely by fishing licence sales, some agencies also expend resources on encouraging participation in recreational fisheries (e.g. "take a child fishing" events, public service announcements) and in providing and/or enhancing fishing opportunities (e.g. put–grow–take fisheries, installation of fishing platforms). In many regions, there is jurisdictional overlap between state/provincial and federal agencies. In such cases, there are typically agreements in place to specify which aspects of recreational fisheries research and management fall under their purview. In that respect, federal agencies often focus on broad legislation (e.g. habitat protection) and broad-scale research while state/provincial agencies tend to focus more on day-to-day management activities (e.g. fisheries assessment, enforcement, outreach). Federal agencies also typically become involved when it is necessary to participate in regional fishery bodies (RFBs), including regional fisheries management organizations (RFMOs) and other international cooperative mechanisms. The range of capacity and responsibility within agencies varies widely, particularly between developed and developing countries. Indeed, in some jurisdictions, there is little in the way of recreational fisheries management, resource monitoring or research. Many natural-resource agencies employ education and communication experts that are able to develop outreach materials and deliver programming related to fisheries and natural resources. Specific examples of the role national and regional agencies should play in the implementation of the TGRF include:

- using the TGRF to craft a code of conduct for their organization and then adopting and embracing the content;
- working to further the practices that will strengthen and sustain recreational fisheries by ensuring that their core mission is aligned with the TGRF;
- integrating the provisions of the TGRF in fisheries management decision-making and fisheries management processes nationally and regionally;
- cooperating and integrating programmes with other organizations and entities to further the TGRF across states and nations;
- using the TGRF as one means to develop a certification scheme for sustainable recreational fisheries;
- developing outreach, education and awareness materials of various formats that can be used to disseminate information within and beyond their agency and to stakeholders;
- influencing national policy to strengthen recreational fisheries based on the TGRF.

9.1.2 Regional fishery bodies and regional fisheries management organizations

Given that many fisheries and fisheries management issues transcend jurisdictional boundaries (either state/province or federal), RFBs are often established to manage fisheries or to provide a platform for managerial processes. They typically address issues in international waters but are also set up for large freshwater lakes or rivers that transcend international borders. Usually, RFBs comprise government appointees from member jurisdictions but may host representatives from NGOs. In a commercial context and where an RFMO is established, these bodies may have the mandate to set and allocate quotas for the fish stocks under their management within the boundaries set out in their conventions, and thus are of relevance for recreational fisheries if stocks are also targeted by them. They are also responsible for enforcing quotas through control, monitoring and surveillance activities. The RFBs related to recreational fishing are no different in that they work largely on the development of coordinated management policies. Some RFBs directly manage fisheries while others serve in more of an advisory capacity. The responsibilities of RFBs have been outlined in various international agreements such as the Code (FAO, 1995).

Often, RFBs engage in, fund and/or coordinate research activities. Outreach and education activities are used by RFBs to engage other stakeholders, in particular fishers (recreational and otherwise). In marine environments, RFBs are typically more focused on commercial fisheries issues and management mandates (e.g. the Northwest Atlantic Fisheries Organization, Inter-American Tropical Tuna Commission, International Commission for the Conservation of Atlantic Tunas, and North Atlantic Salmon Conservation Organization[2]) and given the challenges with international fisheries management, these RFMOs are quite large and complex. An RFB can also be established by two countries (e.g. the Pacific Salmon Commission and the Great Lakes Fishery Commission between Canada and the United States of America) and across states/provinces within a country (e.g. the Atlantic States Marine Fisheries Council in the United States of America). Those RFBs that deal with inland fisheries, such as the Mekong River Commission, often have mandates that can extend to include water management. Similar to national States and related state/provincial governments, RFBs have the potential to play a strong role in the implementation of the TGRF by integrating the perspectives and interests of recreational fisheries into large-scale fisheries management. Moreover, given the fact that many of the marine RFBs have already adopted the Code, the TGRF could be easily embraced and incorporated into how RFBs and RFMOs operate. Specific examples of the role of RFBs and RFMOs in the implementation of the TGRF are similar to the above and include:

- using the TGRF to craft a code of conduct for their organization and then adopting and embracing the content;
- using the TGRF to guide fisheries management decision-making that affects recreational fisheries;
- integrating and coordinating fisheries management decisions;
- providing a platform for working with member states/provinces/ countries to develop and implement management practices that will strengthen and sustain recreational fisheries;
- developing outreach, education and awareness materials of various formats that can be used to disseminate information within and beyond their organization;

[2] The FAO Web site provides a complete list of regional fishery bodies: www.fao.org/fishery/rfb/search/en

- using the TGRF to revise the traditional focus on commercial fisheries recognizing that RFBs are important players affecting recreational fisheries;
- supporting research and management activities financially.

9.1.3 Non-governmental organizations

A broad range of NGOs involved with the recreational fisheries sectors exists, including clubs, associations and special interest groups that act at a variety of spatial scales (e.g. a specific waterbody, region, watershed) and with diverse foci (e.g. species-specific, gear-specific). The missions of these organizations vary widely and usually include several different foci such as the improvement of fishing success, exchange of information on gear types, fish biology or techniques, socializing, conservation and restoration, citizen science and monitoring, fundraising to support research activities, and advocacy for access to fish and fisheries management activities. Some organizations are rooted in business (i.e. industry associations interested in ensuring the future of fishing and fishing opportunities) while others are charitable organizations where the fish and fishing serve as a backdrop for conservation (e.g. Trout Unlimited). In central Europe, clubs and angler associations are leaseholders of fisheries and then are responsible for the day-to-day management of fisheries. What is common across these groups is that they each have a role to play in the implementation of the TGRF. Specific examples of their potential role in implementation include:

- using the TGRF to craft a code of conduct for their organization and then adopting and embracing the content;
- using the TGRF as a roadmap for fisheries management decisions;
- using the TGRF as an information source for lobbying and conflict resolution;
- encouraging industry associations to work with their members to ensure that innovations in gear and services are consistent with TGRF principles;
- debating within their own organizations the research needs for recreational fisheries and sharing information with other entities and stakeholders;
- developing outreach, education and awareness materials of various formats that can be used to disseminate information within and beyond their group;

- advocating activities needed to ensure that government agencies responsible for fisheries management are aware of the TGRF and embrace the contents;
- recognizing that NGOs are important players in recreational fisheries management and science and that they have the ability to contribute to formulating fisheries objectives and developing strategies to achieve them;
- fundraising to support various initiatives including those listed above.

9.1.4 Individual recreational fishers

At the core of the recreational fishing community are the recreational fishers – about 400–600 million individuals worldwide (Chapter 1). Given the strong interaction of fishers with the environment, they have an important role to play in the implementation of the TGRF, in particular the guidelines in Chapter 6. Some components of the guidelines, such as those that focus on responsible fishing practices, are particularly geared towards the individual actor. Specific examples of the potential role of anglers in implementation include:

- reading and embracing the TGRF and relevant codes of conduct that deal with recreational fisheries practices;
- adopting responsible and stewardship fishing practices consistent with the TGRF;
- working with other recreational fishers to form organized groups to share information, to educate other recreational fishers, and to lobby, advocate and engage management bodies on topics related to recreational fishing;
- embracing and accepting outreach, education and awareness materials;
- recognizing that they are important players in recreational fisheries management and science, that there are opportunities for ensuring that their voice is heard, and that they have the ability to contribute to formulating fisheries objectives and developing strategies to achieve them;
- recognizing that they have the ability to contribute to the generation of new knowledge and collection of fisheries data that will be essential for understanding global trends in fisheries.

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GLOSSARY AND DEFINITIONS

The following definitions were taking from EIFAC (2008), modified by Cochrane and Garcia (2009), Chapin, Kofina and Folke (2009) and Chapin *et al*. (2010). Some specific ones for recreational fisheries were developed by the authors.

Adaptive capacity: capacity of social-ecological systems (such as recreational fisheries), including both their human and ecological components, to respond to, create and shape variability and change in the state of the system.

Adaptive management: the management process of modifying policies and actions in light of evaluation of the success/failure of past actions related to previously defined, operational objectives. Adaptive management may be pursued passively or actively. Active adaptive management refers to the deliberate approach of choosing interventions as to maximize learning and insights into a complex system's reaction to that interventions (e.g. treating management as experiments).

Aquatic biodiversity: the diversity of aquatic organisms at all levels (genetic, species, communities and populations).

Bag limit: number of fish that may be retained by an individual over a specified time interval.

Best practice: planning, organization, managerial and/or operational practices that have proved successful in particular circumstances in one or more regions in the field and that can have both specific and universal applicability.

Catch-and-release: the process of capturing a fish, usually by angling, and releasing it alive. Catch-and-release ranges from legally required mandatory release of protected sizes and species to voluntary catch-and-release of fish that could have been retained.

Comanagement (Cooperative management): a process of management in which government shares power with resource users, with each given specific rights and responsibilities relating to information and decision-making. A partnership arrangement in which government, the community of local resources users (fishers), external agents (non-governmental organizations, research institutions) and sometimes other fisheries and coastal stakeholders (boat owners, fish traders, credit agencies or money lenders, tourism industry, etc.) share the responsibility and authority for decision-making over the management of a fishery (Berkes *et al.*, 2001).

Community-based management: a form of comanagement where a central role for management is delegated to a community and where Government would usually have a minor role.

Creel survey: a survey approach in which recreational fishers are intercepted on-site and data on catches, harvest, effort and social and economic information collected. Creel refers to a woven basket in which recreational fishers may store fish.

Commercial fisheries: fisheries whose primary aim is to generate resources to meet nutritional (i.e. essential) human needs; in both full-time and part-time commercial fisheries, fish and other aquatic organisms are sold on domestic and export markets. Commercial fisheries include fisheries that supply feed to the aquaculture and agriculture sectors and raw material to other industrial sectors (e.g. the biomedical sector).

Ecosystem approach to fisheries: an ecosystem approach to fisheries strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions, then applying an integrated approach to fisheries within ecologically meaningful boundaries.

Ecological services: ecological services are all services humans derive from aquatic ecosystems and fish stocks. They comprise four categories: supporting (e.g. nutrient cycling), regulating (e.g. water quality), provisioning (e.g. fish yield, recreational fishing experience) and cultural (e.g. existence value, spiritual and education dimension) services.

Environmental stewardship: environmental stewardship involves the wise and sustainable use of natural resources. It can be defined as the moral obligation to care for aquatic environments and the actions undertaken to provide that care and is a strategy to respond to and shape social-ecological systems under conditions of uncertainty and change to sustain the supply and opportunities for use of ecosystem services to support human well-being. This means that recreational fisheries stakeholders strive to maintain, enhance and protect fish populations and aquatic ecosystems. Any kind of damage to aquatic biodiversity and aquatic ecosystems is to be avoided and where it, for whatever reasons, occurs it should be managed with the best resources available.

Exploitation rate: the rate of removals of fish out of a stock in a specified time period. The exploitation rate may or may not involve by-catch or fish that die after release.

Fish welfare: good welfare means that an individual fish is in good health, with its biological systems functioning properly and with no impairment of fitness.

Ground-bait: bait scattered on the fishing site to attract fish.

Harvest regulation: a fishing regulation that specifies what fish may be harvested (caught and kept) from a fishery, e.g. minimum size or daily bag limits.

Hook bait: bait that is attached to a hook, as opposed to ground-bait.

Input control: fishing regulations that limit the manner and amount of fishing allowed.

Institutions: the humanly devised constraints that structure human interactions (rules, laws, constitutions), informal constraints (norms of behaviour, conventions, self-imposed codes of conduct) and their enforcement characteristics.

Introduction: species or races of fish and other aquatic organisms that are intentionally or accidentally transported and released by humans into an aquatic environment outside their natural range set by biogeographic barriers.

Live bait: use of live invertebrates (e.g. crayfish), vertebrates (typically teleost fish) and worms and maggots as bait in recreational fishing.

Management organization: those persons or groups with the authority to make management decisions about the fishery.

Maternal effects: effects of the phenotype of a female on the phenotype of her offspring.

Maximum size limit: a regulation in recreational fisheries where fish exceeding the size limit are to be released alive.

Minimum size limit: a regulation in recreational fisheries where fish below the size limit are to be released alive.

Output control: fishing regulations that limit the disposition of fish caught.

Precautionary approach: a term used in fisheries management to denote prudent foresight to avoid unacceptable or undesirable situations in the face of uncertainty, taking into account that some changes in fisheries systems are only slowly reversible, difficult to control, not well understood and subject to change in the environment and human values.

Recreational fisheries sector: the entire network of stakeholders involved in or fully or partly dependent on recreational fisheries including, among others. fisheries ministries and agencies, managers, non-governmental organizations (e.g. umbrella fishing associations and clubs), recreational fishers, tackle shops and tackle manufacturers, bait suppliers, charter-boating industry, recreational boat builders and chandlery suppliers, marina operators and specialized angling and fishing media, recreational fishing tourism and other related business and organizations as well as all other enterprises supporting recreational fisheries including aquaculture operations that produce stocking material or commercial fishing enterprises that sell angling tickets on their waters. A range of other stakeholders and managerial regimes are not included in this definition although they may run or advocate activities and developments that have a direct impact on the recreational fishing quality and the recreational fisheries sector, the sector's viability and growth potential (e.g. hydropower generation, water management, irrigation).

Recreational fishing: fishing of aquatic animals that do not constitute the individual's primary resource to meet nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets. The unambiguous demarcation between pure recreational fisheries and pure subsistence fisheries is often difficult. However, using fishing activity to generate resources for livelihood marks a clear tipping point between recreational fisheries and subsistence fisheries. Globally, angling is by far the most common recreational fishing technique, which is why recreational fishing is often used synonymously with angling.

Recreational fishing effort: the amount of recreational fishing with gear of a specific type used on the fishing grounds over a given time span, typically normalized per area fished.

Recreational fishing mortality: the part of the total mortality rate acting on a fish stock that is due to recreational fishing.

Recreational fishing quality: a subjective evaluation by a recreational fisher of the perceived fulfilment of the needs that the fishing experience was supposed to provide.

Resilience: capacity of a social-ecological system to absorb a spectrum of disturbances and to sustain and develop its fundamental function, structure, identify and feedbacks as a result of recovery or reorganization in a new context.

Recruitment: fish of a given age that are produced by a spawning stock.

Stakeholder: any person or legal entity (e.g. non-governmental organization) with an explicit or implicit interest (or stake) in an issue.

Size limit: a fishing regulation in which the fate of fish caught is determined by their size (usually length).

Slot limit: size-based fishing regulation in which only intermediate sized fish may be kept (open or protected slot) or must be released (closed or inverse slot).

Stock: a term used for the entire or a component of a fish population that is under consideration by management actions.

Stock assessment: the process of assessing the status of a fish stock to derive some management response in case certain criteria (reference points) are achieved.

Stocking: the release of cultured or wild caught aquatic organisms into the wild.

Structured decision-making: the structured process of arriving at a management response in light of objectives and trade-offs.

Subsistence fisheries: fishing for aquatic animals that contribute substantially to meeting an individual's nutritional needs. In pure subsistence fisheries, fishing products are not traded on formal domestic or export markets but are consumed personally or within a close network of family and friends. Pure subsistence fisheries sustain a basic level of livelihood and constitute a culturally significant food-producing and distributing activity.

Sustainability: the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development concerns land, water, plant and animal genetic resources and is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable. The three pillars of sustainability are social, economic, ecological, while the institutional dimensions is thought to facilitate the emergence of the sustainability triangle.

Transfers: species or races of fish and other aquatic organisms that are intentionally or accidentally transported and released by humans into an aquatic environment within their natural range but from which they were previously absent.

Transformability: the capacity to reconceptualize and create a fundamentally new system with different characteristics (e.g. a tourism-dominated fisheries system originally dominated by resident recreational fishers).

Utility: an economic term describing the capacity of individuals or societies to meet their own needs. The needs, and hence the utilities, desired by recreational fishers of often multi-dimensional involving multiple aspects, some of which are catch-dependent and others are non-catch dependent (e.g. aesthetic quality of a fishery).

Vulnerability: degree to which a system is likely to experience harm owing to exposure and sensitivity to a specified hazard or stress and its adaptive capacity to responds to that stress.

Zeitgeist: encompasses the cultural, intellectual, moral, ethical, spiritual and political climate within a nation or specific groups, along with the general sociocultural mood within an era.

ANNEX

RECOMMENDED GUIDELINES FOR GOVERNANCE AND MANAGEMENT OF RECREATIONAL FISHERIES

Normative framework for responsible recreational fisheries

- Sustainability constitutes a suitable normative goal for recreational fisheries, which involves context-dependent biological, social, economic and institutional dimensions, and its implementation as a broad fisheries management goal is recommended.
- All management decisions in recreational fisheries are to be taken in light of an explicit normative framework guiding thought and action. A common denominator for all recreational fisheries is biological sustainability, but every normative framework must involve locally- or regionally-tailored social and economic criteria. Decision-makers and managers should disclose their normative framework and consider stakeholder values in its articulation.
- In light of the multiuse patterns of aquatic ecosystems in which many recreational fisheries operate, decision-makers in charge of management of water and aquatic ecosystems and their supporting terrestrial habitats should ensure that recreational fisheries interests, including the need to conserve fisheries resources and supporting habitats, are taken into account in management decisions; recreational fisheries stakeholders should be integrated into all decision-making processes that affect aquatic ecosystems.
- Relevant international, national and regional administrations, fishing rights holders and other parties and persons that own or are responsible for fisheries resources should consider recreational fisheries, and subsequently protect, promote and encourage access to recreational fisheries and its quality while ensuring exploitation is sustainable and that potentially conflicting societal demands are taken into account in integrated management plans.
- Recreational fisheries are best viewed as a subsystem of the overarching ecological system. Therefore, conservation of the structure and function of aquatic ecosystems, fish populations and biodiversity constitute

a prerequisite for maximizing the social and economic benefits of recreational fisheries through appropriate management interventions.

- Aquatic stewardship provides an action-oriented framework to sustain recreational fisheries in the face of uncertainty and change and the complex, usually non-linear interactions between fishers and fish stocks. This applies at all levels of recreational fisheries (governance, management, managers, individual fisher behaviour) and involves:
  - moving away from single objectives (such as maximum sustainable yield) to the management of multiple objectives in line with prevailing local and regional conditions;
  - engaging in a range of pro-environmental behaviours whenever interacting with aquatic ecosystems and their associated natural resources to ensure long-term use, conservation, management and development of such ecosystems for present and future generations;
  - maintaining biological diversity within and among fish populations, including habitat diversity, genetic diversity and size- and age-class diversity, and maintaining diversity and flexibility at all levels, socially and institutionally;
  - maximizing the quality of recreational fisheries for as many different fisher types as possible in light of the need to maintain ecological integrity in more natural fisheries;
  - building and promotion of leadership, knowledge networks and the adaptive capacity of all involved in recreational fisheries so as to be empowered to react to unexpected developments, uncertainty and change;
  - paying particular attention to critical slow variables, thresholds, alternative stable states and positive and negative feedbacks among recreational fishers, management and fish stocks.

Adaptive management framework for sustainable recreational fisheries

- The following principles are conducive to achieving sustainable recreational fisheries:
  - responsibility – responsibility to use resources in an ecologically sustainable, economically efficient and socially just way though internalization of the aquatic stewardship framework;
  - precaution – the need to take uncertainty about potentially irreversible impact into account by erring on the side of caution; the

level of precaution exercised should be commensurate to the risk of long-lasting, undesirable outcomes and the benefits expected for a given action (e.g. stock enhancement);
- ecosystem perspective – the need to develop a holistic perspective rather than a focus on a single target species, considering the interactions of land use, other non-fishery activities, access to resources, habitat diversity, water quality and, ultimately, recreational fishing quality;
- monitoring and adaptation – continuously monitoring social, economic and ecological variables because they are dynamic and have some level of uncertainty, and adjusting actions and strategies based on new knowledge;
- participation – the importance of full stakeholder participation in the formulation and implementation of decisions about fisheries resources;
- full cost allocation – the need to identify and allocate all internal and external costs and benefits (social and ecological) of alternative uses of resources, e.g. the need to account for unintended consequences of own actions on third parties and other stakeholders (externalities);
- multilevel governance and scale-matching– the sharing of decision-making power across multiple levels of organization to take advantage of knowledge networks and to achieve matching of scales of management. This is particularly relevant where local recreational fisheries depend on human actions in other sectors or within a catchment, requiring integration across sectors and bureaucracies whenever possible and technically and socially feasible.

- In light of the above principles, adaptive management in its various forms, from passive to deliberate active adaptive management, is a suitable management process in recreational fisheries to deal with irreproducible uncertainties about the proper management actions to take and reach robust solutions to deal with uncertainties and the potential for ecosystem-level effects.
- Adaptive management, no matter whether passive or active, will be enhanced using structured decision-making processes, which increases stakeholder buy-in and acceptability of proposed solution.
- Sustainable recreational fisheries depend on continuous learning loops that emanate from evaluation of previously agreed and measurable objectives after implementation of action strategies. Therefore,

identification of measurable objectives and continued revision of objectives based on new information should be conducted whenever possible and be the basis of adaptive management.

- To facilitate adaptive management, the installation of some form of monitoring processes to regularly assess key system variables (e.g. catch, composition of catch, effort, human satisfaction) is needed in order to supplement qualitative insights with empirical data. To this end, investment into an adequate monitoring capacity involving funding and trained staff is essential. This involves capacity building for smaller recreational fisheries communities that are not linked to an overarching management body.
- In adaptive management applied to recreational fisheries, social, economic and ecological data and indicators are to be measured and monitored.
- Where possible and feasible, testing of management approaches in the field may be combined with model-based analyses using an iterative approach where models are modified in light of new information from field-based assessments.
- The highest degree of information gain about the effects of management actions on the coupled social-ecological system of recreational fisheries can be generated from active adaptive management. Such an approach is preferred where large uncertainties are to be reduced and stakeholder conflicts are pervasive about which management direction to take. However, in many smaller recreational fisheries, this experimental approach will not be practical owing to expertise or financial limitations. In such cases, passive adaptive management is still recommended.

Policy and institutional frameworks

- Structure and function of the governance framework must be clearly delineated to ensure transparency and trust in decisions, and respect for authority.
- An appropriate legal framework should establish parties holding property rights, agents responsible for management, and regulations governing the use of the resource.
- Authorities responsible for enforcement of regulations and graduated penalties for non-compliance must be established.
- Management organizations need the power to ensure that the fundamental goals of fishery management are achieved.

- Management organizations should promulgate regulations necessary to develop, conserve and enhance fishery resources and their environment, and should promote compliance with regulations through shared rule-making, outreach, monitoring and enforcement, with recreational fishers sharing responsibility through self-policing.
- Regulations should be developed in a collective choice arrangement with stakeholders, including recreational fishers and other interested parties.
- Mechanisms should be in place to manage conflicts among stakeholders, the fishery management organization and other management authorities.
- Regulations should be clear, uncomplicated, well publicized, and reviewed periodically.
- The management organization should develop policies and procedures to ensure the safety, efficiency, effectiveness and integrity of its members and the organization.
- The organization's policies and procedures should be reviewed and updated regularly.
- Funding mechanisms need to be identified to support management:
  - Fee-based licensing provides funding but fee-free licensing is also a mechanism for limiting fishery access, and identifying primary stakeholders.
  - User fees (and surcharges on licences) may be useful for managing special circumstances (restricted access, fishing methods, or species).
- Recreational fishing should be considered a privilege; the management authority should be able to revoke the licence of anglers who commit serious violations of fishing or other environmental regulations.

The unit of management

- The unit of management must be specified before status of the fishery can be assessed or management can be prescribed.
- Stocks should be defined by eco-evolutionary criteria (genetic, morphomeristic, behavioural, and ecological traits) to ensure that fishing and its management preserves the integrity of the population and sustains benefits to humans.

- Managers should strive to maintain a diverse "portfolio" of fish stocks of a given species as insurance against unexpected environmental fluctuations.

Assessment of the fishery

- Present status of the fishery in socio-economic and biological terms should be determined and used to identify potential problems or constraints and opportunities to improve the fishery prior to choosing management objectives.
- Managers should integrate information from local knowledge, stock assessment surveys, creel surveys and complementary human dimension surveys, and ecosystem surveillance to characterize the present status of the fishery.
- Integrated modelling of the biological and social system can be used to evaluate the relative status of the fishery compared with alternative system states that could be achieved through management.
- Modelling can be used to expand the management purview beyond the traditional single-species view. Potential management actions should also be evaluated with respect to their effects on the ecosystem in the light of fisher behavioural responses to any management intervention.
- Integrating information from fish stocks, ecosystems and the social and economic aspects of fisheries provides for a more holistic and predictive conceptual model for fisheries and fishery management.
- Recreational fisheries require periodic reassessment.

Management goals and objectives

- The fundamental goals of fisheries management apply to all recreational fisheries: (i) conservation of biodiversity; (ii) biologically sustainable use of its components; and (iii) equitable sharing of benefits and optimization of the socio-economic benefits fishing provides to society at large.
- Recreational fishery management should maintain and improve the quality of the fishing experience (a socio-economic objective) while maintaining ecological integrity and protecting natural systems (a biological and conservation objective) for present and future generations.
- Managers must explicitly state clear fishery-specific goals (e.g. increase satisfaction of coastal recreational fishers) and quantifiable objectives

(e.g. achieve X fish per angler per hour, mean size of catch ≥ Y cm) as part of an adaptive management framework.

- Selecting goals and objectives should be a societal choice, not an administrative one; goals and objectives should be developed cooperatively with a spectrum of stakeholders, not only recreational fishers, and reflect heterogeneous benefits sought by various stakeholders and fisher groups while avoiding undesirable biological impacts on natural fish stocks.
- When goal and objective setting is contentious, conflict management techniques should be used to reach mutually acceptable solutions.

Implementation of management strategies

- Managers should recognize that taking no action is in fact a management choice that must be monitored and evaluated regularly.
- Managers must have an understanding of the fishery's status and constraints, combined with accurate knowledge of stakeholder goals and objectives before choosing a management strategy.
- Managers should know how the multitude of recreational fishery management tools and approaches operate and when to use them.
- When higher education coursework is impractical, short courses and workshops can provide the fundamentals.
- An economic analysis (e.g. benefit–cost) should be conducted to compare management alternatives. The benefits of recreational fisheries should be measured using appropriate non-market evaluation techniques and not by expenditure alone.
- When planning is completed, the fishery management plan should be disseminated so stakeholders understand the project's goals and rationale and can provide comments on the plan and its revision.
- After choosing a course of action that is most likely to meet objectives, the manager should initiate regulation changes and develop a plan for monitoring and enforcement and supplement these activities with education and outreach.

Monitoring and evaluation of actions

- Management authorities should strive to maximize learning from management actions using all possible forms of monitoring and evaluation. Evaluating the outcome of a management action is required in order to learn about system behaviour to promote more informed and effective management in the future.

- Adaptive management, an iterative form of structured decision-making, provides a method to maximize learning from management manipulations. In this context, evaluating the outcome of a management action is necessary in order to determine whether goals and objectives are being achieved.
- Management authorities should provide training for managers in the fundamentals of study design, basic data analysis and inference.
- Survey and monitoring methods, both biological and socio-economic, should be standardized to ensure data comparability across projects and through time.
- Standardized methods should be as simple as possible to facilitate adoption and adherence to protocols, and field crews must be trained in the use of the methods.
- Managers should be required to document thoroughly their management actions and results obtained. Standardization of data reporting is also required.
- Information gathered from monitoring and evaluation efforts should be validated, compiled into centralized databases and shared with other experts and interested stakeholders.
- Enforcement of regulations is required if management outcomes are to be interpreted correctly.
- Managers should monitor ecosystem indicators to detect and understand the broader implications of management actions.
- Sampling methods should be chosen to minimize adverse effects on the environment and the stock, and bycatch of non-target organisms.

Matching management to objectives

- Three general principles apply to the selection of a management strategy: (i) recreational fishers are a heterogeneous group with diverse expectations; (ii) ecological constraints (e.g. evolutionary history, environmental conditions, existing fish assemblage) can dictate what management strategies can or should be applied; and (iii) regardless of stakeholder desires, constraints preclude some management strategies.
- The duty of the responsible manager is to understand stakeholder desires and then optimize when it is biologically possible and educate when it is not.

- The manager must investigate reported inadequacies in the fishery and choose an appropriate course of action to achieve objectives for the fishery.
- A decision tree can be useful for identifying particular habitat or fishery-oriented actions, depending on the issue and the biological properties (growth and natural mortality) of the stock.

Habitat conservation

- Habitat protection and enhancement are powerful tools for promoting healthy fisheries and should be employed wherever possible.
- Managers should be alert to potential environmental problems created or aggravated by recreational fishers and their activities.
- Managers should foster environmentally responsible behaviour among recreational fishers to protect the environment and reduce societal objections to recreational fishing.

Stocking

- Stocking is not a panacea, is often unsuccessful, and can be ecologically harmful.
- Managers considering a stocking programme should first evaluate whether stocking would be an effective remedy for fishery ills and then decide whether stocking is feasible and appropriate on eco-evolutionary and fiscal grounds.
- Habitat improvement or appropriate harvest regulations could be more cost-effective and less risky than stocking to ecological integrity of the system.
- It is essential that managers have clear and appropriate objectives, consider ecological factors that influence survival of stocked fish and their impacts on the ecosystem, and evaluate outcomes.
- Managers should minimize inadvertent impacts to fitness of stocks by adhering to best practices when hatchery reared fish are produced for restoration or enhancement stocking.
- Managers should be cognizant of trophic considerations that affect success and acceptability of stocking: predation on recruits, increased consumptive demand, competition for food, depletion of prey, and effects on sensitive species.

- Managers contemplating the introduction of non-native species or genotypes should consider the option carefully and adhere to professional codes of practice because effects of fish introductions can be severe and irreversible.
- Where introducing a non-native fish or genotype is inadvisable, managers must educate anglers about the need for environmental sustainability of management practices, and provide more sustainable options.
- Given the ease with which non-native fish may be introduced without management approval and the potential for permanent, unmitigable harm, deterring unauthorized stocking should be a management priority.
- Managers should regularly evaluate success of stocking programmes, with respect to achievement of management objectives, cost-effectiveness, and undesirable consequences.

Harvest regulations

- Effective use of harvest regulations allows the manager to use recreational fishing as a tool to manipulate fish population structure, increasing its productivity and utility to recreational fishers.
- Size-based harvest limits and bag limits (daily, weekly, monthly or seasonal) can improve recreational fisheries, but only when consistent with the fish population's demography, recreational-fisher desires and level of exploitation.
- The recreational fishery manager should acquire the necessary biological and fishery information before appropriate harvest regulations can be identified:
  - fishing mortality rate (or exploitation rate or fishing effort from creel survey);
  - natural mortality rate (catch curve, maximum age, von Bertalanffy approaches);
  - size-specific growth rate (hard parts, tagging, size-frequency methods);
  - recruitment (catch curve, population age structure, catch per unit of effort of juveniles);
  - recreational-fisher utility, willingness to harvest fish of various sizes, and comply with regulations.

- Ideally, managers should forecast potential effects of various regulations using simulation modelling prior to regulation implementation.
- Managers should follow up regulation changes with evaluation, including methods such as stock assessment, creel surveys including user satisfaction criteria, and ecosystem surveillance.
- Safety
- Each recreational fisher should be aware of, and comply with, local and national safety rules, health advisories and regulations, and where such directives do not exist, consider voluntary actions that will increase the safety of all participants.
- Governments and NGOs should develop safety guidelines and material to educate recreational fishers about safety practices related to this activity, including safe consumption.

Sale and trade of fish

- Selling or otherwise trading fish or other aquatic products harvested during the pursuit of recreational fishing is discouraged in order to demarcate clear boundaries between recreational and commercial or subsistence fisheries, unless the occasional trade or sell of recreationally captured fish is conducted to offset fishing costs and where it is explicitly allowed in a given jurisdiction, and provided that this does not interfere with interests of commercial or subsistence fisheries;
- It is recommended that indicator systems be developed to distinguish between fish captured from the recreational and commercial sectors as a means of evaluating and ensuring compliance with regulations.

Use of harvested aquatic animals

- Recreational fishers should not take more aquatic organisms than immediately needed to supplement the diet of their own household or within their network of relatives and friends; other aquatic animals should be released alive in agreement with national and regional legislation, needs and local customs, while maximizing the opportunity for survival.
- Recreational fishers should preserve the quality of aquatic animals that are removed for consumption such as by putting them on ice, immediate removing and disposing of the entrails, quick storage in freezers or early consumption; dead fish should not be left in the environment.

Fishing gear

- Each recreational fisher should always use fishing tackle and methods that comply with national regulations or where regulations fail to exist, use no more than can be tended and observed simultaneously by the recreational fisher.
- Fishing gear should not be left unattended, with the exception of techniques that are designed to be fished passively without continuous oversight (e.g. gillnetting, traps).

Litter and pollution

- Each recreational fisher should:
  - not litter the environment; it is best not to bring potential litter material to the water and to pack all equipment, bait and food in recyclable container;
  - if feasible, remove litter left by other people and leave the fishing location litter-free; always bring a container to collect litter at the fishing site.
  - should minimize the use of lead weights on the fishing line and use alternatives to lead where possible and when appropriate.
- The tackle industry should explore the development of biodegradable fishing tackle and lines made from materials that do not cause potential negative consequences to human or aquatic ecosystem health.
- Governments should work collaboratively with the fishing industry and provide incentives to develop environmentally benign fishing gear.
- Governments or bodies that own or manage lands used for recreational fishing (e.g. boat ramps, parking lots, harbours) should provide refuse facilities for the disposal of fishing-related litter.

Disturbance of environment and wildlife

- Each recreational fisher should:
  - avoid damage to riparian vegetation caused by accessing the fishing location, construction of fishing sites, piers, removal of woody debris, trampling or felling of fuelwood;
  - avoid disturbance or possible disturbance to wildlife, in particular avoid fishing near nesting birds and avoid using hook bait that might be ingested by waterfowl;

- minimize boat travel, speed, noise and boat wash when these may disturb and potentially damage fish, riparian vegetation, seagrass beds, coral reefs, waterfowl and other water users;
- anchor boats only in areas that are not environmentally sensitive;
- avoid wading in streams, lakes and coastal habitats during the reproductive periods of fish and other aquatic wildlife;
- thoroughly clean boats, trailers and other fishing gear (e.g. waders), disinfecting as appropriate, when moving from one catchment/ system to the next in order to minimize potential of spreading non-native species.

- Government agencies and NGOs should educate recreational anglers about the sources of disturbance to the environment and wildlife, including the provision of best practices to avoid or minimize negative consequences.

Reporting observed environmental problems

- Each recreational fisher should immediately report pollution incidences, distressed or dead fish/animals, the presence of unusual and non-native species, and other environmental impacts/observations to the relevant authorities.
- Government agencies and other entities responsible for aquatic environments should provide clear mechanisms by which recreational fishers are able to report environmental problems or infractions.

Baiting and collection of bait

- Each recreational fisher should:
  - moderate the amount of chum and ground-bait introduced to waterbodies and not use potentially toxic chemicals (e.g. preservatives, colouring agents) in ground-bait and hook bait;
  - use bait, particularly live bait, only in agreement with local or national regulations, and use aquatic organisms only in the waterbody from which these were collected; never transfer aquatic live bait from one waterbody to another.
- When collecting bait, each recreational fisher as well as the bait harvest industry should adopt environmentally friendly practices to minimize disturbance to habitats and the environment (e.g. backfill holes on the foreshore that are dug in the process of bait collection).

- Bait harvesters or growers, dealers and, where bait regulations exist, governments should ensure that species being sold are legal and appropriate for use in a given area.
- Governments and NGOs should develop outreach and education materials related to sustainable bait harvest and use for recreational fishers and the bait industry.

Illegal transfer of fish by recreational fishers

- Individual recreational fishers shall never stock, introduce or transfer live fish or other aquatic organisms within or between catchments without permission from the authorities. This applies particularly to non-native organisms and may also apply to non-native genotypes of a native species transferred across catchments.
- Incidences of illegal transfer of fish should be reported immediately to the relevant authorities.
- Governments should establish rigorous and visible penalties to combat illegal transfer of non-native fish or genotypes by recreational fishers.
- Governments should work together with NGOs to develop outreach materials and popularize successful condemnations of illegal stocking across countries and regions. A zero tolerance policy is advisable given the ecological impacts that can result from the successful establishment of a non-native fish species from just a few individuals of that species illegally introduced by recreational fishers.

Fish welfare

- All recreational fishers and the recreational fishing sector as a whole should recognize that their behaviour and gear choices have the potential to influence the outcome of a fishing event for the fish. Thus, behaviour and gear should be adopted that are most likely to yield outcomes that are as positive as possible.
- Recreational fishers who use nets, spears or other techniques not involving rod and line should consult guidelines for commercial fisheries where those gear types are commonly used. In general, however, recreational fishers using those gear types do not release fish; therefore, the most relevant guidelines relate to handling and killing fish.

- Each recreational fisher should use tackle and gear that is appropriate for the size and type of fish or other aquatic organism targeted. In recreational fishing, tackle and gear should be chosen in a way that:
  - minimizes landing duration where possible, recognizing that landing a fish prematurely can also lead to fish injury or drop-offs;
  - minimizes injury during handling;
  - avoids hooking outside the mouth region if possible;
  - allows safe landing.
- After landing a fish, it is to be restrained gently but firmly to control it during unhooking; and the fish is to be killed immediately after landing if it is to be harvested, by an appropriate method such as a sharp blow to the cranium and then exsanguination (bleeding-out).
- If fish are to be held alive after capture, devices should be used that provide sufficient space and water quality and keep the fish for the shortest time possible.
- Practices should be developed and promoted that cause the least physical, physiological and behavioural impact on fish if they are to be assessed (e.g. weighed) and released after capture, as in some recreational fishing competitions and tournaments.
- Fish and other organisms that are to be released after capture should be released in the best condition possible and only if legal according to national and regional legislation. Specifically, in recreational angling. this entails:
  - obtaining, reading and observing regionally available best practice catch-and-release guidelines;
  - using appropriate landing devices to avoid mucus loss and damage to the skin and other fish organs;
  - carrying and using appropriate unhooking devices such as pliers, forceps, side-cutters;
  - assessing the size of fish and taking photos while keeping it under water, if possible;
  - avoiding extended periods of air exposure, preferably unhooking the fish in the water and touching fish only with wet hands;
  - avoiding touching the fish’s gills and eyes while unhooking;
  - never squeezing a fish or using unnecessary force while unhooking;
  - releasing deeply hooked fish by cutting the line and only if survival is likely;

- not releasing fish that show signs of impaired function or severe injury;
- using validated and legal techniques to increase chances of survival when fish show signs of barotraumas;
- avoiding fishing when the intention is to catch-and-release fish in situations that are known to substantially reduce the chances of post-release survival (e.g. for some species, a particularly high or low water temperature, or deep water);
- avoiding catch-and-release of fish during their reproductive period unless deemed sustainable at the population level by management agencies;
- reviving fish before release by moving water over the fish's gills (i.e. using figure-eight pattern) if necessary;
- releasing fish as quickly as possible by placing them gently into the water;
- being alert to the presence of predators and moving to an alternate location if released fish are being eaten by predators;
- monitoring the condition of fish at time of release to determine if they have been handled to the point that they have lost equilibrium – if that occurs, future fisher behaviour should be modified to reduce stress on fish such that they are likely to be able to maintain equilibrium at time of release.

Information and knowledge sharing

- Promote awareness of various documents and guidelines including the TGRF to encourage responsible recreational fisheries through targeted information, education, and training of recreational fishers, managers, policy-makers and other stakeholders, and facilitate translations.
- Increase international exchange of knowledge and the information transfer from science to management by developing international platforms for exchange of knowledge and international conferences, meeting and working groups on recreational fisheries.
- Facilitate interaction among fisheries management staff in governmental agencies so that they can connect across state and national boundaries, e.g. by attending international conferences on recreational fisheries.
- Publicize and make available all relevant recreational fishing information, research results and salient conservation and management

measures. This holds across the entire recreational fishing sectors from small clubs to management agencies.

- Ensure that laws, regulations and policies governing their implementation are effectively disseminated and explained in plain language.
- Ensure that local fishing communities and individual fishers are involved and are aware of policy formulation and the associated implementation, enforcement and evaluation process, while facilitating awareness and implementation of the TGRF.
- Objectively and routinely communicate recent advances in recreational fisheries science, management and conservation both within the sector and with external actors using appropriate instruments including awareness and education programmes, and provide incentives for university-based academic staff to publish locally and regionally.
- Improve information on recreational fishing by collecting data on catch per species (lowest possible taxonomic level), type of gear, etc. and have member countries submit these data to central bodies such as the FAO.
- Improve ability to assign recreationally related fish production (e.g. baitfish production, fish for stocking) to the recreational fisheries sector in global fisheries assessment, and routinely include recreational fisheries assessments alongside production estimates at the global scale.
- Make effort towards and invest in recruiting new recreational fishers, especially young people and children, instilling a sense of environmental stewardship with new recruits.

Research

- Given the data-poor situation in terms of recreational fisheries, research should 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 will need to adopt a multidisciplinary, interdisciplinary and transdisciplinary research approach to problem solving.
- Adequate resources, including research facilities and trained staff, should be provided for recreational fishery research programmes. These programmes should receive financial support from public sources and

from a variety of self-sustaining funding mechanisms, such as user-pay initiatives and cost-recovery mechanisms. Alternative funding models to assist with supporting fisheries research are needed, particularly in developing countries.

- Capacity building is essential to ensuring that fishery research programmes are effective. States and relevant international organizations with the ability to provide capacity-building support should work towards provision of resources to developing countries' fishery research programmes, such as technical training.
- Research must use robust and accurate data collection and analysis strategies that incorporate appropriate standardized methods.
- 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.
- Researchers should encourage recreational fishers to contribute actively to the monitoring of fish populations by reporting relevant data and other observations to fisheries managers and researchers. Relatedly, it is necessary to study different approaches to data collection and to understand fully the biases and limitations in data reported by recreational fishers.
- Recreational fisheries research should include an understanding of the social, economic, marketing and institutional factors affecting recreational fishers and fisheries, and focus on feedbacks on 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 adaptive management approaches, and outputs of research are essential for evaluation of management effectiveness.
- Given the limited financial and human resources available, recreational fisheries research efforts may need to focus on a subset of fisheries. Where recreational and commercial fisheries coexploit the same fish stocks, collaborative research should be established.

Particular issues for developing nations and economies in transition

- Sustainable recreational fisheries development in developing nations and economies in transition will be promoted by the installation of the appropriate institutional frameworks (including organizational ones) to guide development and management of the sector.
- Training of decision-makers in modern recreational fisheries policy and management may help the transition.
- Where recreational fisheries exploit the same waters as commercial or subsistence fisheries in developing nations, priority should be given to combating hunger and poverty. The sustainable management of the joint capture fisheries sector and any resulting conflicts between the sectors should be minimized.
- Recreational fisheries in economies in transition should be developed jointly with commercial fisheries. Both fisheries should be managed such that the combined exploitation is sustainable, economic benefits maximized and social impacts on the poorest fishing communities minimized.
- Where recreational fisheries in developing countries or economies in transition involve not only resident fishers but also tourists, the tourism sector should make sure that economic benefits are accrued specifically to the local communities and the regional economy (e.g. transportation, accommodation, fish processing, bait), and the local communities should be proactively involved prior to taking decisions on tourism development.
- Development of the recreational fisheries sector should take due account of the potential for conflict on moral grounds emerging from different perspectives as to the acceptable use of fish, particularly in light of the dichotomy between fishing for food versus fishing as a leisure pursuit.
- To make appropriate allocation decisions, economic cost–benefit analysis and social impact studies are recommended in order to account for impacts – economic (jobs), value (changes to consumer and producer surpluses) and social (e.g. altered access, employment, number of people involved, changes to cultural identity) – induced by altered scenarios in relation to livelihood.
- Many of the “decisions” as to whether or not to develop resident recreational fisheries will occur naturally in relation to changes in the economic prosperity and wealth of a given country. However, decision-

makers should be prepared to have policy and institutional frameworks in place in order to help the sector move on a sustainable trajectory.

Implementation of the Technical Guidelines for Responsible Fisheries: Recreational Fisheries

- The Technical Guidelines for Responsible Fisheries: Recreational Fisheries (TGRF) or the most salient chapters of the publication containing them should be adopted by the international community and all relevant stakeholders in the recreational fisheries sector.
- The TGRF are not intended to be a "static document" but rather to be further developed and revised as new issues, opportunities, conflicts and knowledge arise; any adaptation to local and regional conditions to meet specific challenges is strongly advised.
- Implementation strategies will vary among sectors, but some general strategies include:
  - using the TGRF to craft an organization-specific code-of-conduct and then adopting and embracing the content;
  - using the TGRF as a basis to develop a sustainability certification scheme to certify fisheries management activities regionally and locally;
  - working with other stakeholders to develop and implement management practices that will strengthen and sustain recreational fisheries in light of the provisions in the TGRF;
  - developing and/or embracing outreach, education and awareness materials of various formats related to the TGRF;
  - adopting or encouraging responsible and ethical fishing practices consistent with the TGRF;
  - supporting research and management activities financially or via participation in the process that aligns with the TGRF.

These Technical Guidelines for Responsible Fisheries are focused on recreational fisheries and describe strategies to promote environmentally sustainable and socially responsible management of such fisheries. To this end, the document details policy, management and behavioural recommendations for sustainable recreational fisheries that are an increasingly important component of global fisheries. Specifically, the Guidelines translate the relevant provisions of the FAO Code of Conduct for Responsible Fisheries into specific advice for recreational fisheries. The concept of aquatic stewardship is introduced as an overarching ethical framework needed to achieve ecologically sustainable recreational fisheries on a global scale. Within this normative mindset, the adaptive management philosophy based on quantifiable and transparent objectives and continuous learning and feedback loops is proposed along with the acknowledgement of principles such as the ecosystem approach and the precautionary approach. Adherence to the guidelines and recommendations presented in this document will enable policy-makers, managers and the entire recreational fisheries sector to orient recreational fisheries towards maintaining or achieving sustainability.

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