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Towards resilient recreational fisheries on a global scale through improved understanding of fish and fisher behaviour

R. ARLINGHAUS

Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin and Inland Fisheries Management Laboratory, Faculty of Agriculture and Horticulture, Humboldt-Universität zu Berlin, Berlin, Germany

S. J. COOKE

Department of Biology, Carleton University, Ottawa, ON, Canada

W. POTTS

Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown, South Africa

Abstract Despite recreational fisheries serving as a prime example of a coupled social–ecological system, much of the research on such fisheries has been monothematic in orientation and focused either on fisheries ecology or human dimensions. An attempt was made to break down some of the barriers to more interdisciplinary research on recreational fisheries at the 6th World Recreational Fishing Conference. The overall conclusion was that future research and management efforts should increasingly focus on the feedbacks between the interacting human and ecological components of recreational fisheries. Doing so promises to improve understanding of how recreational fisheries respond to social–ecological change. In this context, the behaviour of both fishes and humans provides an important, yet often overlooked, integrator of the ecological and social components of recreational fisheries. A better understanding of the behavioural dynamics of recreational fishers as well as exploited fishes will help predict how recreational fisheries change, evolve, adapt and reorganise through time to maintain resilience and achieve sustainability on a global scale.

KEYWORDS: angler, catch-and-release, coupled social–ecological system, fisher behaviour, harvest regulations, fisheries management.

Introduction

Recreational fisheries have become the dominant or sole user group of many wild-living freshwater and coastal fish populations in industrialised countries and several economies in transition (Arlinghaus *et al.* 2002; Mora *et al.* 2009; Ihde *et al.* 2011). On average, across countries with reliable statistics, 10.6% of people participate in recreational fishing (Arlinghaus & Cooke 2009), which amounts to an estimated 140 million recreational fishers in North America, Europe and Oceania alone. Global estimates range between 220 million (World Bank 2012) and 700 million people (Cooke & Cowx 2004). In view of these numbers, there is a growing recognition of the economic, socio-cultural and ecological importance of recreational fishing as part of the global fisheries sector (e.g. Welcomme *et al.* 2010; World Bank 2012). This in turn has motivated dedicated

Correspondence: Prof. Robert Arlinghaus, Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany (e-mail: arlinghaus@igb-berlin.de)

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research, management and policy initiatives activities related to recreational fisheries (FAO 2012). Because the exploitation pressure of recreational fishing on aquatic ecosystems can be equally intense as commercial fisheries and thus similarly affect fish stocks (Lewin *et al.* 2006), a range of sustainability and biodiversity conservation issues specific to recreational fisheries have recently emerged (Cowx *et al.* 2010).

The triennial World Recreational Fishing Conference (WRFC) Series provides an opportunity to advance the knowledge foundation on which to base resilient and sustainable recreational fisheries on a global scale. The WRFC is one of the few opportunities where recreational fisheries scientists, managers, policy makers, fishers, lobby groups and other stakeholders can meet and exchange cutting-edge information about the state and development of recreational fisheries. The history of the WRFC was reviewed by Schratwieser *et al.* (2011), and the latest conference was held at Humboldt-Universität zu Berlin, Germany, from 1 to 4 August 2011, attracting about 300 delegates from 33 countries who presented 190 talks and posters. The conference theme was '*Toward Resilient Recreational Fisheries*', and its objectives were to:

- discuss the latest research on recreational fisheries across interdisciplinary themes (called 'knowledge interfaces' at the conference) that span the biological and social sciences, including economics and the humanities,
- facilitate cross-fertilisation of ideas among the many countries where recreational fisheries are thriving or developing,
- promote the development of networks among scientists, managers, policy makers, representatives from non-governmental organisations and
- identify conditions that promote adaptive and resilient recreational fisheries.

The aim of this overview is to summarise the key insights that emerged from the conference as reflected in the articles included in this proceedings. In line with the interdisciplinary conference theme, generic interactions between social and ecological components of recreational fisheries are discussed first. Second, important behavioural dimensions that shape the development of recreational fisheries are highlighted. Finally, the implications of the reviewed work for the resiliency of recreational fisheries are discussed.

An integrated view of recreational fisheries as coupled social–ecological systems

One of the primary conclusions from the 6th WRFC was that a better understanding of how selected components of the coupled social–ecological system interact is sorely needed (Fig. 1). The social–ecological framework of Hunt *et al.* (2013) constitutes an important step forward in this regard. The authors propose a novel conceptual framework for recreational fisheries that depicts them as strongly coupled social–ecological systems. Implicit in this perspective is the recognition of many layers of complexity that are inherent in the social dimension, including the role of social networks and the behaviour of policy makers and institutions. Such a perspective is far broader than the traditional human dimension-related analyses of *individual* angler behaviour or the pure fisheries ecological research tradition. Hunt *et al.* (2013) specifically highlighted the many areas where a more focused understanding of the often-overlooked or simplified social dimension of recreational fisheries will better help to predict how recreational fisheries respond to change and interventions such as those resulting from harvest regulations or stock enhancement.

The importance of the social dimension in recreational fisheries in concert with their many biological issues was also echoed by Post (2013), who discussed some of the most important frontiers of recreational fisheries science in the context of biological overfishing. Similar to Hunt *et al.* (2013), Greiner *et al.* (2013) and other previous work (e.g. Larkin 1978; Arlinghaus *et al.* 2008), Post (2013) identified the diversity (heterogeneity) in angler behaviour as a key ingredient contributing to the complex dynamics of recreational fisheries. Post (2013) also reminded us about the largely overlooked, and so far only superficially considered, importance of diversity in fish life history (Johnston *et al.* 2013), and various

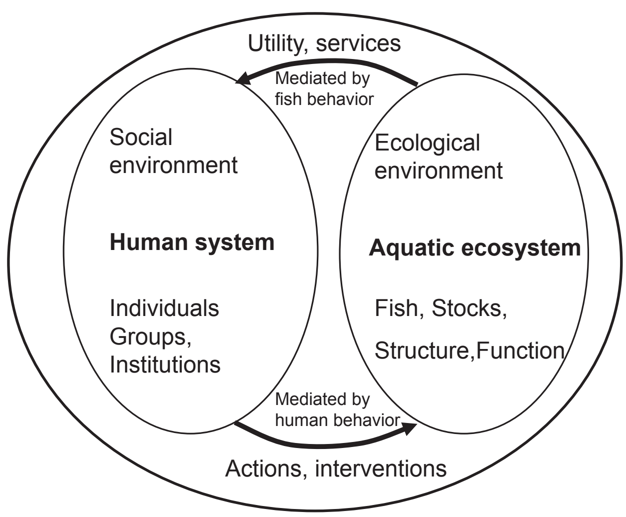

Figure 1. A conceptual sketch of a coupled social–ecological framework for recreational fisheries. Behaviour (of people, institutions and fish) is introduced as a bridging concept that tightly couples the social and ecological components of recreational fisheries.

depensatory mechanisms at low fish population sizes (e.g. density-dependent catchability, Hunt *et al.* 2011), which can strongly reduce the resilience of a fishery to the point of collapse (Post *et al.* 2002). It is the interactions of social and ecological dimensions that collectively determine such outcome, and more research is needed to understand how fish and fishers interact to shape emergent properties such as collapsing fisheries.

Behavioural links among the social and the ecological dimensions of recreational fisheries

A number of contributions highlighted, implicitly or explicitly, the importance of both human and fish behaviour in shaping the before-mentioned interactions and dynamics of recreational fisheries (Fig. 1). Behaviour can indeed be considered a key, yet often overlooked, mediator between the social and ecological subsystems by determining the reactions of fisheries to internal and external drivers (Fig. 1). Oversimplifying, misrepresenting or even overlooking the behaviour of fishes, for example, is known to result in unexpected outcomes of management interventions (Pine *et al.* 2009). Similarly, not representing angler behaviour appropriately in exploitation models can result in mismanagement and collapse of fisheries (Johnston *et al.* 2010; Post 2013).

An example of the importance of human behaviour in shaping recreational fishing quality is the study by Jansen *et al.* (2013). Using a novel state-based modelling approach, the authors found that the two of the most important aspects affecting a lentic pike, *Esox lucius* L., population were the behaviour of commercial fishers that were coexploiting the pike stock with anglers, and the behaviour of anglers themselves, in particular, their propensity to release pike after capture. Informal institutions by anglers defined as mutually agreed-upon rules or modes of behaviour that are conducted independent of formal laws and regulations, including their engagement in voluntary catch-and-release (C&R), are indeed major contributors to the dynamics of fishery systems, although such informal institutions are rarely strategically used by fisheries managers (Cooke *et al.* in press). Similarly, Ferter *et al.* (2013) documented high levels of voluntary C&R in traditionally harvest-oriented Norwegian marine fisheries targeted by tourist anglers. Their voluntary engagement in C&R may reduce fishing mortality considerably if post-capture mortality remains low. However, if effort is high and barotrauma issues severe, C&R may still lead to unintended fishing impacts with effects similar to a total catch-and-kill fishery (Ferter *et al.* 2013).

Despite a notable increase in voluntary C&R behaviour in some fisheries (Ferter *et al.* 2013), the release of harvestable fish remains low elsewhere because people like to keep fish for personal consumption. Examples include Mediterranean coastal fisheries (Lloret & Font 2013) and tourist anglers in Karumba, Queensland, Australia, who target grunter, *Pomadasys kaakan* (Cuvier) (Greiner *et al.* 2013). Lloret and Font (2013) found that the low propensity for C&R was problematic in the coastal waters of Spain, particularly because many of the fishes caught were immature and retained illegally. In the case of the grunter fishery, the biological consequences of the fish harvest by tourists were even judged to be a threat to the livelihoods of the local communities (Greiner *et al.* 2013). A better understanding of the social dimension of fisheries compliance, including how social norms can influence individual compliance behaviour with regulations, is critical for the future. If these aspects are not well considered, many well-intended regulations will fail to meet their objectives (e.g. Pierce & Tomcko 1998).

Other angler behavioural dimensions can also strongly affect management outcomes. Allen *et al.* (2013), for example, showed how dynamic responses in effort by harvest-oriented anglers strongly altered the effectiveness of traditional minimum-size limits that were implemented to avoid recruitment overfishing. To add further complexity, interactions among fishes and anglers are not only dependent on angler behaviour, but also on fish behaviour. The catchability of a population of fish may, for example, be strongly altered either by fisheries-induced evolution (Philipp *et al.* 2009) or by learning to avoid future capture. In this context, Klefoth *et al.* (2013) examined the ability of carp, *Cyprinus carpio* L., to avoid capture after exposure to experimental angling. They reported a rapid-avoidance response to the initiation of angling under controlled experimental conditions in both large indoor tanks and outside ponds, as well as a genetic component to the trait 'vulnerability to angling', similar to studies on largemouth bass, *Micropterus salmoides* (Lacepède) (Philipp *et al.* 2009). The avoidance reaction of carp and potentially other fish to angling gear poses a significant challenge because it would affect the validity of fishery-dependent stock assessments and also reduce catch-dependent fishing quality (i.e. catch rates) in the long term. However, Heermann *et al.* (2013) found that angling skill and other angler variables explained more of the variance in the catch rate of Eurasian perch, *Perca fluviatilis* L., than the basic limnological variables that were hypothesised to affect perch population size (and hence catch rates) across lakes. Collectively, the studies reviewed suggest that accounting for the impact of changing fish behaviour and type of angler fishing and reporting CPUE data may be necessary to improve fishery-dependent stock assessment; otherwise, CPUE data generated from anglers (e.g. using diaries or creel surveys) may provide biased signals about underlying fish stock developments.

Towards resilient recreational fisheries on a global scale

As with other applied sciences, recreational fisheries research ultimately contributes to the development of fisheries management strategies aimed at sustainability (both biological and social) and resilience to undesirable change. While many fisheries managers lament the 'messiness' of human behaviour (Hunt *et al.* 2013), and although fisheries managers are indeed confronted with a complex task, the situation is not hopeless. For example, Crowe *et al.* (2013) revealed how allocation arrangements can be developed and sustained over time to manage a multisector marine fishery that included both commercial and recreational fisheries. Critical to its success was the quantification of the fishing mortality in each sector, an independent allocation rights process and robust sectoral representation in the decision-making process. This exemplified the value of good science, high-quality management and inclusive participation procedures for determining robust, results-oriented decision-making.

To achieve such positive outcomes, the institutional arrangements, including appropriate governance structures and a suitable policy framework, as well as significant long-term financial investments for both scientific research and stakeholder participation, are needed (FAO 2012). Often, this can only be sustained for the more valuable fisheries and can rarely be implemented in the hundreds or thousands of small freshwater fisheries (Post *et al.* 2002). Here, other comanagement arrangements and data-collection processes may be needed, including the use of novel survey tools such as using the World Wide Web to predict developments and foresee trends (Wilde & Pope 2013).

Notwithstanding Crowe *et al.*'s (2013) success story, Fenichel *et al.* (2013) drew attention to the differences between positive science and normative considerations in recreational fisheries management. They advocated for the disclosure of management objectives and normative criteria used to underpin and rationalise the various management recommendations provided by both researchers and managers in recreational fisheries research. This call was inspired by the observation that all too often, recreational fisheries science ends with management recommendations, while the underlying normative criteria and management objectives implicit in selecting these remain cryptic. Without explicit disclosure of the chosen normative framework, however, management recommendations derived from an empirical or theoretical study could be misunderstood by stakeholders, which in turn, may amplify the already substantial communication barriers that exist between fishery researchers, managers and recreational anglers (Dedual *et al.* 2013). Fenichel *et al.* (2013) concluded with a plea for the application of a bioeconomic framework because it forces the analyst to be implicit about which components to model and which objectives and criteria to use when evaluating the choice of policy (see Johnston *et al.* 2010, 2013 for example).

One of the most-often used normative criteria in fisheries management is loosely speaking 'the conservation of fish populations' (Cowx *et al.* 2010). In this context, there is a long-standing controversial debate over whether recreational fishing can overfish stocks biologically or economically. Post's (2013) opinion, 10 years after publishing the highly cited 'invisible collapse' article (Post *et al.* 2002), was that many agencies and anglers still did not believe that angling mortality could drive fish populations to collapse, defined as population size reductions to <10% of virgin biomass. Models, however, have shown that such sharp declines are indeed conceivable, even at realistically low levels of fishing effort (Hunt *et al.* 2011). Allen *et al.* (2013) supported this conclusion by showing that unresponsive fishing effort, which essentially mimicked a situation where angler satisfaction was not only determined by catch rate or size of fish but also be non-catch factors such as travel distance, required reasonably high minimum-size limits or other harvest constraints to avoid recruitment overfishing. Van Poorten *et al.* (2013) analysed the harvest-reduction effect of marine recreational fisheries regulations in the USA, and similarly noted that restrictive minimum-size limits would be needed to reduce harvest notably, while other harvest restrictions (e.g. daily bag limits) were ineffective (Ferter *et al.* 2013; Van Poorten *et al.* 2013). However, minimum-size limits are no panacea. Under high levels of effort, some protection of very fecund mega-spawners through harvest slots (e.g. Arlinghaus *et al.* 2010) or even entirely unselective exploitation (Law *et al.* 2012) is advisable to maintain resilient fisheries. In addition, minimum-size limits encourage removal of larger sized fish, which may have negative impacts from an evolutionary perspective (Matsumura *et al.* 2011). Overfishing by anglers can also result in cascading effects through trophic levels, as shown in a coastal saltmarsh in the USA. (Altieri *et al.* 2012). Based on these findings, it can be concluded that overfishing in its various forms is not confined to industrial fisheries, and proper fisheries management is also needed in the many recreational fisheries worldwide (FAO 2012).

Harvest regulations will always constitute an important tool to manage fishing mortality when effort cannot be curtailed (Ferter *et al.* 2013; Van Poorten *et al.* 2013), for example, to maintain spawning stocks above limit reference points (Allen *et al.* 2013). Although all harvest regulations require some form of mandatory C&R, a low survival rate of fish after C&R may render any harvest regulation ineffective at high effort (e.g. Coggins *et al.* 2007). The sublethal impacts of C&R may be equally important to consider (Arlinghaus *et al.* 2007), and this is particularly relevant in the context of the emerging discussions on fish welfare, which poses one of the greatest challenges to recreational fisheries in contemporary, urbanised societies (Arlinghaus *et al.* 2012). Cooke *et al.* (2013) reviewed the use and abuse of physiological tools to measure sublethal impacts of C&R on fish, which offers both managers and anglers useful toolboxes to understand the more subtle impacts of this practice. Recommendations on how to improve release practices are provided in the EIFAC Code of Practice for Recreational Fisheries (EIFAC 2008) and the FAO Technical Guidelines for Responsible Fisheries: Recreational Fisheries (FAO 2012), as well as related work (e.g. Arlinghaus *et al.* 2007; Cooke & Sneddon 2007). Adhering to these practices would increase the social resilience of recreational fisheries by reducing the exposure of the sector to perspectives that threaten the entire activity by abolition on moral grounds (Arlinghaus *et al.* 2009, 2012).

Conclusions

The suite of complex feedbacks and interactions inherent in recreational fisheries render such fisheries far from linear and simple. A greater emphasis on integrated approaches that link social and ecological models and insights is needed if one is to predict the outcomes of management policies and regulations that trickle in their effects through both the human and ecological components of fisheries systems. Without this approach, recreational fisheries science will remain parochial and fragmented, and probably not realise its full potential. While some of the needed integration of social and fisheries biological science can be accomplished using qualitative or conceptual models, it is predicted both here and elsewhere (Fenichel *et al.* in press) that greater use of quantitative models will be needed to understand whole fishery system dynamics (see Johnston *et al.* 2010, 2013; Hunt *et al.* 2011 for examples). It is not suggested that the monothematic, empirical contributions from either recreational fisheries ecology or human-dimensions studies are bound to lose importance in the future, but the integrated approach will allow one to contextualise both dimensions into a broader systems view (Fig. 1) to help understand better the feedbacks among ecology, evolution, non-fishing anthropogenic impacts and the social and policy dimensions (Hunt *et al.* 2013; Post 2013).

This issue provides one further step towards interdisciplinary recreational fisheries science. What is needed for the future is to encourage the building of interdisciplinary teams of fisheries natural scientists, applied social scientists, ecological modellers, outreach staff and anglers to develop a novel brand of science that offers promise to maintain viable recreational fisheries by merging the study of issues of high practical importance with profound theoretical insight. This will solve local problems, while also generating general understanding that can be transferred to other contexts. Such integrated research approaches will not only generate more relevant results that serve the needs of fisheries managers but will also improve the communication of this science to the end users (Dedual *et al.* 2013). The likelihood of achieving the described state will be significantly enhanced by the development of appropriate institutional structures, funding and policy frameworks, which in developing-economy countries and elsewhere, are seen as a critical first step towards sustaining recreational fisheries in a world of unprecedented change and transformation (FAO 2012).

The resilience of recreational fisheries will be further enhanced by maintaining diversity at all levels (genetic, species, community and type of fisheries), engaging in adaptive management, and taking due notice of cross-scale interactions and the management of critical characteristics of the fishery that only change slowly over time (e.g. coarse woody debris, nutrient content and other habitat structure, social norms about appropriate management strategies), but collectively strongly shape the dynamics of coupled social–ecological systems such as recreational fisheries (FAO 2012). An action-oriented framework towards sustainable and resilient recreational fisheries will then have the following core areas (modified from FAO 2012).

- A focus on adaptation and flexibility in management processes and the building of adaptive management capacity.
- Moving away from single dominant management objectives and targets, such as maximum sustainable yield, to the management of multiple objectives in line with prevailing local and regional conditions.
- A focus on the management of critical feedbacks and variables, taken due account of behavioural dynamics of both fishers and fishes.
- A focus on maintaining and promoting the full range of biological, stakeholder and institutional diversity,

including habitat diversity, genetic diversity, size- and age -class diversity and diversity of rules in use (institutions).

• A focus on the incorporation of the interests and knowledge base of multiple stakeholders and a management to suit the needs of multiple angler types whenever ecologically feasible.

• In fresh waters, a move towards a landscape perspective of fisheries management to complement the traditional single-fishery focus.

When following these principles in management practice, the prospects for sustainable recreational fisheries that are resilient to undesirable change will probably be enhanced.

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References

Allen M.S., Ahrens R.N.M., Hansen M.J. & Arlinghaus R. (2013) Dynamic angling effort influences the value of minimum-length limits to prevent recruitment overfishing. *Fisheries Management and Ecology* **20**, 247–257.

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

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

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

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

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

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

Arlinghaus R., Matsumura S. & Dieckmann U. (2010) The conservation and fishery benefits of protecting large pike (*Esox lucius* L.) by harvest regulations in recreational fishing. *Biological Conservation* **143**, 1444–1459.

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

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

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

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

Cooke S.J., Donaldson M.R., O'Connor C.M., Raby G.D., Arlinghaus R. *et al.* (2013) The physiological consequences of catch-and-release angling: perspectives on experimental design, interpretation, extrapolation, and relevance to stakeholders. *Fisheries Management and Ecology* **20**, 268–287.

Cooke S.J., Suski C.D., Arlinghaus R. & Danylchuk A.J. (2012) Voluntary institutions and behaviours as alternatives to formal regulations in recreational fisheries management. *Fish and Fisheries* doi: 10.1111/j.1467-2979.2012.00477.x.

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

Crowe F.M., Longson I.G. & Joll L.M. (2013) Development and implementation of allocation arrangements for recreational and commercial fishing sectors in Western Australia. *Fisheries Management and Ecology* **20**, 201–210.

Dedual M., Sague Pla O., Arlinghaus R., Clarke A., Ferter K., Geertz-Hansen P. *et al.* (2013) Communication between scientists, recreational fishers, fishery managers and recreational fishers: lessons learned from a comparative analysis of international case studies. *Fisheries Management and Ecology* **20**, 234–246.

EIFAC (European Inland Fisheries Advisory Commission) (2008) *EIFAC Code of Practice for Recreational Fisheries*. Rome: FAO, EIFAC Occasional Paper 42, 45 pp.

FAO (Food and Agricultural Organization of the United Nations) (2012) *Technical Guidelines for Responsible Fisheries: Recreational Fisheries*. Rome: Food and Agriculture Organization of the United Nations. 176 pp.

Fenichel E.P., Abbott J.K. & Huang B. (2012) Modelling angler behaviour as part of the management system: synthesizing a multi-disciplinary literature. *Fish and Fisheries* doi: 10.1111/j.1467-2979.2012.00456.x.

Fenichel E., Gentner B. & Arlinghaus R. (2013) Normative considerations for recreational fishery management: a bioeconomic framework for linking positive science and normative fisheries policy decisions. *Fisheries Management and Ecology* **20**, 223–233.

Ferter K., Borch T., Kolding J. & Vølstad J.H. (2013) Angler behaviour and implications for management - catch-and-release among marine angling tourists in Norway. *Fisheries Management and Ecology* **20**, 137–147.

Greiner R., Franklin D.C. & Gregg D. (2013) Towards an improved understanding of angler tourism in northern Australia. *Fisheries Management and Ecology* **20**, 161–173.

Heermann L., Emmrich M., Heynen M., Dorow M., Borcherding J. & Arlinghaus R. (2013) Explaining recreational angling catch rates of Eurasian perch, *Perca fluviatilis* – the role of natural and fishing-related environmental factors. *Fisheries Management and Ecology* **20**, 187–200.

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

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

Ihde J.F., Wilberg M.J., Loewensteiner D.A., Secor D.H. & Miller T.J. (2011) The increasing importance of marine recreational fishing in the US: challenges for management. *Fisheries Research* **108**, 268–276.

Jansen T., Arlinghaus R., Als T.D. & Skov C. (2013) Voluntary angler logbooks reveal long-term changes in a lentic pike, *Esox lucius*, population. *Fisheries Management and Ecology* **20**, 125–136.

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

Johnston F.D., Arlinghaus R. & Dieckmann U. (2012) Fish life history, angler behaviour and optimal management of recreational fisheries. *Fish and Fisheries* doi: 10.1111/j.1467-2979.2012.00487.x

Klefoth T., Pieterek T. & Arlinghaus R. (2013) Impacts of domestication on angling vulnerability of carp, *Cyprinus carpio*: the role of learning, foraging behavior and food preferences. *Fisheries Management and Ecology* **20**, 174–186.

Larkin P.A. (1978) Fisheries management – an essay for ecologists. *Annual Review of Ecology and Systematics* **9**, 57–73.

Law R., Plank M.J. & Kolding J. (2012) On balanced exploitation of marine ecosystems: results from dynamic size spectra. *ICES Journal of Marine Science* **69**, 602–614.

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

Lloret J. & Font T. (2013) A comparative analysis between recreational and artisanal fisheries in a Mediterranean coastal area. *Fisheries Management and Ecology* **20**, 148–160.

Matsumura S., Arlinghaus R. & Dieckmann U. (2011) Assessing evolutionary consequences of size-selective recreational fishing on multiple life-history traits, with an application to northern pike (*Esox lucius*). *Evolutionary Ecology* **25**, 711–735.

Mora C., Myers R.A., Cool M., Libralato S., Pitcher T.J., Sumaila R.U. *et al.* (2009) Management effectiveness of the world's marine fisheries. *Public Library of Science Biology* **7**, e1000131, doi:10.1371/journal.pbio.1000131.

Philipp D.P., Cooke S.J., Claussen J.E., Koppelman J.B., Suski C.D. & Burkett D.P. (2009) Selection for vulnerability to angling in largemouth bass. *Transactions of the American Fisheries Society* **138**, 189–199.

Pierce R.B. & Tomcko C.M. (1998) Angler noncompliance with slot length limits for northern pike in five small Minnesota lakes. *North American Journal of Fisheries Management* **18**, 720–724.

Pine III W.E., Martell S.J.D., Walters C.J. & Kitchell J.F. (2009) Counterintuitive responses of fish populations to management actions: some common causes and implications for predictions based on ecosystem modeling. *Fisheries* **34**, 165–180.

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

Post J.R., Sullivan M., Cox S., Lester N.P., Walters C.J., Parkinson E.A. *et al.* (2002) Canada's recreational fishery: the invisible collapse? *Fisheries* **27**(1), 6–17.

Schratwieser J., Sutton S.G. & Arlinghaus R. (2011) Introduction. *American Fisheries Society Symposium* **75**, 1–9.

Van Poorten B.T., Cox S.P. & Cooper A.B. (2013) Efficacy of harvest and minimum size limit regulations for controlling short-term harvest in recreational fisheries. *Fisheries Management and Ecology* **20**, 258–267.

Welcomme R.L., Cowx I.G., Béné C., Funge-Smith S., Halls A. & Lorenzen K. (2010) Inland capture fisheries. *Philosophical Transactions of the Royal Society B* **365**, 2881–2896.

Wilde G.R. & Pope K.L. (2013) Worldwide trends in fishing interest indicated by Internet search volume. *Fisheries Management and Ecology* **20**, 211–222.

World Bank (2012) *Hidden harvest: the global contribution of capture fisheries*. Report No. 66469-GLB. Washington: International Bank for Reconstruction and Development, pp. 152.