



Review

Recommendations for the future of recreational fisheries to prepare the social-ecological system to cope with change

R. ARLINGHAUS

*Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
Division of Integrative Fisheries Management, Faculty of Life Science, Humboldt-Universität zu Berlin, Berlin, Germany*

S. J. COOKE

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

S. G. SUTTON

Fishing and Fisheries Research Centre, School of Earth and Environmental Sciences, James Cook University, Townsville, QLD, Australia

A. J. DANYLCHUK

Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, MA, USA

W. POTTS

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

K. DE M. F. FREIRE

Department of Fishery Engineering and Aquaculture, Federal University of Sergipe, São Cristóvão, Sergipe, Brazil

J. ALÓS

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

E. T. DA SILVA

Department of Education, Knowledge, Language and Art, Faculty of Education, State of University of Campinas, São Paulo, Brazil

I. G. COWX

Hull International Fisheries Institute, University of Hull, Hull, UK

R. VAN ANROOY

Food and Agriculture Organization of the United Nations, Sub-regional Office for the Caribbean, Bridgetown, Barbados

Abstract This paper presents conclusions and recommendations that emerged from the 7th World Recreational Fishing Conference (WRFC) held in Campinas, Brazil in September 2014. Based on the recognition of the immense social and economic importance of recreational fisheries coupled with weaknesses in robust information about these fisheries in many areas of the world, particularly in many economies in transition, it is recommended to increase effort to build effective governance arrangements and improve monitoring and assessment frameworks in data-poor situations. Moreover, there is a need to increase interdisciplinary studies that will foster a systematic understanding of recreational fisheries as complex adaptive social-ecological systems. To promote sustainable recreational fisheries on a global scale, it is recommended the detailed suggestions for governance and management outlined in the United Nations Food and Agricultural Organization Technical Guidelines for Responsible Fisheries: Recreational Fisheries are followed.

KEY WORDS: adaptation, angling, human dimensions, invasive species, resilience.

Introduction

Recreational fisheries have become the dominant or sole use of many freshwater and coastal fish stocks in industrialised countries and many economies in transition (FAO 2012). For countries with reliable statistics, on average about 11% of people participate in recreational fishing (Arlinghaus *et al.* 2015), which amounts to a global estimate of recreational fishers ranging between 220 million (World Bank 2012) and 700 million (Cooke & Cowx 2004). In view of these numbers, there is growing international recognition of the substantial economic, socio-cultural, ecological and evolutionary importance of recreational fishing (FAO 2012; World Bank 2012). This has motivated dedicated research and management activities intended to ensure that diverse recreational fisheries are sustainable and achieve multiple benefits at a global scale.

The tri-annual World Recreational Fishing Conference (WRFC) series provides an opportunity to advance knowledge relevant to the development of resilient and sustainable recreational fisheries. The conference constitutes one of the few opportunities for fisheries managers, policy-makers, scientists, recreational fishers and other stakeholders to meet and exchange cutting-edge information about the state and development of recreational fisheries on a global scale. The history of the WRFC was reviewed by Schratwieser *et al.* (2011), and the last conference was held at the State University of Campinas, Brazil, from September 1 to 4, 2014. Notably, this was

the first time that the conference was held in an emerging economy country where recreational fishing is on the rise and where there is often limited governance capacity available to manage the sector (FAO 2012).

The theme of the 7th WRFC conference was *Change, transformation and adaptation of recreational fisheries* and its objectives were:

- to serve as a forum for professionals and institutions representing all components of the recreational fishing sector to exchange ideas and new knowledge related to the science and management of recreational fisheries;
- to foster and develop multi- and interdisciplinary actions directed toward the maintenance and enhancement of recreational fisheries and its practices, and to identify opportunities in the present and future;
- to stimulate scientific investigations and the development and application of science-based management practices in recreational fisheries around the globe, particularly in developing countries.

The 7th WRFC made progress in understanding the multifaceted problems related to recreational fisheries, noted the increased use of multi-disciplinary analyses of issues related to recreational fishing, and provided evidence that appropriate institutional capacity and effective communication among stakeholders and among scientists and managers are essential to promote the sustainability of recreational fisheries.

Rather than summarising the contributions of this special issue, the objective of this paper is to present key insights that emerged from the 7th WRFC conference in

light of the recent peer-reviewed literature on recreational fisheries. Key conclusions and recommendations for the future are presented, based on a mini-review of key developments in the science and management of recreational fisheries at a global level. A particular focus in the selection of themes is placed on improving recreational fisheries in economies in transition and emerging economies, but some of the issues equally apply in the developed world.

Recent developments in recreational fisheries science and management

Economic and social importance

As elaborated in the governance and management framework for inland fisheries by Welcomme (2001), the initial step towards sustainable management of any recreational fishery is assessing and acknowledging its social and economic importance within a given region or country. Hence, the 1st WRFC conference held in 1996 in Dublin (Ireland) was heavily focused on establishing country profiles about key characteristics, and the economic value and social impact of recreational fisheries (Hickley & Tompkins 1998). This mirrored a long tradition in basic descriptive research on the socio-economics of recreational fisheries conducted in North America (e.g. Weithman 1999; Cooke & Murchie 2015). Recently, Parkkila *et al.* (2010) summarised methods and approaches for evaluating the economic importance and social benefits of recreational fisheries. These methods are now routinely being applied in several countries that can be classified as “economies in transition” (e.g. Argentina: Baigún *et al.* 2006; Brazil: Freire *et al.* 2012, 2016; Barrella *et al.* 2016), providing a first step to characterising the size and structure of the recreational fishing sector, the number of people engaged in recreational fishing, and its social and economic value in a given country or region. As more and more basic descriptive knowledge about the economic and social importance of recreational fishing accumulates it will likely lead to a greater appreciation of the sector by policy makers and fisheries managers in relation to science and management of capture fisheries in general (e.g. Arlinghaus *et al.* 2002; Cowx 2015; Cooke *et al.* 2016). The socio-economic importance of recreational fisheries often remains unnoticed in many emerging economy countries, and consequently governance structures have not sufficiently developed to cater for the unique social-ecological characteristics of recreational fisheries. In the more developed countries with longer traditions of assessing the benefits of recreational fisheries, the focus of science is increasingly moving away from simply characterising

participation, expenditure or basic motivations of anglers to the assessment of the psychological, social and ecological importance of recreational fishing, including assessment of health benefits (Pretty *et al.* 2006), the social benefits of angling for integration of minority groups (Freudenberg & Arlinghaus 2010), fishing as a contributor to life satisfaction (Griffiths *et al.* in press), the role and importance of anglers and other recreational fishers for conservation (Bate 2001; Cowx *et al.* 2010), assessment of angler mental models about ecological processes (Li *et al.* 2016) and development of novel monitoring methods using social media and citizen science applications (Papenfuss *et al.* 2015). Moreover, there is an increasing realisation that national-level changes in demographics, economics and social values strongly affect both participation at a national level (Arlinghaus *et al.* 2015) and the moral acceptability of recreational fishing in some so-called “post-modernized” societies (Arlinghaus *et al.* 2012; Riepe & Arlinghaus 2014). Recreational fisheries may thus become increasingly vulnerable to changing social values on the acceptability of how anglers interact with aquatic environments and their living resources.

Governance

With a long history of participation, many developed nations have, over time, constituted comprehensive governance structures for recreational fisheries that include policies that outline broad goals and principles, include national or regional-level fisheries laws and regulations, and identify the organisations or structures that fulfil the governance and management roles. By contrast, developing countries generally have a limited history of recreational fishing and therefore seldom have well developed recreational fisheries governance structures and associated competencies and training of fisheries managers (FAO 2012). This is particularly problematic as growing recreational fisheries often conflict directly with the objectives of other (subsistence, small-scale, commercial) fisheries sectors. Ultimately, failure to develop comprehensive governance strategies for recreational fisheries will negatively impact the sustainable development of the sectors in economies in transition and emerging economies.

Tourism-based recreational fisheries

Angling has emerged as important form of domestic and international tourism in several areas of the world (e.g. Solstrand 2013). The largely unregulated and rapid growth of tourism-based recreational fisheries in developing countries has caused social and ecological issues

(Bower *et al.* 2014; Sheaves *et al.* 2016), and similar patterns have been seen in some industrialised countries that attract considerable numbers of tourists (Moksness *et al.* 2011; Solstrand 2013). Tourism imports new technology and fishing cultures, which can have both positive and negative impacts locally. In some countries, such as Argentina, tourism has influenced local angling behaviour as previously catch-and-kill tournaments targeting sharks have been converted to tag-and-release events (Dellacasa & Braccini 2016). As recreational fishing tourist destinations emerge, mechanisms that channel some of the economic benefits that are normally accrued primarily by foreign investors into the local communities must be developed (Freire *et al.* 2012).

Ecological impacts

The ecological impacts of recreational fisheries have been underestimated compared with those of commercial fisheries (Cooke & Cowx 2006). However, there is now abundant evidence to suggest that recreational fishers can substantially affect abundance, size structure and evolutionary trajectories of fish stocks as well as the water quality and terrestrial ecotones of both marine and freshwater ecosystems (reviewed in Post *et al.* 2002; Cooke & Cowx 2006; Lewin *et al.* 2006). Some recreationally targeted species are being overexploited (e.g. Post *et al.* 2002; Sheaves *et al.* 2016) and this has, in some cases, resulted in shifts in effort towards new target species for which there may be no active monitoring or management, or which may include endangered species (e.g. Bower *et al.* 2014). To deal with overfishing, traditional management strategies of harvesting size and quota limits are common in many countries but occasionally are failing to prevent declines in stock status (e.g. Maggs *et al.* 2016), demanding more active management of effort (Johnston *et al.* 2015). In this context, the realisation that angling can be a major source of mortality on some coastal stocks is increasing (e.g. Strehlow *et al.* 2012), which is also happening in several African countries (Belhabib *et al.* 2016) that traditionally focused on commercial or subsistence fisheries.

Catch-and-release is regularly considered by managers and some angler groups as a solution to trade-off fishing effort and fishing impacts on stocks. Accordingly, the utility of catch-and-release angling and its effects on individual fish and populations has received considerable attention in recent years (e.g. Hühn & Arlinghaus 2011; Bower *et al.* 2016; Olaussen 2016). Although with a primary objective to reduce mortality, catch-and-release can also lead to fitness impacts (Richard *et al.* 2013) and affect entire populations (Coggins *et al.* 2007; Johnston

et al. 2015), in turn demanding continued attention by scientists and managers to develop science-based best-practice guidelines (Arlinghaus *et al.* 2007).

Recent research has moved beyond describing and documenting ecological impacts of recreational fishing towards a mechanistic understanding of what drives the interactions between anglers/fishers and fish stocks in a spatially explicit fashion (Post *et al.* 2008; Hunt *et al.* 2011). This has been done using mechanistic models of angler behavior (Fenichel *et al.* 2013) to study how dynamic angler behavior systematically affects fish stocks across a range of fish life histories (Johnston *et al.* 2013, 2015). Extending single fishery cases to a landscape perspective (Lester *et al.* 2003; Hunt *et al.* 2011) is also revealing how anglers may be important vectors of the spread of novel (and possibly invasive) organisms released from bait buckets (Johnson *et al.* 2009) or attached to fishing gear and boats (Drake & Mandrak 2014).

There is an increasing realisation of the potential for fisheries-induced evolution of life-history and behavioural traits, which can affect population dynamics and catchability/catch rates (Philipp *et al.* 2009; Sutter *et al.* 2012; Alós *et al.* 2015; Arlinghaus *et al.* in press a). The largest impact of anglers on the genetic composition of fish stocks is, however, likely to originate from stocking-based stock enhancement (van Poorten *et al.* 2011), for which there is a growing conservation concern (Cowx *et al.* 2010; Arlinghaus *et al.* 2016). Also, there is growing recognition of the importance of maintaining diversity in age classes and demographic structure of fish populations to maintain resilient fisheries (FAO 2012). This includes conserving large individuals in exploited stocks, which can have the advantage of improving the angling experience for trophy-oriented angler types (Gwinn *et al.* 2015).

Monitoring and assessment

Managing recreational fisheries in the absence of at least some form of monitoring information is problematic (Hansen *et al.* 2015; Arlinghaus *et al.* in press b). However, monitoring poses particular challenges when assessing the usually diffuse recreational anglers dispersed across hundreds if not thousands of lakes, along the banks of a long river channel or across the coastal landscape (Lester *et al.* 2003). Novel data-poor assessment methods are thus urgently needed (Beard *et al.* 2011), and some important progress has been made (Lorenzen *et al.* 2016). In some areas of the world, there are large initiatives designed to improve the monitoring of recreational fisheries (Camp *et al.* 2016; Dedual & Rohan 2016; Motta *et al.* 2016; Ryan *et al.* 2016). For

example, large-scale survey efforts are underway in European marine fisheries to characterize catch and harvest of anglers and include the information in stock assessments (Strehlow *et al.* 2012). One case from an emerging economy country is the marine recreational fishery in Kwa-Zulu Natal, South Africa, which offers a 40-year catch and effort monitoring dataset (Maggs *et al.* 2015). While this monitoring project was built on conventional techniques and strong institutional support, this is seldom the case and novel assessment methods for data poor regions are needed for most recreational fisheries (Beard *et al.* 2011). Initiatives featuring under “citizen science” show great promise but are still under development and require data calibration and well-developed incentives for anglers to support the collaboration with scientists and/or managers (Papenfuss *et al.* 2015).

Recreational fisheries as coupled social-ecological systems

The 6th WRFC in 2011 in Berlin focused strongly on an integrative view of recreational fisheries as complex adaptive social-ecological systems (SES) (Arlinghaus *et al.* 2013) where behavioural dynamics of anglers, managers and policy makers are key drivers shaping system outcomes (Ward *et al.* in press). Coupled SESs differ from simple systems due to the presence of cross-scale interactions, non-linear feedbacks and the existence of large individual and spatial heterogeneity (reviewed in Arlinghaus *et al.* in press b). There is much to gain from developing a systematic understanding of how recreational fisheries function and how macro-scale emergent properties such as regional overfishing emerge from localised interactions among anglers and ecosystems (e.g. Carpenter & Brock 2004; Hunt *et al.* 2011; van Poorten *et al.* 2011; Arlinghaus *et al.* in press b). It is likely that analysing the sustainability of coupled SES based on a complex adaptive system view will become more important in the future, as will be integrated interdisciplinary projects in general (Arlinghaus *et al.* in press b). Taking a complexity-science view on recreational fisheries is particularly important to understand how the system deals with change, whether it can adapt to new situations and how to move particular recreational fisheries from one state to another where there is a desire to transform (see Arlinghaus *et al.* in press b for a full account). In this context, collaboration between researchers, fisheries managers, recreational fishers and other stakeholders is of great importance to the sector and the management of recreational fisheries (Dedual *et al.* 2013). This can be best accomplished by fostering integrated, interdisciplinary recreational fisheries science and management, which is rarely done (Arlinghaus *et al.* 2014).

Conclusions and recommendations for the future

In light of the issues discussed above: the following key conclusions and recommendations were derived at the 7th WRFC.

- In many developed and most developing nations, a strong focus towards commercial fisheries has created a large data gap in relation to recreational fisheries. Well funded assessments of recreational fisheries (including long-term commitments to development of reliable national-scale survey instruments) and capacity building programmes are needed to address the issues and to foster greater acceptance of recreational fisheries as a significant component of global fisheries. Gaps in knowledge of recreational fisheries that need to be addressed include: the biology of target species, monitoring of the resource status, fishing pressure, sustainability and ecological impact, demographics and human dimensions of fishers, economic impact and value, efficacy of management interventions, and options to apply new technologies to obtain data and information from the sector (Beard *et al.* 2011; Cooke *et al.* 2016; Lorenzen *et al.* 2016). Partnerships among scientists from different countries will be important when there is lack of local knowledge on some of these issues.
- The capacity of recreational fisheries practitioners to deal with global and regional change depends on a solid interdisciplinary knowledge base (FAO 2012). There is an urgent need and scope for universities and research institutions to develop interdisciplinary recreational fisheries science programmes that cross and integrate social and ecological sciences to train and educate a new generation of scholars and managers that will be able to work collaboratively and across disciplines (Arlinghaus *et al.* 2014). Such programmes need to adhere to the same rigor as disciplinary approaches to recreational fisheries. It is not a trivial task for a biologist, for example, to become proficient with angler survey methods and psychometric scaling techniques. Hence, we strongly advocate to build interdisciplinary teams of disciplinary experts rather than individuals or groups trying to accumulate all expertise in a range of methods and competencies as economics, econometrics, survey research, population biology and evolutionary biology (Arlinghaus *et al.* in press b). In both developed and developing nations interdisciplinary capacity need to be urgently developed, possibly assisted by training programmes offered by established programmes as suggested by FAO (2012).
- There is an urgent need to develop rapid data poor assessment methods and generally better monitoring systems of both fish and fishers.

- Increasing needs and demands from a growing recreational fisheries sector call for functional and efficient governance arrangements to ensure sustainable recreational fisheries and integrate management of commercial and recreational fisheries. Recreational fisheries governance improvements require research into the following.

- Institutional frameworks: strong organisations of recreational fishers appear to result in better functioning government institutions for recreational fisheries; stories of success and failures need to be better communicated and shared.
- Policy frameworks: comparative studies of successful and failed frameworks should be conducted and outcomes need to be communicated and shared.
- Licensing frameworks: mechanisms to establish license systems and angler registrations and their benefits and pitfalls should be documented and disseminated.
- Management frameworks: development of rigorous management frameworks based on agreed-upon objectives and harvest control rules are needed.
- To foster sustainable angling tourism, there is a need for case studies that demonstrate effective and responsible development of recreational fisheries in economies in transition that accrue benefits locally as well as those that are managed sustainably in line with local culture and customs.
- To address conflicts and improve co-management of commercial and recreational fisheries, there is a need to build good communication structures where stakeholders with different views and aspirations can work together in a productive atmosphere.
- In some developed countries the angler population is decreasing due to structural change and changing values from anthropocentrism to biocentrism, which strongly affects accepted management policies and angling practices (Arlinghaus *et al.* 2012). To address this issue, there is a need to understand how societal values influence perspectives on angling and how angling, and generally fishing participation, can be fostered through removal of structural barriers. This demands moving beyond the “piscicentric” focus that has characterised recreational fisheries for decades (Cowx 1998).
- Illegal, unreported and unregulated (IUU) recreational fisheries are prevalent in many countries (Baigún *et al.* 2006; Freire *et al.* 2012), causing conflicts, overexploitation and reduced effectiveness of management. The scope and size of this problem is not well-understood, demanding increased scientific and management attention. Traditional management strategies that require extensive enforcement are prohibitive and there is room

for increasing use of non-traditional management approaches that foster compliance (Cooke *et al.* 2013).

- Catch-and-release is common in many recreational fisheries, which is a consequence of harvest regulations or voluntarily done by more specialised anglers (Arlinghaus *et al.* 2007). With evolving fishing techniques and technology and warming waters, there is need to develop and refine species-specific best practice guidelines to maintain the welfare status of fish and ensure sub-lethal effects and post-release mortality are minimised (Cooke & Suski 2005; Arlinghaus *et al.* 2007). This information should be shared with anglers and managers through effective communication channels (Nguyen *et al.* 2012). Conversely, in cases where fish will be consumed or have been over-stressed (decreasing their chance of survival), proper killing techniques should be applied to minimise welfare impacts and maximise flesh quality (Diggles 2015).
- Levels of research and communication on recreational fisheries vary tremendously between countries and regions. This has caused gaps in global knowledge on issues such as exploitation levels/pressure, introductions of species and restocking, or spread of invasive species. New forms of communication technologies, using social media and apps, offer great promise to facilitate data collection and communication within and beyond the sector, but data quality needs to be rigorously assessed. In this context, recreational fisheries researchers, fishers, managers, policy and decision makers and other stakeholders should maintain and increase collaboration (Dedual *et al.* 2013), to maximise the value and utility of recreational fisheries research and management and ensure that work towards sustainability objectives will be coherent and effective, while acknowledging local and regional diversity in values and cultures.

To conclude, recreational fisheries management requires a rapid transition from single objective management to ecosystem management and aquatic stewardship using adaptive approaches that include monitoring and re-evaluation of practices through time (FAO 2012; Arlinghaus *et al.* 2016, in press b). Policy and management decision-makers, and all stakeholders involved in developing and executing policy and technical interventions relevant to recreational fisheries, are recommended to apply the FAO Technical Guidelines for Responsible Fisheries: Recreational Fisheries (FAO 2012), which were developed by an Expert Consultation held in conjunction with the 6th WRFC in Berlin, Germany, and were promoted at the global level by the FAO at the 7th WRFC in Campinas, Brazil. It is hoped that the presented documentation of key papers from the 7th WRFC and the conclusions and recommendations given above assist in achieving healthy, vibrant, resilient and

sustainable recreational fisheries on a global scale. Part of this future includes the need for resilience by dealing with unavoidable change and to adapt, and where necessary, transform to new social and ecological conditions, while maintaining high quality ecosystem services from recreational fisheries into the future.

Acknowledgements

We thank the Advisory Board of the 7th WRFC for their large contributions in shaping the event, the local organizers and sponsors of the conference, in particular: Fundação para o Desenvolvimento da Educação (FNDE), Food and Agriculture Organization of the United Nations (FAO), Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), International Game Fishing Association (IGFA), Fish TV, SANASA-Campinas, PESCARTE, Federação de Pesca Esportiva, Turística e Ambiental de São Paulo, Prefeitura Municipal de Campinas, Rede Anhanguera de Comunicação, Kalua Barco Hotel, PESCAVENTURA, Jair Rigotti Eventos e Promoções, and Campinas Visitors Bureau.

References

- Alós J., Palmer M. & Arlinghaus R. (2015) Recreational angling intensity correlates with alteration of vulnerability to fishing in a carnivorous coastal fish species. *Canadian Journal of Fisheries and Aquatic Sciences* **72**, 217–225.
- Arlinghaus R., Mehner T. & Cowx I.G. (2002) Reconciling traditional inland fisheries management and sustainability in industrialised countries, with emphasis on Europe. *Fish and Fisheries* **3**, 261–316.
- Arlinghaus R., Cooke S.J., Lyman J., Policansky D., Schwab A., Suski C. *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., Schwab A., Riepe C. & Teel T. (2012) A primer on anti-angling philosophy and its relevance for recreational fisheries in urbanized societies. *Fisheries* **37**, 153–164.
- Arlinghaus R., Cooke S.J. & Potts W. (2013) Towards resilient recreational fisheries on a global scale through improved understanding of fish and fisher behaviour. *Fisheries Management and Ecology* **20**, 91–98.
- Arlinghaus R., Hunt L.M., Post J.R. & Allen M.S. (2014) Not fish not meat: some guidance on how to study fisheries from an interdisciplinary perspective. In: W.W. Taylor, A.J. Lynch & N.J. Léonard (eds) *Future of Fisheries: Perspectives for Emerging Professionals*. Bethesda, MD: American Fisheries Society, pp. 223–230.
- Arlinghaus R., Tillner R. & Bork M. (2015) Explaining participation rates in recreational fishing across industrialised countries. *Fisheries Management and Ecology* **22**, 45–55.
- Arlinghaus R., Lorenzen K., Johnson B.M., Cooke S.J. & Cowx I.G. (2016) Management of freshwater fisheries: addressing habitat, people and fishes. In: J.F. Craig (ed) *Freshwater Fisheries Ecology*. Oxford: Wiley Blackwell, pp. 557–579.
- Arlinghaus R., Laskowski K.L., Alós J., Klefoth T., Monk C.T., Nakayama S. *et al.* Passive gear-induced timidity syndrome in wild fish populations and its potential ecological and managerial implications. *Fish and Fisheries* (in press a).
- Arlinghaus R., Alós J., Beardmore B., Daedlow K., Dorow M., Fujitani M. *et al.* Understanding and managing freshwater recreational fisheries as complex adaptive social-ecological systems. *Reviews in Fisheries Science and Aquaculture* (in press b).
- Baigún C., Bernal R., Barrientos D., Oz L.M., Barros E. & Sauad J. (2006) The recreational fishery in cabra corral reservoir (Argentina): a first comprehensive analysis. *Biocell* **30**, 125–130.
- Barrella W., Ramires M., Rotundo M.M., Petrere M. Jr, Clauzet M. & Giordano F. (2016) Biological and socio-economic aspects of the recreational fisheries and its implications to the management of coastal urban areas of south-eastern Brazil. *Fisheries Management and Ecology* **23**, 303–314.
- Bate R. (2001) *Saving Our Streams: The Role of the Anglers' Conservation Association in Protecting English and Welsh Rivers*. London: The Institute of Economic Affairs and Profile Books, p. 125.
- Beard D.T., Arlinghaus R., Cooke S.J., McIntyre P.B., De Silva S., Bartley D. *et al.* (2011) Ecosystem approach to inland fisheries: research needs and implementation strategies. *Biology Letters* **7**, 481–483.
- Belhabib D., Campredon P., Lazar N., Sumaila U.R., Baye B.Y., Kane E.A. *et al.* (2016) Best for pleasure, not for business: evaluating recreational marine fisheries in West Africa using unconventional sources of data. *Palgrave Communications* DOI:10.1057/palcomms.2015.50.
- Bower S.D., Nguyen V.M., Danylchuk A.J., Beard T.D. Jr & Cooke S.J. (2014) Inter-sectoral conflict and recreational fisheries of the developing world: Opportunities and challenges for co-operation. In: P. McConney, R. Medeiros & M. Pena (eds) *Enhancing Stewardship in Small-Scale Fisheries: Practices and Perspectives*. Too Big To Ignore (TBTI) and Centre for Resource Management and Environmental Studies, The University of the West Indies, Cave Hill Campus. CERMES Technical Report No. 73, pp. 88–97.
- Bower S.D., Danylchuk A.J., Raghavan R., Clark-Danylchuk S.E., Pinder A.C. & Cooke S.J. (2016) Rapid assessment of the physiological impacts caused by catch-and-release angling on blue-finned mahseer (*Tor* sp.) of the Cauvery River, India. *Fisheries Management and Ecology* **23**, 208–217.
- Camp E.V., Ahrens R.N.M., Allen M.S. & Lorenzen K. (2016) Relationships between angler effort and fish abundance in

- recreational marine fisheries. *Fisheries Management and Ecology* **23**, 264–275.
- Carpenter S.R. & Brock W.A. (2004) Spatial complexity, resilience, and policy diversity: fishing on lake-rich landscapes. *Ecology and Society* **9**, 8 [online journal <http://www.ecologyandsociety.org/vol9/iss1/art8>].
- Coggins L.C. Jr, Catalano M.J., Allen M.S., Pine W.E. III & 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. & Cowx I.G. (2006) Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation* **128**, 93–108.
- Cooke S.J. & Murchie K.J. (2015) Status of aboriginal, commercial and recreational inland fisheries in North America: past, present and future. *Fisheries Management and Ecology* **22**, 1–13.
- Cooke S.J. & Suski C.D. (2005) Do we need species-specific guidelines for catch and release recreational angling to effectively conserve diverse fishery resources? *Biodiversity and Conservation* **14**, 1195–1209.
- Cooke S.J., Suski C.D., Arlinghaus R. & Danylchuk A.J. (2013) Voluntary institutions and behaviours as alternatives to formal regulations in recreational fisheries management. *Fish and Fisheries* **14**, 439–457.
- Cooke S.J., Arlinghaus R., Johnson B.M. & Cowx I.G. (2016) Recreational fisheries in inland waters. In: J.F. Craig (ed) *Freshwater Fisheries Ecology*. Oxford: Wiley Blackwell, pp. 449–465.
- Cowx I.G. (1998) Aquatic resource planning for resolution of fisheries management issues. In: P. Hickley & H. Tompkins (eds) *Social, Economic and Management Aspects of Recreational Fisheries*. Oxford: Fishing News Books, Blackwell Science, pp. 97–105.
- Cowx I.G. (2015) Characterisation of European inland fisheries. *Fisheries Management and Ecology* **22**, 78–87.
- 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.
- Dedual M. & Rohan M. (2016) Long term trends in the catch characteristics of rainbow trout *Onchorhynchus mykiss*, in a self-sustained recreational fishery, Tongariro River, New Zealand. *Fisheries Management and Ecology* **23**, 234–242.
- Dedual M., Sague Pla O., Arlinghaus R., Clarke A., Ferter K., Geertz Hansen P. *et al.* (2013) Communication between scientists, fishery managers and recreational fishers: lessons learned from a comparative analysis of international case studies. *Fisheries Management and Ecology* **20**, 234–246.
- Dellacasa R.F. & Braccini J.M. (2016) Adapting to social, economic and ecological dynamics: changes in Argentina's most important marine angling tournament. *Fisheries Management and Ecology* **23**, 330–333.
- Diggles B. (2015) Development of resources to promote best practice in the humane dispatch of finfish caught by recreational fishers. *Fisheries Management and Ecology* **23**, 200–207.
- Drake A.R. & Mandrak N.E. (2014) Ecological risk of live bait fisheries: a new angle on selective fishing. *Fisheries* **39**, 201–211.
- 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, p. 176.
- Fenichel E.P., Abbott J.K. & Huang B. (2013) Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature. *Fish and Fisheries* **14**, 137–157.
- Freire K.M.F., Machado M.L. & Crepaldi D. (2012) Overview of Inland recreational fisheries in Brazil. *Fisheries* **37**, 484–494.
- Freire K.M.F., Tubino A., Monteiro-Neto C., Andrade-Tubino M.F., Belruss C.G., Tomás A.R.G. *et al.* (2016) Brazilian recreational fisheries: current status, challenges and future direction. *Fisheries Management and Ecology* **23**, 276–290.
- Freudenberg P. & Arlinghaus R. (2010) Benefits and constraints of outdoor recreation for people with physical disabilities: inferences from recreational fishing. *Leisure Sciences* **32**, 55–71.
- Griffiths S.P., Bryant J., Raymond H.F. & Newcombe P.A. Quantifying subjective human dimensions of recreational fisheries: does good health come to those who bait? *Fish and Fisheries* DOI: 10.1111/faf.12149 (in press).
- Gwinn D.C., Allen M.S., Johnston F.D., Brown P., Todd C.R. & Arlinghaus R. (2015) Rethinking length-based fisheries regulations: the value of protecting old and large fish with harvest slots. *Fish and Fisheries* **16**, 259–281.
- Hansen G.J.A., Gaeta J.W., Hansen J.F. & Carpenter S.R. (2015) Learning to manage and managing to learn: sustaining freshwater recreational fisheries in a changing environment. *Fisheries* **40**, 56–64.
- Hickley P. & Tompkins H. (eds) (1998) *Recreational Fisheries: Social, Economic and Management Aspects*. Oxford: Fishing News Books, Blackwell Science 310 pp.
- Hühn D. & Arlinghaus R. (2011) Determinants of hooking mortality in freshwater recreational fisheries: a quantitative meta-analysis. *American Fisheries Society Symposium* **75**, 141–170.
- Hunt L., Arlinghaus R., Lester L. & Kushneriuk R. (2011) The effects of regional angling effort, angler behaviour, and harvesting efficiency on landscape patterns of overfishing. *Ecological Applications* **21**, 2555–2575.
- Johnson B.M., Arlinghaus R. & Martinez P. (2009) Are we doing all we can to stem the tide of illegal fish stocking? *Fisheries* **34**, 389–394.
- Johnston F.D., Arlinghaus R. & Dieckmann U. (2013) Life history, angler behaviour, and optimal management of recreational fisheries. *Fish and Fisheries* **14**, 554–579.
- Johnston F.D., Beardmore B. & Arlinghaus R. (2015) Optimal management of recreational fisheries in the presence of

- hooking mortality and noncompliance – predictions from a bioeconomic model incorporating a mechanistic model of angler behavior. *Canadian Journal of Fisheries and Aquatic Sciences* **72**, 37–53.
- Lester N.P., Marshall T.R., Armstrong K., Dunlop W.I. & Ritchie B. (2003) A broad-scale approach to management of Ontario's recreational fisheries. *North American Journal of Fisheries Management* **23**, 1312–1328.
- Lewin W.-C., Arlinghaus R. & Mehner T. (2006) Documented and potential biological impacts of recreational fishing: insights for management and conservation. *Reviews in Fisheries Science* **14**, 305–367.
- Li O., Gray S.A. & Sutton S.G. (2016) Mapping recreational fishers' informal learning of scientific information using a fuzzy cognitive mapping approach to mental modelling. *Fisheries Management and Ecology* **23**, 315–329.
- Lorenzen K., Cowx I.G., Entsua-Mensah R.E.M., Lester N.P., Koehn J.D., Randall R.G. *et al.* (2016) Stock assessment in inland fisheries: a foundation for sustainable use and conservation. *Reviews in Fish Biology and Fisheries* DOI:10.1007/s11160-016-9435-0 (in press).
- Mags J.Q., Mann B.Q., Potts W.M. & Dunlop S.W. (2015) Traditional management strategies fail to arrest a decline in the CPUE of an iconic marine recreational fishery species with evidence of hyperstability. *Fisheries Management and Ecology* **23**, 187–199.
- Moksness E., Gjørseter J., Lagaille G., Mikkelsen E., Olsen E.M., Sandersen H.T. *et al.* (2011) Effects of fishing tourism in a coastal municipality: a case study from Risør, Norway. *Ecology and Society* **16**, 11.
- Motta F.S., Mendonça J.T. & Moro P.S. (2016) Collaborative assessment of recreational fishing in a subtropical estuarine system: a case study with fishing guides from Southeastern Brazil. *Fisheries Management and Ecology* **23**, 291–302.
- Nguyen V.M., Rudd M., Cooke S.J. & Hinch S.G. (2012) Differences in information use and preferences among recreational salmon anglers: implications for management initiatives to promote responsible fishing. *Human Dimensions of Wildlife* **17**, 248–256.
- Olaussen J.O. (2016) Catch-and-release and angler utility: evidence from an Atlantic salmon recreational fishery. *Fisheries Management and Ecology* **23**, 253–263.
- Papenfuss J.T., Phelps N., Fulton D. & Venturelli P.A. (2015) Smartphones reveal angler behavior: a case study of a popular mobile fishing application in Alberta, Canada. *Fisheries* **40**, 318–327.
- Parkkila K., Arlinghaus R., Artell J., Gentner B., Haider W., Aas Ø. *et al.* (2010) *European Inland Fisheries Advisory Commission Methodologies for Assessing Socio-Economic Benefits of European Inland Recreational Fisheries*. Rome: FAO: European Inland Fisheries Advisory Commission Occasional Paper 46, 112 pp.
- 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.
- van Poorten B., Arlinghaus R., Daedlow K. & Haertel-Borer S. (2011) Social-ecological interactions, management panaceas, and the future of wild fish. *Proceedings of the National Academy of Sciences of the United States of America* **108**, 12554–12559.
- Post J.R., Sullivan M., Cox S., Lester N.P., Walters C.J., Parkinson E.A. *et al.* (2002) Canada's recreational fisheries: the invisible collapse? *Fisheries* **27**, 6–15.
- Post J.R., Persson L., Parkinson E.A. & Van Kooten T. (2008) Angler numerical response across landscapes and the collapse of freshwater fisheries. *Ecological Applications* **18**, 1038–1049.
- Pretty J., Hine R. & Peacock J. (2006) Green exercise: the benefits of activities in green places. *The Biologist* **53**, 143–148.
- Richard A., Lanie Dionne M.E., Wang J. & Bernatchez L. (2013) Does catch and release affect the mating system and individual reproductive success of wild Atlantic salmon (*Salmo salar* L.)? *Molecular Ecology* **22**, 187–200.
- Riepe C. & Arlinghaus R. (2014) Explaining anti-angling sentiments in the general population of Germany: an application of the cognitive hierarchy model. *Human Dimensions of Wildlife* **19**, 371–390.
- Ryan K.L., Trinnie F.I., Jones R., Hart A.M. & Wise B.S. (2016) Recreational fisheries data requirements for monitoring catch shares. *Fisheries Management and Ecology* **23**, 218–233.
- Schratwieser J., Sutton S.G. & Arlinghaus R. (2011) *Introduction*. Bethesda, MD: American Fisheries Society Symposium **75**, 1–9.
- Sheaves M., Baker R., McLeod I., Abrantes K., Wani J. & Barnett A. (2016) The conservation status of Niugini black bass: a world-renowned sport fish with an uncertain future. *Fisheries Management and Ecology* **23**, 243–252.
- Solstrand M.-V. (2013) Marine angling tourism in Norway and Iceland: finding balance in management policy for sustainability. *Natural Resource Forum* **37**, 113–126.
- Strehlow H.V., Schultz N., Zimmermann C. & Hammer C. (2012) Cod catches taken by the German recreational fishery in the western Baltic Sea, 2005–2010: implications for stock assessment and management. *ICES Journal of Marine Science* **69**, 1769–1780.
- Sutter D.A.H., Suski C.D., Philipp D.P., Klefoth T., Wahl D.H., Kersten P. *et al.* (2012) Recreational fishing selectively captures individuals with the highest fitness potential. *Proceedings of the National Academy of Sciences of the United States of America* **109**, 20960–20965.
- Ward H., Hunt L.M., Allen M., Camp E., Cole N., Matthias B. *et al.* Understanding and managing social-ecological feedbacks in spatially-structured recreational fisheries: the overlooked behavioral dimension. *Fisheries* (in press).
- Weithman A.S. (1999) Socioeconomic benefits of fisheries. In: C.C. Kohler & W.A. Hubert (eds) *Inland Fisheries*

- Management in North America*, 2nd edn. Bethesda, MD: American Fisheries Society, pp. 193–213.
- Welcomme R.L. (2001) *Inland Fisheries: Ecology and Management*. Oxford, UK: Blackwell, p. 350.
- World Bank (2012) *Hidden harvest: the global contribution of capture fisheries*. Report No. 66469-GLB. Washington, DC: International Bank for Reconstruction and Development, 92 pp.