



## Preparing recreational fisheries for the uncertain future: An update of progress towards answering the 100 most pressing research questions

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### ABSTRACT

The socio-cultural, economic, and environmental conditions of the world are changing rapidly and recreational fisheries will have to adapt to the uncertain future. Key research areas include assessing the sustainability of recreational fishing in response to climate change, ongoing biodiversity decline and changing social values. In this context, technological advances and digitalization can play a major role in advancing recreational fisheries. We evaluated the contributions of research that was presented at the 9th World Recreational Fishing Conference relative to 100 key research questions identified for recreational fisheries in 2020. Given that the 9th WRFC happened in the midst of the COVID-19 pandemic, we additionally synthesise impacts of COVID-19 on recreational fisheries. We found that the majority of contributions focused on resource monitoring and catch and release, while less attention was dedicated to governance, management-stock and habitat enhancement, and threats to sustainability. Rapid technological advances represent both a challenge (e.g., difficulty in management response), but also an opportunity for recreational fisheries (e.g., hyper connectivity of digital platforms for communication). Science is helping recreational fisheries to adapt and remain resilient to rapid social and environmental uncertainties, but this knowledge must be incorporated into governance structures and resource allocation strategies to ensure effective implementation.

### 1. Introduction

Fishing has been practised since early prehistoric times as a source of food (Nyboer et al., 2022; Sahrhage and Lundbeck, 2012) and for fun (Pitcher and Hollingworth, 2002). Today, recreational fisheries provide leisure and recreation benefits to about 300 million recreational fishers worldwide (Arlinghaus et al., 2019), but they are still an important source of food (FAO, 2020). Consequently, the economic, socio-cultural and conservation dimensions of recreational fisheries need to be considered alongside commercial and subsistence fisheries in striving for sustainability and resilience (Arlinghaus et al., 2019). The high social relevance has motivated research dedicated to the advancement our knowledge of recreational fisheries and satisfy the interest of policy makers in monitoring and sustainably managing recreational fisheries (Arlinghaus et al., 2013; Brownscombe et al., 2019).

The socio-cultural, economic, and environmental conditions of the world are changing rapidly and recreational fisheries will have to adapt to be sustainable. Issues such as climate change, ongoing biodiversity decline and changing social values all affect the recreational fisheries sector (Arlinghaus et al., 2021; Ban et al., 2010; Townhill et al., 2019). Changes are also happening within the recreational fisheries sector, for example, some fisheries are developing high rates of voluntary catch-and-release (Arlinghaus et al., 2021; Cooke and Schramm, 2007). Technological advances (e.g., livescope sonar, drones) are also changing the way in which recreational fishers exploit fishes (Cooke et al., 2021;

Winkler et al., 2022) and exchange information on things such as fishing sites (Lennox et al., 2022). However, technological advances can also be used to improve knowledge generation. For example, digitalization is changing the pathways by which the dynamics of recreational fisheries can be studied (Lennox et al., 2022). The incorporation of these changes into governance will be critical to maintain sustainable and viable recreational fisheries.

The tri-annual World Recreational Fishing Conference (WRFC) is the most prominent international scientific conference where recreational fisheries scientists, managers, policy makers, fishers of all types, private and corporate interests, and other stakeholders meet to share cutting-edge scientific information about recreational fisheries worldwide. The 9th WRFC was planned to be held in Rotterdam (The Netherlands) in July 2020, and it had attracted about 400 delegates from 25 countries who were going to present more than 200 contributions. Unfortunately, as many other events around the globe, the 9th WRFC was postponed to 2021 due to the COVID-19 pandemic. A smaller online event was organised on 28th and 30th of July 2021 where 48 talks were selected among those previously submitted in 2020. The online event attracted about 500 participants from 42 countries. The conference theme was “*Recreational fishing in a changing world*”, and the main objectives were to shed light on changes associated with the recreational fishing sector, social relevance and acceptance, interactions with stakeholders, environmental changes and stock management.

Here, we present an overview and commentary on the contributions

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from the special issue associated with the 9th WRFC that are published in Fisheries Research (Fig. 1), and evaluate them relative to a previously published list of 100 pressing research questions in recreational fisheries for global consideration in a horizon scan (Holder et al., 2020). We used nine the conceptual categories (i.e., human dimensions; bioeconomics; resource monitoring and data acquisition; governance; management-regulatory actions; management-stock and habitat enhancement; catch-and-release; impacts of recreational fisheries on populations, communities and ecosystems; outreach, education and engagement) presented by Holder et al., 2020, and examined how the papers in the special issue contributed to these key areas (Sections 2–11). Finally, the major impact that the COVID-19 pandemic has had on human activities related to the environment (Bates et al., 2021; Rutz et al., 2020) emphasises the unprecedented changes we face in understanding and managing resource use, including recreational fisheries. Considering the global effects of COVID-19 pandemic, including on the regular organisation of the WRFC (which was initially postponed and then moved entirely online), we dedicated specific attention to synthesising the recent documented effects of COVID-19 pandemic on recreational fisheries (Section 12).

## 2. Human dimensions

Managing people is a central paradigm of many fisheries (Hilborn, 2007), especially of recreational fisheries where the understanding of fishers and the drivers of their behaviour represents a link between social (i.e., benefits that individuals receive from fishing) and ecological (i.e., fishing-related stressors on aquatic ecosystems) systems that is crucial for effective management (Hunt et al., 2013). Despite this being a well-established concept, the integration of human dimensions' research of recreational fisheries with ecological fisheries science and management is still scarce. Holder et al. (2020) presented 15 questions to be answered to provide foundational information from which managers can predict impacts from fishing by understanding anglers' responsiveness (effort) to changing social and ecological conditions and anglers and managers' abilities to influence catchability and harvest of fish and

compliance with the regulations. Among them, an overarching question is related to identifying the most important factors for achieving angler satisfaction given an increasingly diverse angling community. Birdsong et al. (2022) compared catch outcomes and satisfaction in two German recreational fisheries with contrasting governance and cultural contexts. They showed that catch rate and size of fish positively affect catch satisfaction in both contexts, but anglers in the small-scale club context from north-western Germany were, on average, more satisfied with their catch than anglers in a large-scale regional context from north-eastern Germany. These findings suggest that managers cannot expect anglers to be similarly satisfied with identical catch outcomes in different social-ecological contexts, even within the same nation. In another contribution, Yamashita et al. (2022) provided an example from a non-Western country by providing insights on the factors contributing to the anglers' satisfaction and their requests concerning salmonid recreational fisheries management in two strictly regulated, reservation-only, catch-and-release stream fishing areas in Japan. Surveyed recreational anglers showed that catch numbers of large salmon were positively related to their satisfaction, but enhancing the number of large fish received the lowest priority among the requests for fisheries management. Therefore, the key determinants of angler satisfaction may not be the most important management targets, which is an important aspect to consider to avoid management pitfalls. Another important question is how regulations, enforcement, and behavioural nudges could be used to foster greater compliance and stewardship activities among recreational fishers. Bova et al. (2022) tackle this problem by using the ballot box method for reducing social desirability bias and found extremely high levels of non-compliance (52%) among South African marine shore-based recreational fishers. Most importantly, they suggest that calls for increased enforcement as a means of improving compliance behaviour will probably not be effective because perceptions and observations of enforcement activity had no significant impact on compliance behaviour (e.g., recreational fishers that had previously been caught by law enforcement violating the regulations were still more likely to violate the regulations than participants that had not faced enforcement action; Bova et al., 2022). These findings suggest that normative interventions may also be necessary to improve compliance in this fishery.

## 3. Bioeconomics

The economic dimension of fisheries is a crucial factor linked to fishers' behaviour, natural resources, yield, and management actions (Anderson and Seijo, 2010). Within the recreational fisheries realm, bioeconomics models are intimately linked to human dimensions, specifically expectations of benefits and behavioural responses to changes in the environment (Abbott et al., 2018; Fenichel and Abbott, 2014; Johnston et al., 2010). Economic measures, such as angler utility, can also be used as a measure of optimal social yield outcomes, which can be a more suitable management objective than physical yield (Arlinghaus et al., 2019; Johnston et al., 2010; Malvestuto and Hudgins, 1996; Roedel, 1975). Holder et al. (2020) presented 11 questions that focus on understanding the production process that leads a valuable and enjoyable recreational fishing experience. Although those questions were not directly addressed among the contributions of this special issue, there are two contributions that highlighted interesting economic topics. Schilling et al. (2022) used a travel-cost method to estimate the overall value generated by two regional spearfishing competitions in eastern Australia. They showed that both competitions generated substantial economic activity within the towns that hosted them (i.e., localised expenditure constituted 60–71% of a competition's overall value). Spearfishing tournaments may contribute to increase the understanding of recreational spearfishing, which is poorly understood with respect to angling (Sbragaglia et al., 2021a), and this study demonstrates that there is a local economic benefit that should be taken into consideration by managers. Bronnmann et al. (2022) showed that German cod (*Gadus*

**Fig. 1.** Word cloud of the most frequent words used in the abstracts of the 28 contributions published in the special issue. We cleaned the text of the abstracts of the papers by removing numbers, stopwords and punctuations. Subsequently, we tokenized the text by isolating all the words and quantified their frequency of occurrence.

*morhua*) anglers received high benefits from catching and consuming cod, and anglers preferred to catch as large cod as possible. Thus, cod anglers were found to be highly harvest-oriented, indicated by no utility gained at the individual level from catching and releasing cod. Anglers expressed clear preferences for tightening harvest regulations that involve increased rates of mandatory catch-and-release. Recently, following the stock collapse of the western Baltic cod, regulations of both commercial and recreational fisheries have indeed tightened, including reductions of a daily bag limit of 5 cod per day to just only one cod per day and angler. The choice experiment data by Bronnmann et al. (2022) implied that such a measure resulted in a significant reduction of anglers' welfare, with unknown benefits for the recovery of the cod stock.

#### 4. Resource monitoring and data acquisition

Resource monitoring in the context of recreational fisheries is one of the primary actions of management agencies, where data acquisition plays a fundamental role (Board and Council, 2006). The goal of monitoring is mainly focused in characterising the status of fish resources as well as socio-economic indicators of recreational fisheries with the ultimate goal to design effective management and policy (Arlinghaus and Cooke, 2009). The intrinsic difficulties in monitoring recreational fisheries is related to the fact that data collections usually depend on willingness to report, disperse nature of fishing activity or heterogeneity of fishers (Pollock et al., 1994). Such difficulties have stimulated a continuous research interest in increasing robustness of existing methods, and developing new ones with the help of emerging technologies such as smartphone applications (Venturelli et al., 2017), digital cameras (Hartill et al., 2020), drones (Provost et al., 2020), and internet-based data streams (Lennox et al., 2022). Holder et al. (2020) presented 11 questions that address persistent and emerging challenges associated with recreational fisheries data collection. Among these questions, one of the most obvious ones is how data-poor recreational fisheries can be assessed. Venerus and Parma (2022) proposed a two-stage approach to estimate the number of boat-fishing trips based on an access-point survey developed for situations in which recreational fishers make several fishing trips during their stay. The application of the method into a recreational fishery targeting rocky-reef fishes in Argentina showed that it can produce unbiased and more precise estimates of the number of boat-days compared to the traditional access-point survey method. This method can increase efficiency in monitoring recreational fisheries in remote locations where traditional approaches could be too resource consuming. Desfosses et al. (2022) applied nonparametric hierarchical bootstrapping to determine the mean mass for retained lobsters by Australian recreational fishers using several survey design-based methods. They showed that a fishing method-based survey is able to provide accurate estimates in particular when the ultimate sampling unit (i.e., level) is the lobster, helping to guide survey analyses to generate accurate estimates for fisheries management. Lewin et al. (2023) compared data obtained from diaries of German Baltic Sea cod anglers who were recruited from a list of angling permit holders (non-probability-based sample) with those who were recruited simultaneously during a probability-based representative telephone survey among the general population. The results indicated that recruiting diarists from the list of permit holders may be more successful in terms of participation rates, but may be more exposed to avidity and recall biases than recruiting from a general probability-based population survey.

In the context of resource monitoring, specific attention can be directed to knowledge gathered by recreational fisheries. Foster et al. (2023) collected recreational spearfishers' ecological knowledge and information on individual specialization using an online questionnaire. When they considered the responses from the most specialized spearfishers, they found that spearfishers' ecological knowledge information aligned with biological information collected using traditional methods.

Spearfishers' ecological knowledge data also provided information, such as spawning locality which was not collected using traditional methods. In a further study, van den Heuvel and Rönnbäck (2023) assessed anglers' perceived change in salmon and sea trout stocks in Sweden. The majority of the respondents perceived a negative trend for both species, and their engagement was an important moderator of such perception. Moreover, anglers with a longer history of fishing had a more negative perception overall suggesting the occurrence of the shifting baseline syndrome. Zumpano et al. (2022) conducted a review of recreational fishing research in South America and showed a scarcity of studies with the exception of Brazil and Argentina, which may lead only to a partial understanding of the benefits and impacts of recreational fisheries at the regional scale. They suggested unconventional monitoring tools such as citizen science and social media as a possible solution for mitigating the data-poor conditions (Lennox et al., 2022; Sbragaglia et al., 2020a).

#### 5. Governance

Recreational fisheries have not been historically considered on equal footing with commercial fisheries (Arlinghaus et al., 2019). From a governance perspective this has two major consequences. First, recreational fisheries governance systems in developed countries are poorly integrated into the wider fishery policy, and in developing countries governance systems often lack efficient governance structures and capacity (Arlinghaus et al., 2019; Potts et al., 2020). In this context, boosting and facilitating cooperation between stakeholders and managers could be one of the most effective solutions to bypass the problems related to the lack of effective governance structures (Cooke et al., 2013). This is a core issue to consider to increase sustainability of recreational fisheries at regional, national, and global levels. Holder et al. (2020) presented 8 questions surrounding the role that recreational fisheries governance can play in supporting sustainable management of fish populations and fisheries activities in situations that increasingly require cooperation among stakeholders. Klefoth et al. (2023) showed that anglers and managers in local club context shared many similarities in their perspectives about how to engage in management, but also important differences. Managers focused more on habitat enhancement and less on stocking, which was the most preferred management option by anglers (see also Section 7 for more specific contribution about stocking). This research emphasised the need for developing alignment in the perspectives of multiple stakeholders. While the co-production of knowledge in cooperation constitutes one way to reconcile divergent perspectives (Fujitani et al., 2017), care must also be taken when this information is communicated trying to align the perspectives of multiple stakeholders as they may perceive scientific information differently (Young et al., 2016).

#### 6. Management-regulatory actions

Regulatory actions in recreational fisheries have been historically oriented towards harvest control tools such as daily bag limits and minimum harvest size with the goal to control fishing mortality or direct it towards fishes with less vulnerable life histories (Radomski et al., 2001; Woodward and Griffin, 2003). Other regulatory tools include harvest slot limits (Ahrens et al., 2020; Gwinn et al., 2015), periodic spatial/temporal closures (Chagaris et al., 2019), harvest tags (Jackson et al., 2016; Johnston et al., 2007), quotas or limited access (Arlinghaus et al., 2019; Radomski, 2003). Although all these regulatory tools may positively and negatively contribute to the management goals (Ayllón et al., 2018; Maggs et al., 2016), there is consensus that the efficacy of each is highly context dependent (Navarro et al., 2022). Holder et al. (2020) presented 11 questions needing exploration regarding regulatory actions. Among them an interesting question is to identify the best ways to limit effort in specific areas (e.g., national parks, protected areas) or at specific times (e.g., during sensitive life history stages) while still allowing some level of recreational fishing activity. Nikolaus et al.



(2022) studied the effects of lake-scale riparian protected areas voluntarily assigned by recreational fishing clubs in Germany (i.e., reduced trampling and access to anglers and other recreationists). They showed that small-scale riparian protected areas had positive effects on habitat structure, riparian vegetation, local fish abundance and abundance of sensitive songbirds at the lake scale. Therefore, area-based constraints self-imposed by angler communities can have positive feedback at the lake scale both to recreational fishers (e.g., quality of fishing experience) and other recreationists (e.g., spotting of songbirds).

## 7. Management-stock and habitat enhancement

Fish stocking (i.e., release of aquaculture or wild captured fish to increase local stocks, Taylor et al., 2017) and habitat enhancement (i.e., artificial reefs or restoration of natural habitat) are two important management actions of recreational fisheries. Fish stocking has been historically applied in freshwater systems (Arlinghaus et al., 2015, 2022), but applications exist also in marine systems (Kitada, 2018). Although there is uncertainty around the economic, ecological, and genetic impacts of stocking (Arlinghaus et al., 2022; Kitada, 2018), generally, stakeholders prefer fish stocking over other types of regulations (Arlinghaus et al., 2022; Dorow and Arlinghaus, 2012; Klefoth et al., 2023). However, fishers support for stocking can vary depending on the level of motivation and fishing intensity or specialisation of the angling group (Arlinghaus and Mehner, 2005; Garlock and Lorenzen, 2017). Habitat enhancement impacts on recreational fisheries have rarely been documented. Artificial reefs have been tested as possible enhancement for marine recreational fisheries (Blount et al., 2021; Buckley, 1985), while habitat restoration have been mainly applied in freshwater systems (Roni et al., 2008). However, there is still a poor evidence base related to if and how habitat enhancement can increase fish production (e.g., Ziegler et al., 2019). Holder et al. (2020) presented 9 questions to clarify the role of whole-ecosystem manipulative studies to address the effects of stocking and habitat changes in the management of recreational fisheries. Among them, one question focused on whether and how stocking-based enhancement can be optimised to generate additive ecological and social effects. Kaemingk et al. (2022) explored whether certain waterbodies sizes receive a disproportionate amount of fish stocked and attract more angler effort (i.e., intended as a measure of ecosystem service). They found that smaller water bodies receive a disproportionate amount of fish stocked per area and also attract more angler effort per area. This highlights that small water bodies are prioritised by both managers and users and contribute more (per area) to recreational fisheries compared to large and more visible water bodies on the landscape. In a governance context (see Section 5), Klefoth et al. (2023) showed that managers focused more on habitat enhancement and less on stocking, which was the most preferred management option by anglers.

## 8. Catch-and-release

Voluntary catch-and-release (C&R) angling is an increasingly popular practice in recreational fisheries, with over half of captured fish being released worldwide (Cooke and Cowx, 2004). This can be an effective conservation practice; however, fish C&R survival rates and sublethal impacts are highly variable due to the interactive effects of angler behaviour and environmental conditions on fish physiology and behaviour (Brownscombe et al., 2017; Cooke and Suski, 2005). Further, when C&R is mandated by law through harvest regulations, compliance rates can be variable (Gigliotti and Taylor, 1990). Thus, it is important to understand the social and biological factors that lead to C&R behaviours by recreational anglers to ensure this practice is applied effectively to avoid overexploitation of recreationally angled fish stocks. Holder et al. (2020) highlighted that although many elements of C&R fisheries are well studied and basic tenants established, there remain many important questions to advance the sustainability of this practice.

One of the key questions posed by Holder et al. (2020) was to what extent can generalisations be made about fish responses to angling and to what degree species or site-specific studies are needed. The present special issue contains numerous C&R studies focused on how angling factors relate to fish health outcomes across diverse contexts. Butler et al. (2022) assessed the impacts of C&R practices on physiological stress, reflex impairment, and survival of previously unstudied dusky kob (*Argyrosomus japonicus*) in South Africa. Longer air exposure times resulted in higher stress and reflex impairment, although hooking injury was the primary determinant of survival. This research provided further support for the generalised '10 s rule' for minimising air exposure duration, as well as the importance of selecting hook and lure types that minimise hooking injuries. In a very different ecological system, Griffin et al. (2022) assessed the effects of C&R practices on giant trevally (*Caranx ignobilis*) in tropical flats of the Seychelles, and found that this species is robust to air exposure durations of up to 30 s, but can suffer mortality due to hooking injury. To further our understanding of dealing with fish hooking injuries, Cooke et al. (2022a) assessed a wide range of fish dehooking tools in bluegill in Canada, and found that they removed hooks quicker than bare hands, but caused significantly more tissue damage, as did barbed hooks compared to un-barbed, regardless of removal strategy. Cooke et al. (2022b) assessed the efficacy of a novel 'through-the-gills' hook removal technique for deeply hooked small-mouth bass in Canada, and found that it increased fish injury, leading to the conclusion that for fish hooked deeply in sensitive tissues, the best course of action remains to cut the line and leave the hook embedded in the tissue. These findings build upon our knowledge of generalised C&R best practices (Brownscombe et al., 2017), yet the question still remains to what degree species or even site-specific studies are required to develop effective guidelines – the large body of C&R literature provides a basis for this potential future synthesis project.

Although it is essential to characterise best angling practices for optimal fish outcomes in C&R, it is equally important to understand the underlying motivations of angler behaviours in terms of whether they participate in C&R and how fish are treated during the process. Blyth and Rönnbäck (2022) surveyed sea trout anglers in Sweden to assess their perceptions and motivations in deciding whether or not to release fish, and found anglers reported that their assessment of the fish's probability of survival and its spawning status were the strongest determinants of C&R behaviour. However, many anglers lacked awareness of delayed post-release mortality as well as the importance of angling factors (e.g., hook types, water temperatures) in fish survival. Skov et al. (2022) used a citizen science platform to acquire a large sample size ( $n = 35,826$ ) of self-reported data on angling outcomes from anadromous brown trout in Denmark. They found C&R rates were high ( $\geq 80\%$ ), driven primarily by minimum fish size harvest regulations; however, similar to the findings of Blyth and Rönnbäck (2022), anglers also appeared to prioritise harvesting fish in poor health (bleeding).

## 9. Impacts of recreational fisheries on populations communities and ecosystems

Recreational fisheries can have non-negligible impacts on exploited populations with possible repercussions at the ecosystem level (Coleman et al., 2004; Cooke and Cowx, 2006; Lewin et al., 2006, 2019). In many freshwater systems of developed countries fish biomass is predominantly and almost exclusively harvested by recreational fishers, while in marine coastal habitats recreational fishers can harvest similar biomass to those of commercial fisheries for some specific species (Arlinghaus et al., 2019; Radford et al., 2018). Characterising trade-offs between the ecological impacts and socio-economic benefits of recreational fisheries and adopting balanced regulatory actions with respect to other users of aquatic habitat and resources is one of the major challenges of many management systems. Holder et al. (2020) presented 11 questions focusing on strategic topics that provide managers with the information required to promote recreational fisheries activities that will maintain

the integrity of ecosystems. Among them one recurring topic is related to identifying appropriate indicators of population and ecosystem status. Lewin et al. (2022) used an eleven-year time series of recreational fisheries data to identify change points in the number of German cod anglers and in their catch and harvest rates, which may have occurred corresponding to the recent cod stock collapse. Results indicated that catch rates corresponded only weakly with cod stock biomass, suggesting that this fishery-related indicator was more responsive to the introduction of the daily bag limit than to the stock status. This underlines the importance of long-term monitoring programs for identifying change points as an integral component of fisheries management. Furthermore, the impact of recreational fisheries on population and ecosystems may be strongly mediated by fish behaviour (Arlinghaus et al., 2017; Diaz Pauli and Sih, 2017; Sbragaglia et al., 2021b). In this context, a fundamental question is related to understanding the mechanisms and consequences of recreational fisheries-changes of behaviour. Czapla et al. (2023) re-examined the common finding that a carp (*Cyprinus carpio*) may avoid being hooked for more than a year after being caught by angling and released. They found that individuals who had experienced hooking when on their own were more cautious when they approached a hook for up to seven months. However, they found that individuals that witnessed hooking of conspecifics (i.e., social hooking experience) had no memory effects. These contrasting findings illustrate the difficulties in replicating previous experiments on the effects of recreational fishing on fish behaviour. Yoshiyama et al. (2023) investigated the catchability of three sympatric salmonid species in a recreational fishery in Lake Shikaribetsu (Japan), using a combination of stock assessment and angler survey data. They found that differences in catchability among these three salmonids was related to differences in fish and angler behaviours. These results indicate that behavioural characteristics of both fish species and anglers can cause different fishing pressure via interspecific differences in catchability, which is an important issue to be considered in management.

## 10. Threats and sustainability

Recreational fisheries depend on appropriate aquatic biodiversity conservation. Consequently, the major stressors that are threatening aquatic biodiversity are indirectly threatening the quality and sustainability of recreational fisheries. These are habitat destruction, overfishing, climate change, pollution, and invasive species (Arlinghaus, 2006; Brownscombe et al., 2019; Cooke et al., 2019; Townhill et al., 2019), but some of these threats can also create positive feedback on specific recreational fisheries such as the arrival of invasive species with qualities that are appreciated by recreational fishers (Rees et al., 2017; Sbragaglia et al., 2022). Although interdisciplinary research has contributed to increase our knowledge on the threats of these stressors on recreational fisheries and biodiversity, there are still uncertainties about the most appropriate mitigation and adaptation strategies, specifically to face the socio-ecological threats triggered by climate change. Holder et al. (2020) presented 9 questions addressing new and emerging threats underlining the need to develop strategies for managing recreational fisheries and biodiversity towards sustainability. One overarching question was related to characterise how climate change and invasive species impact marine and freshwater habitats and ecosystems and the surplus that supports recreational fishing. Lyach (2022) analysed 32 years (1986–2017) of reported catches by anglers in Czech Republic and showed that the catch of non-native fish species started increasing from early 2000. This trend was explained by the relative decrease in native piscivores and cyprinids and by the increase of non-native salmonids and cyprinids in the overall fish yield. These findings suggested that native fishes are being replaced by non-native fishes in the catch of recreational anglers in central Europe.

## 11. Outreach, education and engagement

Communication, engagement and participatory processes that involve recreational fishers are probably one of the most important key ingredients that can boost effective management and sustainability of recreational fisheries (Cooke et al., 2013; Delle Palme et al., 2016; Fujitani et al., 2017; Granek et al., 2008; Mannheim et al., 2018). In the context of general stakeholders organization, bottom-up voluntarily activities represent crucial social dynamics to foster and support (Cooke et al., 2013), in particular when recreational fishers invest time or money for ensuring catch-and-release sustainability (Guckian et al., 2018) or fighting against environmental issues (Sbragaglia and Arlinghaus, 2020). Most importantly, adequate and effective outreach, communication, and above all, engagement with recreational fishers should aim to establish a solid and trusted relationship among management agencies, scientists and recreational fishing community (Dedual et al., 2013), which is crucial for promoting well-accepted management plans and foster compliance with regulatory actions (Read et al., 2011). Holder et al. (2020) presented 7 questions regarding angler outreach, education, and engagement that need to be addressed. Among them one of the questions was related to finding the best ways to share information on responsible and sustainable fishing practices with recreational fishers that lead to long-term improvements in fisher behaviour and discourage bad behaviours. Farthing et al. (2022a) investigated whether fishing guides are perceived to be role models by the recreational fishers in (27 countries). The majority (91%) of the recreational fishers perceived fishing guides as behavioural models, but only half of them (55%) are likely to adopt or pursue new goals. These findings suggest that fisheries managers have an opportunity to influence general angler behaviour through focussed behavioural interventions with angling guides. However, Farthing et al. (2022b) showed that despite some fishing guides' good knowledge of appropriate behaviours, positive attitudes towards the environment and towards C&R practices, there is room for improvement to meet sustainability goals for such fisheries, which may be facilitated through opportunities for best practice training.

Although the role of digital fisheries data has been already highlighted in the context of monitoring research in recreational fisheries (Holder et al., 2020; Lennox et al., 2022; Sbragaglia et al., 2020b), there is still underexplored potential in the context of outreach, education and engagement. For example, Allison et al. (2022) explored whether user-generated content on Facebook has the potential to encourage pro-environmental behaviour among recreational anglers and highlight how fisheries managers and scientists can facilitate this process. They found evidence for pro-environmental reform over time, despite no intervention from fishery scientists or managers. This suggests that fisheries scientists and managers could consider social media interventions as an important management tool of recreational fisheries.

## 12. COVID-19 and recreational fisheries

The SARS CoV-2 pandemic (herein called COVID 19) has impacted people, society, the economy and ecosystems around the globe. Indeed, changes have been observed even in the recreational fishing sector. As highlighted above, this special issue was intended to be a spin-off of the in person WRF in The Netherlands but public health restrictions and travel uncertainty led to a postponement and then a transition to a shorter online event focused on providing a mechanism for early career researchers to share their work with the community.

The early phases of the pandemic (especially from March to June 2020) were characterised by various lockdowns and stay-at-home restrictions whereby at one point nearly 60–65% of the global population were functionally confined at home (Bates et al., 2021). In fact, Bates et al. (2021) termed this the “anthropause” in recognition of the dramatic decline in human activity. Access to parks and boat ramps were restricted and in some jurisdictions competitive fishing events were

paused (Paradis et al., 2021). Fishing guide services/charter boats, angling related tourism (especially international travel or travel from urban to rural areas) and tackle store access were also limited (Guerri-Marrero et al., 2021; Paradis et al., 2021; Ryan et al., 2021). In a review of rules enacted that limited recreational fishing in North America, it was apparent that states/provinces were relatively inconsistent with the limitations that were imposed (Paradis et al., 2021). Over time those restrictions specific to fishing were lifted or became more generic (e.g., social distancing, limiting interactions to a small group of people).

A survey of anglers in Ontario revealed that fishing effort was reduced for the first few months of the pandemic lockdowns and, as public health measures morphed, fishing activity quickly returned to and even exceeded pre-pandemic levels (Howarth et al., 2021). A similar study in the UK focused on sea anglers only focused on the early lockdown phase and revealed dramatic reductions in catch and expenditures (Hook et al., 2022). Fishing (especially alone or with a few family members) became regarded as a safe way to get outside and connect with nature. More generally, there was an interest in getting outside after the lockdowns such that some researchers termed the next phase the “anthrocrush” (Kadykalo et al., 2022). Recreational fishers that had not fished for years as well as new ones engage with fishing leading to major increases in licence sales in some areas (Gundelund and Skov, 2021; Trudeau et al., 2022; see also <https://www.cbc.ca/news/canada/edmonton/fishing-alberta-pandemic-1.5726943>). In Wisconsin there was evidence of redistribution of fishing effort during the pandemic with increases on water bodies that had good shoreline access for anglers (Trudeau et al., 2022). In Denmark fishing effort shifted from being primarily a weekend activity to be one that was more common during weekdays coincident with demographic shifts where participants were younger, more likely to live in urban areas, and less experienced as anglers (Gundelund and Skov, 2021).

Data from a rainbow trout fishery in Ontario exemplify the anthropause and anthrocrush. (Bunt and Jacobson, 2022) reported that during the initial phase of restrictions imposed during early 2020, angler exploitation rates decreased to half that reported prior to the pandemic yet by fall 2020, there was an 8-fold increase in exploitation rate and a 4.5-fold increase in harvest compared to seasons prior to the pandemic. Harvest rates were also higher for anglers in Denmark (Gundelund and Skov, 2021). Philipp et al. (2023) revealed that the initial anthropause in 2020 was of great benefit to nesting male smallmouth bass in eastern Ontario, Canada. Poor compliance with regulations that are intended to protect bass from fishing during the reproductive period had been an ongoing problem but it was highlighted by massive reductions in hook wounds (evident when fish are inspected by snorkelers) and concomitant increases in reproductive success. In this case, the data collected during the anthropause revealed that existing regulations were failing to protect nesting black bass populations. There are four key lessons specific to recreational fisheries science and management that arise from the pandemic.

First, people value the outdoors and fishing and use it as an escape but also to support nutritional security. A survey of recreational anglers in the European Union reported that 64% felt that fishing was an effective means of pandemic stress reduction (Karpinski and Skrzypczak, 2022). Similar observations were made in a survey of anglers in the USA where stress relief was a key driver of their interest to fish during the pandemic (Midway et al., 2021). Many individuals had additional free time (e.g., working from home, temporary layoffs) and were interested in disconnecting from the continuous negative media. However, during the early phases of the pandemic when fishing was limited some recreational fishers reported a reduction in happiness and wellness that they attributed in part to reduced access to fishing sites (Hook et al., 2022; Pita et al., 2021). Such restrictions varied among regions as did compliance with public health restrictions such that in some areas fishing pressure increased even during the most severe lockdown periods (Midway et al., 2021). Although poorly documented (Pita et al.,

2021), there is a concern that the recreational fishers that were most negatively impacted by COVID-19 were those that are marginalised and vulnerable (e.g., food insecure).

Second, clear and frequent communication by fisheries management agencies is valued by recreational anglers. There was much confusion during the early phases of the pandemic where it was unclear what was legal vs illegal when it came to recreational fishing. The survey of anglers by Howarth et al. (2021) revealed that anglers were generally dissatisfied with governments (regional, state/provincial, federal) and were forced to rely on NGOs (like the Ontario Federation of Anglers and Hunters) to access information on fishing during the pandemic. This is a salient reminder that compliance (with public health regulators or fisheries regulations) can only be achieved if there is clarity in messaging.

Third, there is need to reinstate efforts to engage the angling community in recreational fisheries management. From public consultation regarding changes in regulations or participation in fisheries management councils, the pandemic reduced opportunity for such interactions in a face-to-face manner. Some of these activities transitioned online but given the importance of relationships and trust, face-to-face activities are crucial (Knoepke et al., 2019). Efforts to reinstate these activities should be a priority.

Fourth, education and outreach efforts need to focus on new recreational fishers. The pandemic saw a rise in new recreational fishers as well as a return to fishing by those that had ceased fishing for years or decades. Education and outreach are essential components of ensuring policy compliance (e.g., understanding regulations) and building a community of responsible recreational fishers (e.g., that know how to properly release fish, that know how to identify species). Although enforcement activity by game wardens/fisheries officers continued through all phases of the pandemic, Ban et al. (2022) reported lower levels of compliance by recreational fishers targeting rockfish in the coastal waters of British Columbia emphasising need for additional outreach and education to supplement enforcement efforts. In the coming years there is a need for targeted outreach and education focused on “new” recreational fishers.

### 13. Conclusions

This special issue documents a continued and generally vibrant interest in recreational fisheries research spanning from human dimensions, to economics and ecology and evolution in different areas of the world (Fig. 1). Although there are still many questions to be answered in the recreational fisheries sphere (see Holder et al., 2020), the accumulating social and ecological knowledge on recreational fisheries provides a solid foundation to identify, plan, implement and test possible solutions for the uncertain future. In a rapidly changing, digitised world, hyper connectivity through digital platforms and social media represents both a challenge but also an opportunity for recreational fisheries. For example, the online event organised for the 9th WRFRC in 2021 attracted more participants than the traditional in-person conference which almost doubled the number of countries represented (42 instead of 25). The digital revolution is not only permeating into recreational fisheries research (Lennox et al., 2022), but it is also providing a powerful means for increasing connections among researchers, managers, and recreational fishers (Allison et al., 2022) and improving monitoring, governance and information spread.

The future of recreational fisheries will depend on how well the sector is able to adapt to rapid changes and uncertain across the socio-ecological system. Without continued funding into research, the science-governance interface and the establishment and development of governance and management capacity, the further development of recreational fisheries will be constrained. Perhaps the factors that will have the greatest and most immediate impact on the sector is climate change and the growing biodiversity crisis, followed by more slowly changing issues, such as social value change as to what society considers



important, relevant and worth investing in. There are a growing number of examples of where fish and fishers are being impacted by climate change and this is anticipated to become more apparent in the coming decades. The issues are so pressing that fishers, managers and management bodies are already responding to climate change through changes in individual behaviour or imposition of various management strategies (reviewed by Holder et al., 2020). The COVID 19 pandemic also revealed that recreational fishers and management agencies can respond rapidly to unexpected changes. As such, learning from the pandemic provides a unique opportunity to reflect on how we may prepare for the uncertain future. The contributions of the special issue show the various areas where research is being developed and the implications derived for governance and management. The sector as a whole will benefit from the science-based recommendations and improved governance, thereby allowing the sector to remain resilient and adaptive to the uncertain future.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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