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Exploring ecological knowledge in recreational fishing for conservation purposes: A literature review

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ABSTRACT

Fishing is a widely popular activity that provides an opportunity for laymen to collect reliable ecological data. It is now recognized that recreational fishers possess valuable ecological knowledge (recreational FEK) that can significantly enhance our understanding of nature, and prioritizing nature conservational tasks. This literature review focuses exclusively on the ecological knowledge of recreational fishers, their perceptions of nature, and the potential for co-production of knowledge through citizen science programs. By conducting literature searches in Google Scholar and Web of Science, we have analysed published articles and evaluated the contributions of recreational anglers and spearfishers to conservation and other ecologically relevant fields. We reviewed a total of 81 studies from five continents, including 22 studies that examined other stakeholder groups, predominantly commercial fishers. Our findings suggest that the mapping of recreational fishers' knowledge presents an opportunity to gain a better understanding of aquatic habitats and wetlands. Their factual observations and perceptions can also provide essential data for species conservation and habitat management, and can help establish citizen science projects for marine and freshwater ecosystems worldwide.

1. Introduction

Traditional and local ecological knowledge (TEK and LEK) have gained significant attention in recent years. In general, ecological knowledge refers to all kind of knowledge about nature, including organisms (animals and plants), ecosystems and ecological interactions, held by local people who interact with and use natural resources (Berkes, 2017). It can be seen as a knowledge-practice-belief complex, therefore it contains factual information and understanding, as well as subjective and individual

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interpretations (perceptions). These fields of science combine knowledge obtained from ecology and ethnography. Research has shown that TEK and LEK from different stakeholders can be a valuable tool for effective biodiversity conservation and management in various habitats worldwide (Fraser et al., 2006; Nelson and Shilling, 2018; Aswani et al., 2018; Joa et al., 2018). This is especially important in the case of marine and freshwater ecosystems, which are among the most threatened ecosystems, and upon which human well-being is highly dependent (Millennium Ecosystem Assessment, 2005).

Recreational fishing is a popular activity worldwide (Arlinghaus and Cooke, 2009), it has led to several interconnections between fishers' LEK and the way they use habitats (Garavito-Bermúdez and Lundholm, 2017). Similarly to traditional fishers, commercial fishers' ecological knowledge can be used for scientific purposes. They can contribute to fish ecology and fisheries management (Silvano and Valbo-Jørgensen, 2008), provide data on the ethnoecology of important fish species (Silvano and Begossi, 2005), detect ecological decay in an ecosystem (Veneroni and Fernandes, 2021), and even help to identify specialized topics such as environmental changes and fish abundance trends (Hallwass et al., 2013).

Despite all their valuable assistance, the ability of recreational fishers to provide ecological data has been debated, as scientists still often mistrust the reliability of their information (Griffiths et al., 2007; Harris et al., 2009). Specialists also tend to over- or underestimate the damage caused by recreational fishers in different ecosystems (Lewin et al., 2021). This may be attributed to the comprehensive nature of TEK, as it encompasses both objective and subjective forms of understanding. Additionally, their high fishing activity and extensive catch have contributed to the formation of decades old stereotypes that portray them in an exploitative image, which is often accompanied by the assumption that this is primarily driven by their ignorance (Pratt, 1977; Wine, 1980). These issues led to cautious and mixed opinion among scientists, indeed there is still no consensus on some elements of the real biological impact of recreational fishing (Lewin et al., 2006), as published scientific papers are often contradictory in terms of the amount of fish caught both regionally and globally. According to the very few recent articles investigating the topic, the potential contribution of angling is probably somewhere between 12% and 19% of the global fish harvest (Cooke and Cowx, 2004; Galbraith et al., 2017).

In the last couple of decades scientists argued that evaluation of recreational fishers' ecological knowledge (hereafter recreational FEK) can significantly contribute to learning more about nature (Ainsworth and Pitcher, 2005). Numerous studies, conducted worldwide, recently have highlighted that recreational FEK can be efficiently used for better understanding of the sustainable management of both marine and freshwater habitats (Granek et al., 2008), to reconstruct trends in fish abundances (Colloca et al., 2020), conserve fish populations (Cooke et al., 2016; Shiffman et al., 2014), ecological monitoring for the early detection of species (Pecl et al., 2019), improve sustainable management of local freshwaters (Mamun, 2007; Johannes et al., 2000) and it also represents a practical tool for ecosystem-based fisheries management (Leite and Gasalla, 2013). Although recreational fishing has impacts on fish populations and ecosystems, the overall outcomes are not necessarily negative. Despite they might have a significant contribution to habitat exploitation, alteration, introduction and transport/dispersal of non-native species, they also provide conservation services through their activities (Cooke et al., 2015), while traditionally, recreational fishers have been even key guardians of aquatic ecosystems (Arlinghaus et al., 2021).

Ecological awareness among anglers, however, is growing, and there is a strong desire to engage the recreational fishing community in water ecosystem conservation (Hind, 2015; Zukowski et al., 2011; Beaudreau and Levin, 2014; Font and Lloret, 2014). Studies also prove that observations made during recreational fishing can be important for habitat or biodiversity conservation (Adams and Murchie, 2015; Copeland et al., 2017; Tufts et al., 2015). Despite all of the above, the number of studies evaluating the importance of recreational FEK still seems to be limited.

To raise awareness of recreational fishers' ecological knowledge, our study had two aims: (i) to conduct a literature review of studies that primarily or at least partially investigated recreational FEK; and (ii) to develop recommendations for further research on recreational FEK, which includes exploring new digital approaches (ii/a) and establishing citizen science projects (ii/b) that could potentially involve recreational fishers in the future.

2. Materials and methods

We conducted a literature review to collect published articles on recreational fishers' ecological knowledge in marine and freshwater ecosystems. Our focus was limited to recreational fishers, excluding the LEK of commercial fishers and the TEK of artisanal fishers, or other recreational users of such ecosystems (free divers, beachgoers, etc.) However, we included papers that negotiated both commercial and recreational fishers in the same study and ecologically relevant data provided by recreational charter captains. In addition to original research papers, we also included undergraduate theses, doctoral dissertations, and scientific reports published in English, as well as citizen science studies of recreational fishers, where relevant elements of ecological knowledge were presented. It should be noted that non-electronic sources or non-English literature were not included in the review.

We performed a classic literature review during our work, utilizing Google Scholar and Web of Science for online searches. First, we used the keywords 'recreational fishers' AND 'ecological knowledge' in Google Scholar, which returned 1030 hits (papers published before December 2021). Second, we performed a further search using the keywords 'local ecological knowledge' AND 'recreational fishers' OR 'anglers', which returned 852 hits. We repeated our searches in Web of Science with the same keywords resulting 3950 and 47 hits, respectively. All hits were screened by title and abstract of the first two and the last searches, while the first 1000 of the third search were screened. Altogether 2929 papers were investigated, and non-relevant papers were discarded after content analysis by title and abstract screening. In total, 95 of them were found to be relevant to our review. After reading the relevant studies, another 27 papers were discarded based on their content. Furthermore, we added 13 papers to our list after looking through the reference lists of the remaining studies, resulting a review of 81 papers.

3. Results and discussion

3.1. Trend of publications and the engagement ratio of recreational fishers

The number of studies on recreational FEK has significantly increased in recent years (Fig. 1). However, we found relatively few papers entirely dedicated to analysing recreational FEK compared to studies on FEK as a whole. Of the 81 relevant studies, 61 were original research papers, 9 were reviews, 4 were scientific reports, 3 were doctoral dissertations, and 4 were MSc theses. Among studies that contained relevant ecological knowledge, we reviewed 53 in detail. Of these, 31 original research papers exclusively focused on recreational fishers, while 22 studies evaluated other stakeholders, mainly commercial fishers.

The number of fishers involved (including online methods) varied between 14 and 5646 (median: 158) in studies that only engaged recreational fishers, but from 7 to 84 (6–90 % of the total interviews, median: 45 %) in studies that evaluated other stakeholders as well. A total of 12 studies exclusively used online questionnaires, video sharing platforms or social media, of which 8 papers conducted through questionnaires or interviews. For the summarized engagement ratio of recreational fishers in the reviewed studies, see also Table 1.

Studies were available from 12 countries in 5 continents, while a total of 10 studies being performed in multiple continents, and 3 in Europe but in multiple countries (Fig. 2). The first authors of most publications belonged to Europe (n = 20, 36 %), North America (n = 19, 35 %), and Australia (n = 12, 22 %). Only a few publications were published in Asia (n = 2, 4 %) and South America (n = 2, 4 %), and none of the reviewed papers found in Africa (Fig. 3a). Most of the available studies focused on the US (n = 19), and Australia (n = 14) (Fig. 3b). In terms of research participations Asia, Africa and South America also underperformed, with only Turkey (n = 2), Libya (n = 2), South Africa (n = 1), and Brazil (n = 2) participated (or managed) in studies (Fig. 3b).

3.2. Taxa, topics, and geographical focus

Of the 53 papers reviewed in detail, the majority (n = 44, 83%) were conducted in marine, with only 9 (17 %) focusing on freshwater environments. Out of the 21 papers that evaluated recreational fishers' knowledge, only one evaluated their knowledge of flora, while the rest focused on fauna (Table 2). A total of 14 papers from five continents focused mostly on fishes, two studies exclusively focused on the knowledge of non-native fauna, but many native animals, including decapods (Decapoda), jellyfishes, or in one case, even perceptions of a sea lion species (Beaudreau and Levin, 2014) were also investigated. Other miscellaneous studies included recreational fishers' perceptions and mental models of habitat management and conservation (e.g., Raynal et al., 2020), ecosystem models (e.g., Hunt et al., 2016), and monitoring of some marine and freshwater habitats (e.g., Palas et al., 2017). Two studies (Dowiarz, 2021; Eden, 2012) investigated knowledge about catch composition, whilst two Australian studies (Li et al., 2010;

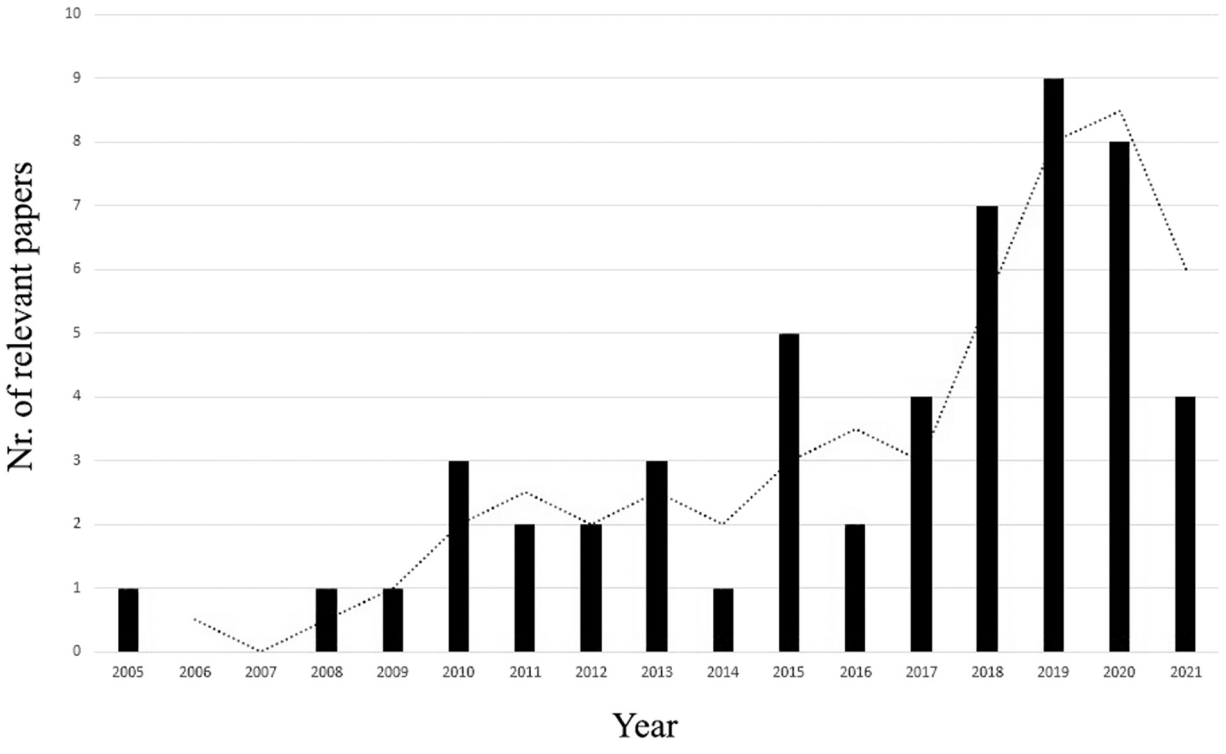

Fig. 1. Number of the reviewed studies by years. Dots represent a trendline of the relevant papers.

Table 1
Engagement ratio of recreational fishers in reviewed papers, which methodology includes questionnaires or various interviews.

Ratio (%)	Nr. of studies	Online approach
1–50 %	13	-
51–99 %	6	2
100 %	31	6
not provided	3	-
total	53	8

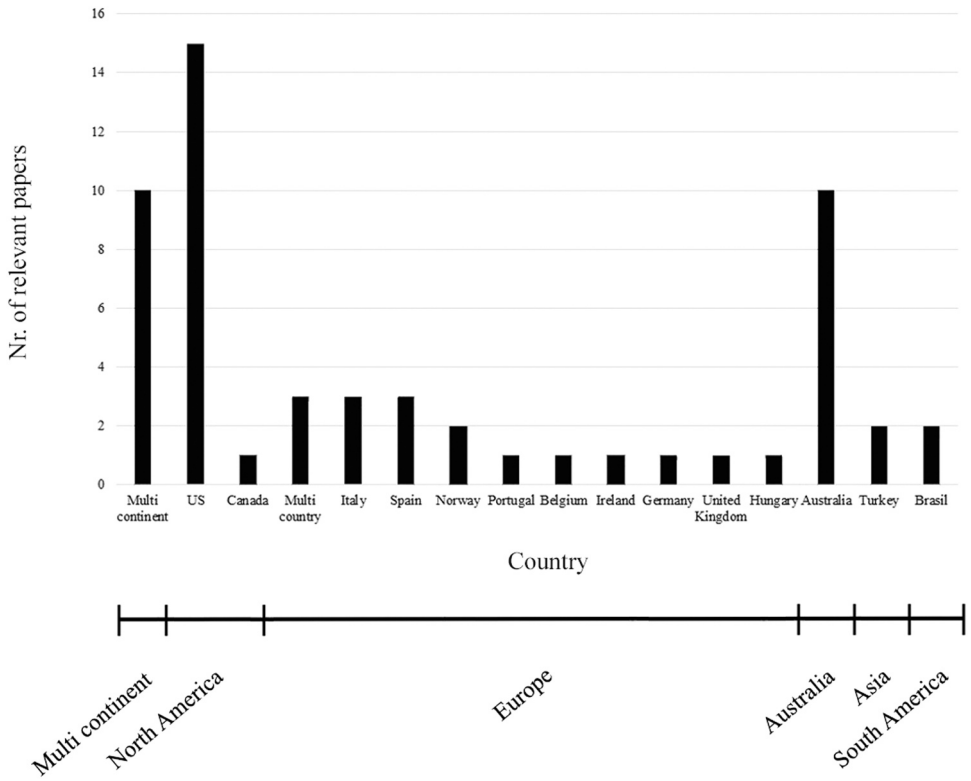

Fig. 2. Number and distribution of the reviewed studies by country.

Florisson, 2015) dealt with environmental education and possible citizen science methods that could engage recreational fishers.

3.3. Factual observations and experiences of recreational fishers

The primary application of recreational FEK is the data provided on observed species, especially fish. Commercial and recreational fishers spend long time in the field, giving them a great chance of encountering many species (Silvano and Begossi, 2012). Therefore, they can provide important occurrence and distribution data for both endangered and invasive species (Giovos et al., 2019; Minasidis et al., 2020). This data can be collected through a variety of sources, including catch reports, logbooks, and other miscellaneous sources, as well as the protocol for collecting LEK. By combining these sources, researchers and conservationists can reconstruct spatial changes and fishing efforts of targeted species over long periods of time (Rehage et al., 2019; Santos et al., 2019). Experienced fishers possess reliable species knowledge not only for fish but also for other aquatic biota. Furthermore, even if recreational fishers do not refer to a species by its scientific name, they can use its local or 'folk name' and/or accurately describe its physical appearance, behavior, and habitat requirements without naming the given organism (Löki et al., 2021). While the significance of such data is indisputable, data obtained from interviews may contain biases and mistakes such as taxonomical issues; therefore, some authors suggest that validation of these procedures is still essential (Poizat and Baran, 1997; Valbo-Jørgensen and Poulsen, 2000).

3.3.1. Occurrence and distribution data of biological invasions

While recreational angling can serve as a vector for invasive species, (Anderson et al., 2014; Cerri et al., 2018; Olaussen and Skonhoft, 2008), it can also provide valuable data on invasive species worldwide, including their occurrence, population dynamics,

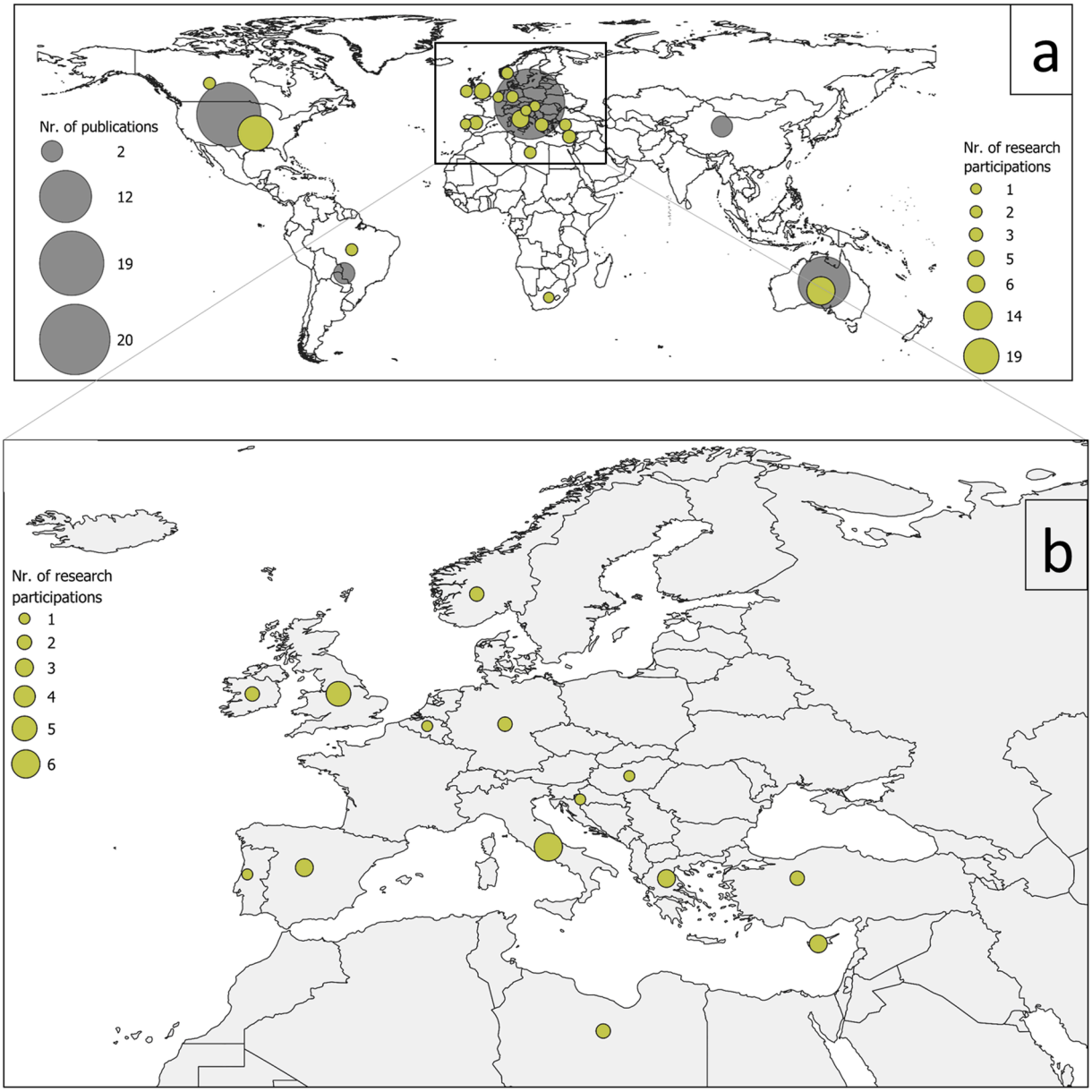

Fig. 3. Geographic distribution of the reviewed studies.

and distribution (Azzurro and Cerri, 2021; Öndes et al., 2018; Özbek et al., 2017). Besides traditional sources (logbooks, catch reports), such information can be collected through interviews, online questionnaires, or digital approaches, such as user-generated content on social media platforms like Facebook, Twitter, and YouTube (Banha et al., 2015, 2017a,b; Giglio et al., 2020; Sbragaglia et al., 2020a, b). Data mining from specific social media sources, such as forums and blogs, can also generate distribution and dispersal data.

3.3.2. Population trends

Statistics on angler catch rates and species composition have been widely used worldwide to monitor changes in the abundance of commercially and recreationally important species (Thurstan et al., 2016; Rehage et al., 2019; Beaudreau and Levin, 2014; Chan et al., 2019; Kroloff, 2016; Florisson, 2015; Quinn, 2018). Recreational FEK has proven to be a valuable tool for estimating historical baselines of fish stocks (Frijlink and Lyle, 2013) and for co-evaluating species demographics, fishing methods, catch composition, and perceptions of recreational fishers (Martínez-Escauriaza et al., 2020). Since current levels of wild fish and seafood catch are unsustainable, data on population trends gain high importance in avoiding overexploitation (Lindenmayer and Likens, 2010). These issues underscore the significance of reliable monitoring of population size, where data can originate from various sources, including the local knowledge of anglers and other recreational fishers (Radinger et al., 2019). On this topic, Chan et al. (2019) emphasize the

Table 2
Papers grouped based on their content and geography. The values in parentheses represent the number of studies available for a given country.

	Focus of research	Nr. of studies	Continents	Countries (Nr. of studies)
Fauna	Fishes	14	5	North America: US (5) South America: Brazil (1) Australia: Australia (2) Asia: Turkey (2) Europe: Norway (2), Cyprus & Greece (1), Italy & Croatia (1)
	Alien fauna	2	1	Italy (2)
	Decapoda	3	2	Australia (2), Canada (1)
	Multi species	1	1	US (1)
	Sharks	1	2	Cyprus – Greece – Italy & Lybia (1)
Flora	Freshwater plants	1	1	Hungary (1)
Miscellaneous	Perceptions and mental modeling	12	6	US (7), Australia (2) Germany (1), Ireland (1), UK – Ireland – US & Australia (1)
	Habitat management and conservation	6	6	Global (3), US (1), Belgium (1), Spain (1)
	Ecosystem models	5	3	US (1), Australia (1), Portugal (1), Spain (1), Italy (1)
	Monitoring	4	3	Australia (2), Spain (1), Brazil (1)
	Catch composition	2	2	US (2), UK (2)
	Citizen science methods	1	1	Australia (1)
	Environmental education	1	1	Australia (1)

importance of interviewing individuals with different types of expertize to achieve a proper estimation of population trends and document environmental change. Frijlink and Lyle (2013) also suggest that while interviewees accurately perceived the direction of abundance trends, they tend to overestimate their extent. Despite this bias, these studies highlight the value of integrating different information and data sources for managing fish stocks, and such kind of information may provide researchers with a better understanding of historical stock trends (Rehage et al., 2019).

3.3.3. Ecology and biological traits

Recreational fishers are primarily interested in fishes and fish-related information, and as such, they can provide valuable knowledge on environmental and ecological topics like feeding behavior, habitat requirements, and information on species' migration and reproduction habits. This information can help in better understanding of macro-ecological patterns (Palas et al., 2017; Sbragaglia et al., 2021) as well as in assessing and conserving exploited species (Zukowski et al., 2018). Although Gray et al. (2015) reported that while some anglers tend to oversimplify relationships among different ecological factors, more specialized anglers develop simple heuristics to deal with complex ecological issues. Further, Dowiarz (2021) suggests that even life history traits and supplementary information of fish species such as age, spawning composition, and geographical distribution can be investigated with the help of experienced recreational fishers, which all praise the sharp eyes of them.

3.4. Perceptions of recreational fishers

In addition to the collection of factual information and understanding of recreational fishers, which includes direct catch records and observational data, it is equally crucial to take into account their subjective opinions (i.e., perceptions). These subjective viewpoints offer valuable insights into their impressions and opinions related to nature and the outdoor experiences they encounter. (Gray, 2010; Gray et al., 2015). The results of such studies can also be useful in identifying necessary conservation actions and issues (see also Copeland et al., 2017).

3.4.1. Perceptions of fish stock size and fisheries management

While recreational fishers provide valuable information about salient or endangered species such as sea lions, dolphins, whales, sea turtles, cephalopods and crabs (Cook et al., 2015; Obregón et al., 2019; Noble et al., 2020; Gallagher et al., 2015; Pita et al., 2018), they focus mainly on fish. As fishers are mostly interested in fish stock size, their perceptions are mostly related to population trends and distribution. Although the estimation of fish population size is often challenging, and can be uncertain (Pine et al., 2003), recreational FEK can provide reliable data about the causes and consequences of declining catch rates (i.e. population size) and the effectiveness of related legislation (Cook et al., 2015; Kroloff et al., 2019; Liu et al., 2019). Many fishers can estimate the level of overfishing, habitat loss, and reduction in biodiversity, pollution, and stock trends caused by climate change. Anglers can provide perceptions of threats and preferences for countermeasures that can be implemented in recovery plans, including threats that are not reported by others (Sawchuk et al., 2015). Furthermore, personal knowledge of fish longevity and past fishing experience can be important predictors that support conservation measures and willingness to take personal action in recovering fish populations (Grilli et al., 2019).

Recreational fishers' opinions can be used not just to complement or optimize some management techniques, but also to highlight key issues caused by improper fishing activities, such as illegal fish restocking (Cerri et al., 2018), or the dangerous effects of abandoned, lost, or discarded fishing gear (Deshpande et al., 2019). Measures and restrictions developed with their help, such as no-take zones (as in Sutton and Tobin, 2009), move towards sustainable and stakeholder-friendly environmental management (Diogo et al., 2020), which is a pledge for long-term sustainability.

3.4.2. Role of fishers' perceptions in nature conservation

Local stakeholders can identify conservation priorities by relying on recreational fishers' perceptions of iconic species and ecosystem threats. This approach can also help to resolve doubts and general misalignments in species management, especially for agile and migratory species, and to address misunderstandings of stakeholder perceptions of threats (Obregón et al., 2019; Noble et al., 2020). For instance, Gallagher et al. (2015) found that anglers did not identify species-specific differences among sharks, but were able to rank certain shark species as the most threatened, which is generally consistent with empirical data. Similarly, perceptions of recreational anglers can help in clarifying public perception of invasive species, and it is required for both conservation and fisheries management to mitigate the impacts of alien species (Anderson et al., 2014). Additionally, investigating recreational users' perceptions of water quality and determining if their values and perceptions can complement bio-assessment surveys (see also Franks, 2013; Ten Brink and Dalton, 2018). Finally, recreational fishers' perceptions can be used to detect knowledge gaps between perceived and actual habitat conditions, which can be further used by restoration ecologists.

Conservation actions often lead to conflict with other stakeholders, especially with recreational fishers. Public opposition towards the management plans may block or delay the implementation of conservation policies and actions (Helvey, 2004). Therefore, finding a common ground with stakeholders and setting up a win-win situation is critical. In this process, the ability of managers to generate support from the recreational fishing community for conservation initiatives can be essential (Sutton and Tobin, 2009). Mapping their attitudes can be important (1) to measure the level of recreational fishers' support of conservation initiatives before taking any major actions or restrictions (Sutton and Tobin, 2009; Voyer et al., 2014); (2) to improve ecosystem knowledge and sustainable fisheries management (Maes et al., 2012; Copeland et al., 2017); or (3) to improve the behavior of recreational fishers to minimize their impact on the marine fisheries (Gray et al., 2010, Li et al., 2010).

4. Synthesis and suggestions for further research and applications

Recreational fishers sometimes spend more time in natural environments than scientists do, and they make detailed observations of their surroundings, which could have important implications for conservation and management. The literature on recreational FEK represents timely and ecologically relevant data, especially in an era when aquatic habitats are increasingly sensitive and significant. According to the above, we believe that recreational fishers' observations are essential and should be incorporated into the decision-making processes for managing marine and freshwater ecosystems in the future. As Eden (2012) has noted, measuring and managing water ecosystems inevitably entails measuring and managing the people who use them, which is especially evident in interdisciplinary fields like recreational FEK. In the following subsections, we summarize the potential applications of this topic.

4.1. Research gaps in recreational FEK

The number of studies related to recreational fishers has been increasing, yet further development of this knowledge is necessary. Our review highlights that there are few papers that focus exclusively on recreational FEK (e.g., Zukowski et al., 2011; Beaudreau and Levin, 2014; see Table 1), with most publications combining and evaluating data from recreational and commercial fishers. Given their larger numbers, varied aims, and types of activities, recreational fishers remain an underexplored source of information. Studies dedicated exclusively to recreational FEK can help refine our understanding of species, habitats, trends, and more.

We found that publications have an overrepresentation of fish-related information (Table 2), with other organisms being of marginal interest to recreational fishers. Knowledge gaps are partly due to uneven geographic representation: dominance of marine environments and scarce information about developing countries. While recreational fishers possess extensive knowledge of fishes, their ecological knowledge extends beyond this taxonomic group. Exploring other organisms including different species of mammals, birds, insects, molluscs, or even plants in both marine and freshwater ecosystems with the help of recreational fishers is feasible and recommended. Their observations of key indicator organisms – in accordance with the future challenges of the Water Framework Directive – can contribute to the reliable evaluation of water conditions (Hering et al., 2010).

4.2. The role of recreational fishers' perceptions in nature conservation

Our literature review confirms that, in addition to FEK, the perceptions of recreational fishers are also helpful in identifying and understanding nature-related issues. Their perceptions deliver relevant social and cultural information, which have relevance in conservation and management (Liu et al., 2019; Young et al., 2016). We argue that perception papers are essential in understanding the motivations and opinions of recreational fishers, while they can also help scientists in the better understanding of environmental issues and processes.

On the one hand, perceptions that are not based on concrete data and assessments can still be useful in sustainable habitat management or species conservation programs, since fishers' activities must be considered as an external factor. On the other hand, perception papers can also help to improve fishers' participation in research activities (Granek et al., 2008), refine fisheries and conservation management (Palas et al., 2017), and even guide the development of environmental education programs (Li et al., 2010). Voyer et al. (2014) suggested that considering fishers' motivations may enable the development of more holistic management responses. Morales-Nin et al. (2021) also argued that future studies should investigate and compare the perceptions and motivations of recreational fishers with those of other stakeholders, including not just commercial fishers or fishpond managers, but for example consumptive, indoor, and outdoor recreationists as well.

4.3. Recreational fishers as conservation partners

Involving recreational fishers in conservation efforts is timely (Arlinghaus and Cooke, 2009; Berkes, 2017; Aswani et al., 2018), because recreational fishers can significantly contribute to the assessment of data-poor species (Beaudreau and Levin, 2014), report the conservation status of ecosystems (Pita et al., 2020b), while they can also help in understanding, managing, and adapting to the ongoing biotic transformations driven by climate change and biological invasions (Azzurro et al., 2019). Moreover, recreational fishers can also participate in promoting conservation, provide input into protected area design, support conservation education (Granek et al., 2008) fostering more sustainable fishing practices (Raynal et al., 2020).

Complex management issues and fully integrated decisions require the involvement of all related stakeholders, including the comparison of different nature related knowledge, especially TEK, LEK, and scientific knowledge (Harrison et al., 2018; Pita et al., 2018). Recreational fishers sometimes lack basic knowledge about the concept and establishment of protected areas and the services they provide (Kerns, 2003), thus engaging recreational fishers in conservation efforts could help to understand relevant cultural factors and ensure that all stakeholders' views are considered (Hamilton, 2011). This approach is especially important in controversial topics, where favouring one stakeholder group might displease another. For instance, this can happen if protected areas with new regulations are established on fishing waters (Voyer et al., 2014), if fishing gears might harm vulnerable birds or aquatic habitats (Pita et al., 2020a; Deshpande et al., 2019), or if recreational fishers are considered as vectors of non-native species and pathogens (Anderson et al., 2014). Future researches should also focus on resolving these opposites, in parallel with the endeavor that regulations should allow all relevant stakeholder groups to carry out their activities, and provide them with an opportunity to share their views. Failure to do so might lead to conflicts between recreational fishers and conservationists (Cook et al., 2015), while we believe that resolving such conflicts between recreational fishers and conservationists could also increase the sustainability of fishing.

4.4. Bridging the knowledge–action gap and knowledge co-production

Bridging conservationists and recreational FEK could be essential in designing the best possible habitat management practices (Anbleyth-Evans and Lacy, 2019; Brownscombe et al., 2019; Pita et al., 2018). Preconditions of knowledge co-production probably include harmonization of recreational fisheries and detailed conservation objectives (e.g., Cowx et al., 2010), and/or the detailed comparison of recreational FEK and scientific knowledge (e.g., Harrison et al., 2018). Unfortunately, it is widely believed that most works have failed to integrate recreational fishers' knowledge into decision-making processes so far (Li et al., 2010). Some believe that this is largely due to poor communication among scientists, fishery managers, and recreational fishers, as well as pre-existing antagonism between commercial and recreational fisheries (Dedual et al. (2013); Voyer et al. (2014). It should be noted that information transaction can be also challenging simply because the nature of this body of knowledge, as these are often difficult to verbally articulate, which results in a major methodological challenge (Garavito-Bermúdez and Boonstra, 2023). One of the key questions of transferring fishers' knowledge to science is still learning more about what it implies for fishers to have their knowledge moved beyond its traditional borders (Maurstad, 2002), and use their knowledge not mainly to fish-related issues. Implications of recreational FEK beyond fishing-related issues is crucial, as failures in recognizing heterogeneity among recreational fishers can lead to a kind of 'fishing versus conservation' partisanship (Khumalo, 2021). Additionally, according to Copeland et al. (2017), motivations for habitat management among recreational fishers are primarily social: hence, it would be the best to approach the topic mainly from the social perspective. To implement robust, well-accepted management actions, future research should aim to gain the confidence and trust of recreational fishers on such topics. This is most likely to happen eventually, as some studies have already indicated that recreational fishers and researchers reported qualitatively similar trends or provided the same information (da Silva et al., 2020). Besides these, establishing associations, societies, and other organizations with conservational purposes might also increase the engagement ratio of recreational fishers, while bridging the knowledge–action gap between stakeholders might be sometimes surprisingly quick (Brownscombe, . et al., 2019).

4.5. Involving recreational fishers in citizen science projects

Citizen science is a collaborative and participatory approach to scientific research in which scientists and citizens collaborate to produce new knowledge for science and society (Vohland et al., 2021). Citizen science projects therefore can effectively support conservation efforts by building scientific knowledge and databases, informing policy formulation, inspiring public action, aiding decision making, and promoting public acceptance of decisions (McKinley et al., 2017). We believe that recreational anglers can be involved in citizen science programs mainly through data collection projects on historically iconic species, other fishing-related organisms, salient, or flagship species on current conservation trends (Beaudreau and Levin, 2014; Cook et al., 2015; Noble et al., 2020; Löki et al., 2021), while engaging the public in monitoring other ecological impacts such as the effects of climate change is also possible (Pecl et al., 2019). Furthermore, participating in citizen science programs offer a possibility to deepen anglers' understanding of the impacts of fishing and recreational activities on nature, while it is also an effective tool to bring conflicting parties closer together (Venturelli et al., 2017; Christel, 2006; Morales-Nin et al., 2021).

The increasing role of digital technology in citizen science projects has also been noted, with emerging technologies providing practical and easy-to-use online platforms for data collection (Newman et al., 2012; Carcia-Soto and van der Meeren, 2017). Kelly et al. (2020) suggested that in this regard, frameworks are also needed to provide practical, hands-on evaluation tools that can more easily monitor and track citizen science progress and development. Smartphone applications, for example, can be useful tools of citizen science surveys as they automatically capture metadata, such as position and time of measurement, and allow users to record catches (e.g., uploaded photograph) and related data, even if they cannot identify the species (Carcia-Soto and van der Meeren, 2017; Pecl et al., 2019; Venturelli et al., 2017). Social media platforms are also an excellent but inefficiently exploited opportunity to reach fishers, and they offer a higher success rate than traditional interviewing methods (Giglio et al., 2020; Stratoudakis et al., 2014). Moreover, Tweedley et al. (2016) suggest that social media is also suitable for recruiting volunteers for citizen science programs and even for regular communication between project managers and recreational fishers. Their work highlights the important role of citizen science as a tool for public engagement and for monitoring rare and endangered marine wildlife in a changing environment. However, using social media for research purposes requires optimization to produce reliable, confident and legal results. The disadvantage of digital platforms is their potential to be biased, as the regularities of social media can favor certain types of content over others (Barbier and Liu, 2011; Sbragaglia et al., 2020a). Therefore, online approaches should be adapted to uneven situations and optimized for scientific purposes.

Despite these challenges, we encourage researchers to use online surveys, smartphone applications, and social media for data collection purposes. Such online campaigns represent a new and data-rich approach to studying recreational fishing, and they can also facilitate the digital engagement of recreational fishers. This activity can serve as a precursor to thematic citizen science projects, which can engage fishers and contribute to scientific research (e.g., Cerri et al., 2020; Dowiarz, 2021). Social factors, ease of participation, and enjoyment also motivate voluntary data sharing (Rotman et al., 2012; Dickinson et al., 2012).

5. Conclusions

In conclusion, traditional and local ecological knowledge (TEK and LEK) offer a promising solution as local communities possess first-hand knowledge of their environment. The mapping of recreational fishers' ecological knowledge (recreational FEK) presents an opportunity to gain a better understanding of aquatic habitats and wetlands. Given the increasing importance of clear water and

natural aquatic habitats, it is imperative to engage with fishers, who are key stakeholders in aquatic habitats, and leverage their FEK to guide habitat management decisions. While recreational fishing may have some potential negative effects on ecosystems, it also offers significant social, economic, individual, and cultural benefits to one of the largest user groups of marine and freshwater habitats. We believe that recreational fishers can provide reliable ecologically related data for scientific research, making them a valuable resource for future citizen science projects focused on nature conservation.

CRediT authorship contribution statement

Viktor Löki: Conceptualization, Methodology, Investigation, Visualization, Writing - Original Draft, Writing - review & editing, Funding acquisition. **Jenő Nagy:** Writing - Review & Editing. **Zsolt Neményi:** Writing - Review & Editing. **Attila Hagyó:** Writing - Review & Editing. **András Nagy:** Writing - Review & Editing. **Zoltán Vitál:** Visualization, Writing - Review & Editing. **Attila Mozsár:** Conceptualization, Methodology, Writing - Review & Editing, Funding acquisition. **Balázs András Lukács:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition.

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.

Data availability

Data will be made available on request.

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References

Adams, A., Murchie, K.J., 2015. Recreational Fisheries as Conservation tools for Mangrove Habitats. American Fisheries Society Symposium,, pp. 43–56.
Ainsworth, C.H., Pitcher, T.J., 2005. Using Local Ecological Knowledge in Ecosystem Models. Fisheries Assessment and Management in Data-limited Situations. Alaska Sea Grant College Program. University of Alaska Fairbanks,, Fairbanks, Alaska, USA, pp. 289–304.
Anbleyth-Evans, J., Lacy, S.N., 2019. Feedback between fisher local ecological knowledge and scientific epistemologies in England: building bridges for biodiversity conservation. Marit. Stud. 18 (2), 189–203.
Anderson, L.G., White, P.C., Stebbing, P.D., Stentiford, G.D., Dunn, A.M., 2014. Biosecurity and vector behaviour: Evaluating the potential threat posed by anglers and canoeists as pathways for the spread of invasive non-native species and pathogens. PLOS One 9 (4), e92788.
Arlinghaus, R., Aas, Ø., Alós, J., Arismendi, I., Bower, S., Carle, S., Yang, Z.J., 2021. Global participation in and public attitudes toward recreational fishing: international perspectives and developments. Rev. Fish. Sci. Aquac. 29 (1), 58–95.
Arlinghaus, R., Cooke, S.J. (Eds.), 2009. Recreational fisheries: socioeconomic importance, conservation issues and management challenges. Recreational Hunting, Conservation and Rural Livelihoods: Science and Practice. Blackwell Publishing Ltd, pp. 39–58.
Aswani, S., Lemahieu, A., Sauer, W.H., 2018. Global trends of local ecological knowledge and future implications. PLOS One 13 (4), e0195440.
Azzurro, E., Cerri, J., 2021. Participatory mapping of invasive species: a demonstration in a coastal lagoon. Mar. Policy 126, 104412.
Azzurro, E., Sbragaglia, V., Cerri, J., Bariche, M., Bolognini, L., Ben Souissi, J., Moschella, P., 2019. Climate change, biological invasions, and the shifting distribution of Mediterranean fishes: a large-scale survey based on local ecological knowledge. Glob. Change Biol. 25 (8), 2779–2792.
Banha, F., Ilhéu, M., Anastácio, P.M., 2015. Angling web forums as an additional tool for detection of new fish introductions: the first record of *Perca fluviatilis* in continental Portugal. Knowl. Manag. Aquat. Ecosyst. (416), 03.
Banha, F., Diniz, A., Anastácio, P.M., 2017a. The role of anglers' perceptions and habits in biological invasions: perspectives from the Iberian Peninsula. Aquat. Conserv.: Mar. Freshw. Ecosyst. 27 (1), 51–64.
Banha, F., Veríssimo, A., Ribeiro, F., Anastácio, P.M., 2017b. Forensic reconstruction of Ictalurus punctatus invasion routes using on-line fishermen records. Knowl. Manag. Aquat. Ecosyst. 418 (56), 729–8.
Barbier, G., Liu, H., 2011. Data mining in social media. Social Network Data Analytics. Springer, Boston, MA, pp. 327–352.
Beaudreau, A.H., Levin, P.S., 2014. Advancing the use of local ecological knowledge for assessing data-poor species in coastal ecosystems. Ecol. Appl. 24 (2), 244–256.
Berkes, F., 2017. Sacred Ecology. Routledge.
Brownscombe, J.W., Adams, A.J., Young, N., Griffin, L.P., Holder, P.E., Hunt, J., Danylchuk, A.J., 2019. Bridging the knowledge-action gap: A case of research rapidly impacting recreational fisheries policy. Mar. Policy 104, 210–215.
Carcia-Soto, C., van der Meeren, G.I., 2017. Advancing citizen science for coastal and ocean research. Eur. Mar. Board IVZW 114.
Cerri, J., Ciappelli, A., Lenuzza, A., Zaccaroni, M., Nocita, A., 2018. Recreational angling as a vector of freshwater invasions in Central Italy: perceptions and prevalence of illegal fish restocking. Knowl. Manag. Aquat. Ecosyst. (419), 38.
Cerri, J., Chiesa, S., Bolognini, L., Mancinelli, G., Grati, F., Dragičević, B., Azzurro, E., 2020. Using online questionnaires to assess marine bio-invasions: a demonstration with recreational fishers and the Atlantic blue crab *Callinectes sapidus* (Rathbun, 1986) along three Mediterranean countries. Mar. Pollut. Bull. 156, 111209.
Chan, M.N., Beaudreau, A.H., Loring, P.A., 2019. Exploring diversity in expert knowledge: variation in local ecological knowledge of Alaskan recreational and subsistence fishers. ICES J. Mar. Sci. 76 (4), 913–924.
Christel, D.W., 2006. The utility of fishermen's cognition in near-shore fisheries management on the east end of Long Island. Univ. Del. 254.

Colloca, F., Carrozzi, V., Simonetti, A., Di Lorenzo, M., 2020. Using local ecological knowledge of fishers to reconstruct abundance trends of elasmobranch populations in the Strait of Sicily. Front. Mar. Sci. 7, 508.
Cook, T.C., James, K., Bearzi, M., 2015. Angler perceptions of California sea lion (*Zalophus californianus*) depredation and marine policy in Southern California. Mar. Policy 51, 573–583.
Cooke, S.J., Cowx, I.G., 2004. The role of recreational fishing in global fish crises. BioScience 54 (9), 857–859.
Cooke, S.J., Arlinghaus, R., Johnson, B.M., Cowx, I.G., 2015. Recreational fisheries in inland waters. Freshw. Fish. Ecol. 449–465.
Cooke, S.J., Hogan, Z.S., Butcher, P.A., Stokesbury, M.J., Raghavan, R., Gallagher, A.J., Danylchuk, A.J., 2016. Angling for endangered fish: conservation problem or conservation action? Fish Fish. 17 (1), 249–265.
Copeland, C., Baker, E., Koehn, J.D., Morris, S.G., Cowx, I.G., 2017. Motivations of recreational fishers involved in fish habitat management. Fish. Manag. Ecol. 24 (1), 82–92.
Cowx, I.G., Arlinghaus, R., Cooke, S.J., 2010. Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. J. Fish. Biol. 76 (9), 2194–2215.
da Silva, L.D.M.C., Machado, I.C., dos Santos Tutui, S.L., Tomás, A.R.G., 2020. Local ecological knowledge (LEK) concerning snook fishers on estuarine waters: insights into scientific knowledge and fisheries management. Ocean Coast. Manag. 186, 105088.
Dedual, M., Sague Pla, O., Arlinghaus, R., Clarke, A., Ferter, K., Geertz Hansen, P., Ueberschär, B., 2013. Communication between scientists, fishery managers and recreational fishers: lessons learned from a comparative analysis of international case studies. Fish. Manag. Ecol. 20 (2–3), 234–246.
Deshpande, P.C., Brattebø, H., Fet, A.M., 2019. A method to extract fishers' knowledge (FK) to generate evidence for sustainable management of fishing gears. MethodsX 6, 1044–1053.
Dickinson, J.L., Shirk, J., Bonter, D., et al., 2012. The current state of citizen science as a tool for ecological research and public engagement. Front. Ecol. Environ. 10, 291–297.
Diogo, H., Veiga, P., Pita, C., Sousa, A., Lima, D., Pereira, J.G., Rangel, M., 2020. Marine recreational fishing in Portugal: current knowledge, challenges, and future perspectives. Rev. Fish. Sci. Aquac. 28 (4), 536–560.
Dowiarz, S.A., 2021. Comparing the Hickory Shad (Alosa mediocris) and American Shad (Alosa sapidissima) Sport Fishery Using Age and Spawning Composition and Social Media. East Carolina University, p. 205.
Eden, S., 2012. Counting fish: Performative data, anglers' knowledge-practices and environmental measurement. Geoforum 43 (5), 1014–1023.
Florisson, J., 2015. Can recreational fishers provide an effective means of monitoring artificial reefs? Doctoral dissertation. Murdoch Univ. 155.
Font, T., Lloret, J., 2014. Biological and ecological impacts derived from recreational fishing in Mediterranean coastal areas. Rev. Fish. Sci. Aquac. 22 (1), 73–85.
Franks, J.M., 2013. Relationships Between Recreational User Perceptions and the Biological Condition of West Virginia Watersheds. (Master's thesis). West Virginia University, p. 110 (Master's thesis).
Fraser, D.J., Coon, T., Prince, M.R., Dion, R., Bernatchez, L., 2006. Integrating traditional and evolutionary knowledge in biodiversity conservation: A population level case study. Ecol. Soc. 11 (2), 4.
Frijlink, S.D., Lyle, J.M., 2013. Establishing Historical Baselines for Key Recreational and Commercial Fish Stocks in Tasmania. Institute for Marine and Antarctic Studies, University of Tasmania, p. 119.
Galbraith, E.D., Carozza, D.A., Bianchi, D., 2017. A coupled human-Earth model perspective on long-term trends in the global marine fishery. Nat. Commun. 8 (1), 1–7.
Gallagher, A.J., Cooke, S.J., Hammerschlag, N., 2015. Risk perceptions and conservation ethics among recreational anglers targeting threatened sharks in the subtropical Atlantic. Endanger. Species Res. 29 (1), 81–93.
Garavito-Bermúdez, D., Boonstra, W.J., 2023. Knowing through fishing: exploring the connection between fishers' ecological knowledge and fishing styles. J. Environ. Plan. Manag. 66 (9), 1841–1860.
Garavito-Bermúdez, D., Lundholm, C., 2017. Exploring interconnections between local ecological knowledge, professional identity and sense of place among Swedish fishers. Environ. Educ. Res. 23 (5), 627–655.
Giglio, V.J., Suhett, A.C., Zapelini, C.S., Ramiro, A.S., Quimbayo, J.P., 2020. Assessing captures of recreational spearfishing in Abrolhos reefs, Brazil, through social media. Reg. Stud. Mar. Sci. 34, 100995.
Giovos, I., Stoilas, V.O., Al-Mabruk, S.A., Doumpas, N., Marakis, P., Maximiadi, M., de Maddalena, A., 2019. Integrating local ecological knowledge, citizen science and long-term historical data for endangered species conservation: additional records of angel sharks (Chondrichthyes: Squatinidae) in the Mediterranean Sea. Aquat. Conserv.: Mar. Freshw. Ecosyst. 29 (6), 881–890.
Granek, E.F., Madin, E.M., Brown, M.A., Figueira, W., Cameron, D.S., Hogan, Z., Arlinghaus, R., 2008. Engaging recreational fishers in management and conservation: global case studies. Conserv. Biol. 22 (5), 1125–1134.
Gray, S., Hilsberg, J., McFall, A., Arlinghaus, R., 2015. The structure and function of angler mental models about fish population ecology: the influence of specialization and target species. J. Outdoor Recreat. Tour. 12, 1–13.
Gray, S.A., 2010. Integrating Stakeholder Knowledge into the Management of a Social-ecological System: Mental Models, Risk, and Trust in Atlantic Coast Fisheries. (Doctoral dissertation). Rutgers University-Graduate School-New Brunswick, p. 139.
Griffiths, S.P., Pepperell, J., Tonks, M., Fay, G., Venables, W., Lyle, J.,. & Edgar, S. (2007). Developing innovative and cost effective tools for monitoring recreational fishing in Commonwealth fisheries. FRDC final report. 14: 211.
Grilli, G., Curtis, J., Hynes, S., O'Reilly, P., 2019. Anglers' views on stock conservation: sea bass angling in Ireland. Mar. Policy 99, 34–41.
Hallwass, G., Lopes, P.F., Juras, A.A., Silvano, R.A., 2013. Fishers' knowledge identifies environmental changes and fish abundance trends in impounded tropical rivers. Ecol. Appl. 23 (2), 392–407.
Hamilton, M., 2011. Comparisons of Ecological Knowledge about Fish Stocks among Fishermen, Fishery Managers, and Biologists in the south Atlantic (Master's thesis). East Carolina University,, p. 108.
Harris, S.A., Urton, A., Turf, E., Monti, M.M., 2009. Fish and shellfish consumption estimates and perceptions of risk in a cohort of occupational and recreational fishers of the Chesapeake Bay. Environ. Res. 109 (1), 108–115.
Harrison, H.L., Rybråten, S., Aas, Ø., 2018. Hatching knowledge: a case study on the hybridization of local ecological knowledge and scientific knowledge in small-scale Atlantic salmon (*Salmo salar*) cultivation in Norway. Hum. Ecol. 46 (4), 449–459.
Helvey, M., 2004. Seeking consensus on designing marine protected areas: keeping the fishing community engaged. Coast. Manag. 32, 173–190.
Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C.K., van de Bund, W., 2010. The European water framework directive at the age of 10: a critical review of the achievements with recommendations for the future. Sci. Total Environ. 408 (19), 4007–4019.
Hind, E.J., 2015. A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science. ICES J. Mar. Sci. 72 (2), 341–358.
Hunt, L.M., Fenichel, E.P., Fulton, D.C., Mendelsohn, R., Smith, J.W., Tunney, T.D., Whitney, J.E., 2016. Identifying alternate pathways for climate change to impact inland recreational fishers. Fisheries 41 (7), 362–372.
Joa, B., Winkel, G., Primmer, E., 2018. The unknown known – a review of local ecological knowledge in relation to forest biodiversity conservation. Land Use Policy 79, 520–530.
Johannes, R.E., Freeman, M.M., Hamilton, R.J., 2000. Ignore fishers' knowledge and miss the boat. Fish Fish. 1 (3), 257–271.
Kelly, R., Fleming, A., Pecl, G.T., von Gönner, J., Bonn, A., 2020. Citizen science and marine conservation: a global review. Philos. Trans. R. Soc. B 375 (1814), 20190461.
Kerns, T., 2003. Recreational Fishermen's Perceptions of Marine Protected Areas. (Doctoral dissertation). Duke University, p. 51.
Khumalo, B., 2021. Individual Decision-making and Cooperation in Freshwater Fisheries Management at the Somme River, Northern France. (Master's thesis). Department of Anthropology Faculty of Humanities. Department of Anthropology Faculty of Humanities, Rhodes University,, p. 117 (Master's thesis).

Kroloff, E.K., 2016. Where Are All the Bonefish? Using Angler Perceptions to Estimate Trends of Bonefish (*Albula vulpes*) Decline in South Florida. (Master's thesis). Florida International University,, p. 56.
Kroloff, E.K., Heinen, J.T., Braddock, K.N., Rehage, J.S., Santos, R.O., 2019. Understanding the decline of catch-and-release fishery with angler knowledge: a key informant approach applied to South Florida bonefish. Environ. Biol. Fish. 102 (2), 319–328.
Leite, M.C., Gasalla, M.A., 2013. A method for assessing fishers' ecological knowledge as a practical tool for ecosystem-based fisheries management: seeking consensus in Southeastern Brazil. Fish. Res. 145, 43–53.
Lewin, W.C., Arlinghaus, R., Mehner, T., 2006. Documented and potential biological impacts of recreational fishing: insights for management and conservation. Rev. Fish. Sci. 14 (4), 305–367.
Lewin, W.C., Weltersbach, M.S., Haase, K., Riepe, C., Skov, C., Gundelund, C., Strehlow, H.V., 2021. Comparing on-site and off-site survey data to investigate survey biases in recreational fisheries data. ICES J. Mar. Sci. 78 (7), 2528–2546.
Li, O., Sutton, S.G., Tynan, L., 2010. Communicating scientific information to recreational fishers. Hum. Dimens. Wildl. 15 (2), 106–118.
Lindenmayer, D.B., Likens, G.E., 2010. The science and application of ecological monitoring. Biol. Conserv. 143, 1317–1328.
Liu, Y., Bailey, J.L., Davidsen, J.G., 2019. Social-cultural ecosystem services of sea trout recreational fishing in Norway. Front. Mar. Sci. 6, 178.
Löki, V., Nagy, J., Nagy, A., Babai, D., Molnár, Zs, Lukács, B.A., 2021. Known but not called by name: recreational fishers' ecological knowledge of freshwater plants in Hungary. J. Ethnobiol. Ethnomed. 17 (1), 1–16.
Maes, F., Coppens, J., Vanhulle, A., 2012. LECOFISH: an Ecosystem Approach in Sustainable Fisheries Management through Local Ecological Knowledge. Research Programme Science for a Sustainable Development. Belgian Science Policy Office 2013, Brussels, p. 107 (Final Report).
Mamun, A.A., 2007. Traditional ecological knowledge and its importance for conservation and management of freshwater fish habitats of Bangladesh. (Master's thesis). University of Manitoba Winnipeg, Manitoba, p. 108 (Master's thesis).
Martínez-Escauriaza, R., Hermida, M., Villasante, S., Gouveia, L., Gouveia, N., Pita, P., 2020. Importance of recreational shore angling in the archipelago of Madeira, Portugal (northeast Atlantic). Sci. Mar. 84 (4), 331–341.
Maurstad, A., 2002. Fishing in murky waters—ethics and politics of research on fisher knowledge. Mar. Policy 26 (3), 159–166.
McKinley, D., Miller-Rushing, A.J., Ballard, H.L., Bonney, R., Brown, H., Cook-Patton, S.C., Evans, D.M., French, R.A., Parrish, J.K., Phillips, T.B., Ryan, S.F., Shanley, L.A., Shirk, J.L., Stepenuck, K.F., Weltzin, J.F., Wiggins, A., Boyle, O.D., Briggs, R.D., Chapin III, S.F., Hewitt, D.A., Preuss, P.W., Soukup, M.A., 2017. Citizen science can improve conservation science, natural resource management, and environmental protection. Biol. Conserv. 208, 15–28.
Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: wetlands and water. World Resources Institute, 80 p.
Minasidis, V., Doumpas, N., Kleitou, P., Spryridopoulou, R.N.A., Papadamakis, P., Giovos, I., 2020. Additional records of tripletail *Lobotes surinamensis* (Bloch, 1790), from the Eastern Mediterranean. Thalassas 36 (2), 557–563.
Morales-Nin, B., Arlinghaus, R., Alós, J., 2021. Contrasting the motivations and wildlife-related value orientations of recreational fishers with participants of other outdoor and indoor recreational activities. Front. Mar. Sci. 1005.
Nelson, M.K., Shilling, D., 2018. Traditional Ecological Knowledge: Learning from Indigenous Practices for Environmental Sustainability. Cambridge University Press,, p. 291.
Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., Crowston, K., 2012. The future of citizen science: emerging technologies and shifting paradigms. Front. Ecol. Environ. 10 (6), 298–304.
Noble, M.M., Harasti, D., Fulton, C.J., Doran, B., 2020. Identifying spatial conservation priorities using traditional and local ecological knowledge of iconic marine species and ecosystem threats. Biol. Conserv. 249, 108709.
Obregón, C., Tweedley, J.R., Loneragan, N.R., Hughes, M., 2019. Different but not opposed: perceptions between fishing sectors on the status and management of a crab fishery. ICES J. Mar. Sci. 77 (6), 2354–2368.
Olaussen, J.O., Skonhoft, A., 2008. On the economics of biological invasion: an application to recreational fishing. Nat. Resour. Model. 21 (4), 625–653.
Öndes, F., Ünal, V., Özbilgin, Y., Deval, C., Turan, C., 2018. By-catch and monetary loss of pufferfish in Turkey, the Eastern Mediterranean. Ege J. Fish. Aquat. Sci. 35 (4), 361–372.
Özbek, E.Ö., Mavruk, S., Saygu, İ., Öztürk, B., 2017. Lionfish distribution in the eastern Mediterranean coast of Turkey. J. Black Sea/Mediterr. Environ. 23 (1), 1–16.
Palas, S., Villasante, S., Pita, P., 2017. Combining fishers' knowledge and cost-effective monitoring tools in the management of marine recreational fisheries: A case study of the squid and cuttlefish fishery of the Ría of Vigo (NW Spain). Fish. Manag. Ecol. 24, 469–477.
Pecl, G.T., Stuart-Smith, J., Walsh, P., Bray, D.J., Kusetic, M., Burgess, M., Frusher, S.D., Gledhill, D.C., George, O., Jackson, G., Keane, J., 2019. Redmap Australia: challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. Front. Mar. Sci. 349.
Pine, W.E., Pollock, K.H., Hightower, J.E., Kwak, T.J., Rice, J.A., 2003. A review of tagging methods for estimating fish population size and components of mortality. Fisheries 28 (10), 10–23.
Pita, P., Villasante, S., & García Allut, A. , 2018. The role of marine stakeholders in the co-production of scientific knowledge: lessons from Galicia (NW Spain). (Oral presentation at International Conference: "Direct impacts of marine species on human activities in a changing world–scientific and stakeholders perceptions) CIESM Research Workshop (Vol. 50).
Pita, P., Alós, J., Antelo, M., Artetxe, I., Biton-Porsmoguer, S., Carreño, A., Villasante, S., 2020a. Assessing knowledge gaps and management needs to cope with barriers for environmental, economic, and social sustainability of marine recreational fisheries: the case of Spain. Front. Mar. Sci. 7, 23.
Pita, P., Antelo, M., Hyder, K., Vingada, J., Villasante, S., 2020b. The use of recreational fishers' ecological knowledge to assess the conservation status of marine ecosystems. Front. Mar. Sci. 7, 242.
Poizat, G., Baran, E., 1997. Fishermen's knowledge as background information in tropical fish ecology: a quantitative comparison with fish sampling results. Environ. Biol. Fish. 50, 435–449.
Pratt, M., 1977. Angling, fishery management and nature conservation. Aquac. Res. 8 (2), 52–54.
Quinn, B.K., 2018. Dramatic decline and limited recovery of a green crab (*Carcinus maenas*) population in the Minas Basin, Canada after the summer of 2013. PeerJ 6, e5566.
Radinger, J., Britton, J.R., Carlson, S.M., Magurran, A.E., Alcaraz-Hernández, J.D., Almodóvar, A., García-Berthou, E., 2019. Effective monitoring of freshwater fish. Fish Fish. 20 (4), 729–747.
Raynal, J.M., Weeks, R., Pressey, R.L., Adams, A.J., Barnett, A., Cooke, S.J., Sheaves, M., 2020. Habitat-dependent outdoor recreation and conservation organizations can enable recreational fishers to contribute to conservation of coastal marine ecosystems. Glob. Ecol. Conserv., e01342
Rehage, J.S., Santos, R.O., Kroloff, E.K.N., Heinen, J.T., Lai, Q., Black, B.D., Adams, A.J., 2019. How has the quality of bonefishing changed over the past 40 years? Using local ecological knowledge to quantitatively inform population declines in the South Florida flats fishery. Environ. Biol. Fish. 102 (2), 285–298.
Rotman, D., Preece, J., Hammock, J. et al. (2012). Dynamic changes in motivation in collaborative citizen- science projects. In: Proceedings of the 2012 Conference on Computer Supported Cooperative Work, CSCW'12. Seatle, pp. 11–15 February 2012). (eds S. Poltrock and C. Simone), ACM, New York, pp. 217–226.
Santos, R.O., Rehage, J.S., Kroloff, E.K.N., Heinen, J.E., Adams, A.J., 2019. Combining data sources to elucidate spatial patterns in recreational catch and effort: fisheries-dependent data and local ecological knowledge applied to the South Florida bonefish fishery. Environ. Biol. Fish. 102 (2), 299–317.
Sawchuk, J.H., Beaudreau, A.H., Tonnes, D., Fluharty, D., 2015. Using stakeholder engagement to inform endangered species management and improve conservation. Mar. Policy 54, 98–107.
Sbragaglia, V., Correia, R.A., Coco, S., Arlinghaus, R., 2020a. Data mining on YouTube reveals fisher group-specific harvesting patterns and social engagement in recreational anglers and spearfishers. ICES J. Mar. Sci. 77 (6), 2234–2244.
Sbragaglia, V., Cerri, J., Bolognini, L., Dragićević, B., Dulčić, J., Grati, F., Azzurro, E., 2020b. Local ecological knowledge of recreational fishers reveals different meridionalization dynamics of two Mediterranean subregions. Mar. Ecol. Prog. Ser. 634, 147–157.
Sbragaglia, V., Coco, S., Correia, R.A., Coll, M., Arlinghaus, R., 2021. Analyzing publicly available videos about recreational fishing reveals key ecological and social insights: a case study about groupers in the Mediterranean Sea. Sci. Total Environ. 765, 142672.

Shiffman, D.S., Gallagher, A.J., Wester, J., Macdonald, C.C., Thaler, A.D., Cooke, S.J., Hammerschlag, N., 2014. Trophy fishing for species threatened with extinction: a way forward building on a history of conservation. Mar. Policy 50, 318–322.
Silvano, R.A., Begossi, A., 2005. Local knowledge on a cosmopolitan fish: ethnoecology of *Pomatomus saltatrix* (Pomatomidae) in Brazil and Australia. Fish. Res. 71 (1), 43–59.
Silvano, R.A., Begossi, A., 2012. Fishermen's local ecological knowledge on Southeastern Brazilian coastal fishes: contributions to research, conservation, and management. Neotrop. Ichthyol. 10, 133–147.
Silvano, R.A., Valbo-Jørgensen, J., 2008. Beyond fishermen's tales: contributions of fishers' local ecological knowledge to fish ecology and fisheries management. Environ., Dev. Sustain. 10 (5), 657–675.
Stratoudakis, Y., Vidal, D., Fernandez, F., Alvarez-Fernández, I., Henriques, M. Verisimo, P., Martins, J., Martins, R. & Freire, J., 2014. Common monitoring trial: design and application of a questionnaire for fishers and stakeholders in three MPAs. Technical report, MAIA (Marine Protected Areas of the Atlantic Arc), 63 p.
Sutton, S.G., Tobin, R.C., 2009. Recreational fishers' attitudes towards the 2004 rezoning of the Great Barrier Reef Marine Park. Environ. Conserv. 245–252.
Ten Brink, T.S., Dalton, T., 2018. Perceptions of commercial and recreational fishers on the potential ecological impacts of the Block Island Wind Farm (US). Front. Mar. Sci. 5, 439.
Thurstan, R.H., Buckley, S.M., Pandolfi, J.M., 2016. Using commercial and recreational fisher knowledge to reconstruct historical catch rates for Queensland snapper (*Chrysophrys auratus*), Spanish mackerel (Scomberomorus commerson) and coral trout (Plectropomus spp.): long-term data for incorporation into future stock assessments. Fish. Res. Dev. Corp. 87.
Tufts, B.L., Holden, J., DeMille, M., 2015. Benefits arising from sustainable use of North America's fishery resources: economic and conservation impacts of recreational angling. Int. J. Environ. Stud. 72 (5), 850–868.
Tweedley, J.R., Florisson, J.H., Bateman, T.A., Chaplin, J.A., Gill, H.S., 2016. Recreational fishing initiatives fund final report: can recreational fishers provide a cost effective means for monitoring artificial reefs? Recreat. Fish. Initiat. Fund. Final Rep. 184.
Valbo-Jørgensen, J., Poulsen, A.F., 2000. Using local knowledge as a research tool in the study of river fish biology: experiences from the Mekong. Environ. Dev. Sustain. 2, 253–376.
Veneroni, B., Fernandes, P.G., 2021. Fishers' knowledge detects ecological decay in the Mediterranean Sea. Ambio 50 (6), 1159–1171.
Venturelli, P.A., Hyder, K., Skov, C., 2017. Angler apps as a source of recreational fisheries data: opportunities, challenges and proposed standards. Fish Fish. 18 (3), 578–595.
Vohland, et al., 2021. The Science of Citizen Science. Springer. https://doi.org/10.1007/978-3-030-58278-4_1.
Voyer, M., Gladstone, W., Goodall, H., 2014. Understanding marine park opposition: the relationship between social impacts, environmental knowledge and motivation to fish. Aquat. Conserv.: Mar. Freshw. Ecosyst. 24 (4), 441–462.
Wine, V.L. , 1980. Southern California private-boat sport fishermen: how familiar are they with the sport fishing regulations? California Department of Fish and Game, Marine Resources Region. Administrative report No.80–4, 10 pp.
Young, M.A., Foale, S., Bellwood, D.R., 2016. Why do fishers fish? A cross-cultural examination of the motivations for fishing. Mar. Policy 66, 114–123.
Zukowski, S., Curtis, A., Watts, R.J., 2011. Using fisher local ecological knowledge to improve management: the Murray crayfish in Australia. Fish. Res. 110 (1), 120–127.
Zukowski, S., Asmus, M., Whiterod, N., Conallin, A., Campbell, J., Fisher, I., Bright, T., 2018. Collaborating with recreational fishers to inform fisheries management: estimating population abundance for an iconic freshwater crayfish. Ecol. Manag. Restor. 19 (1), 85–88.