

# Overturning stereotypes: The fuzzy boundary between recreational and subsistence inland fisheries

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### Abstract

Inland recreational fisheries provide numerous socio-economic benefits to fishers, families and communities. Recreationally harvested fish are also frequently consumed and may provide affordable and sustainable but undervalued contributions to human nutrition. Quantifying the degree to which recreationally harvested fish contribute to food security and subsistence is impeded by lack of data on harvest and consumption and by the difficulty in differentiating among recreational and subsistence fisheries. Recreational harvest records tend to be limited to wealthy, food-secure countries and well-monitored fisheries with clear regulations or permitting systems. These records often neglect components of recreational harvest among food-insecure fishers who are potentially more likely to have consumption as a motivation. Here, we highlight the 'fuzzy boundary' that can exist between inland recreational and subsistence fisheries and argue that unreported consumption is likely to be a hidden contributor to food security in some populations. We draw on local case studies from around the world to highlight specific instances where recreationally harvested fish species contribute food and subsistence benefits to participating communities. We use these examples to highlight the diversity of ways that inland recreational fisheries contribute to

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human nutrition, knowledge gaps in understanding recreational fishing for food, and consequences of not accounting for them as food fisheries in policy and management. The aim of this paper is to draw the attention of resource managers and policy makers, create greater social awareness of the importance of recreational fisheries and bring to light this hidden contribution of inland fisheries to nutrition and subsistence.

#### KEYWORDS

consumptive motivation, fish consumption, food security, freshwater, nutrition, recreational fishers

# 1 | INTRODUCTION

Inland recreational fishing (i.e. that conducted in rivers, streams, lakes and other landlocked waters) is an important leisure activity worldwide, with established or potential social, economic and health benefits to participating communities (Funge-Smith et al., 2018; Parkkila et al., 2010). Motivations to engage in recreational fishing, including leisure, challenge, enjoyment of nature and harvest of fish (Burkett & Winkler, 2019; Driver & Knopf, 1976; Finn & Loomis, 2001; Hunt et al., 2002; Ross & Loomis, 2001; Toivonen et al., 2004; see Fedler & Ditton, 1994 for a review), vary by country, basin, region and individual (Beardmore et al., 2011; Fedler & Ditton, 1994, 2001). In the context of general recreational motivations (Manfredo et al., 1996), the decision to harvest and consume recreational catch is multifaceted (Burger, 2002; Cooke et al., 2018; Hunt et al., 2007), and can be based on the palatability of species, tradition and culture, local rules and regulations, location, economic status of the fisher, desire to share with family and friends, and general propensity to engage in voluntary catch-and-release (Arlinghaus et al., 2007; Cooke et al., 2016, 2018; Ditton & Sutton, 2004; Potts et al., 2019). In some cases, however, the retention of recreational catch is motivated by the need to fulfil or complement the nutritional requirements of fishers and their families (Butler, 2019; Cooke et al., 2016, 2018; Embke et al., 2020; Macinko & Schumann, 2007; Potts et al., 2019; Quimby et al., 2020). This creates a 'fuzzy boundary' between the recreational and subsistence inland fishery sectors that has not been yet well-quantified or addressed in the literature (FAO, 2012). In their 2018 paper, Cooke et al. considered intersections between recreational fisheries, food and nutrition in marine and inland recreational sectors couching their discussion within the broader literature on fisher motivation and consumptive orientation, alongside overviews of consumption trends across six continents. Here, we narrow the focus to inland fisheries and provide detailed descriptions of localized case studies that demonstrate the diverse ways that fuzzy boundaries manifest in inland fisheries around the world. These fisheries are particularly difficult to classify and manage sustainably (FAO, 2012) and put the vulnerable populations who depend on them more at risk. We further reinforce the awareness that stereotypes that separate recreational from subsistence fisheries are not helpful for devising policy and management actions that seek to improve monitoring and sustainable harvest of this sector. By typifying the overlap between the sectors, we demonstrate

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that, when framed in a broader context, inland recreational fisheries may be seen to provide an important, accessible and affordable contribution to human nutrition in some communities. We use our examples to highlight important knowledge gaps that exist even in the best-monitored recreational fisheries and the consequences of not managing these important fisheries as food fisheries. Moreover, in many developing country fisheries where general information on recreational fisheries is not available, economic benefits and livelihood concerns are often the primary interests over the food and nutritive benefits of the sector.

## 1.1 | Unpacking basic definitions

To explore the fuzzy boundary between recreational and subsistence fisheries, we need to begin with clear definitions of each sector to illuminate their distinctiveness and to identify where they intersect. Indeed, the wide variety of definitions of 'recreational' and 'subsistence' fishing indicate the ambiguous distinction between the sectors. The Food and Agriculture Organization (FAO) of the United Nations defines recreational fisheries as 'fishing of aquatic animals (mainly fish) that do not constitute the individual's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets' (FAO, 2012, p. 2). This definition is intentionally flexible and inclusive of the diverse ways of engaging in recreational fisheries that fall on a continuum from purely recreational to subsistence. Taking the definition by FAO (2012) literally would mean that a person that depends on selfcaptured fish for the majority (>50%) of their animal protein and that would be unable to substitute this food by alternative sources would be considered a subsistence fisher. However, would we judge a person that generates 49% of animal protein intake from self-caught fish as a 'pure' recreational fisher? Here, lies the boundary that we address. Also, alternative definitions distinguish more sharply between the two sectors, such as that proposed by the Mediterranean Advisory Council (MEDAC, 2016) that suggest recreational fisheries are separate from subsistence (Hyder et al., 2017).

Definitions of subsistence fishing are similarly diverse and equivocal. Berkes (1988), for instance, defined them as 'local, noncommercial fisheries, oriented not primarily towards recreation but for the procurement of fish for consumption of the fishers, their families and community' (p. 319). On the other hand, FAO (2012) differentiates recreational from subsistence fisheries by the characteristic of the 'individual's primary resource' (p. 2), meaning that if an individual has the monetary resources to substitute self-caught fish for other nutritional sources, it is recreational, not subsistence. Other definitions generally proceed along these lines with language suggesting that subsistence is largely about food provisioning for direct consumption, for survival, or to achieve food security. Therefore, the concept of subsistence fishing does not have a unique interpretation and varies according to the region, case, and the local livelihood context (Schumann & Macinko, 2007). There is the unspoken tendency to associated subsistence fisheries with small-scale fisheries in low- and middle-income countries. However, even cursory field observations in some recreational fisheries in high-income countries have identified a portion of fishers for which self-captured fish is of importance to nutrition. Therefore, the fuzzy boundary among subsistence and recreational fisheries also exists in wealthier countries.

The concept of food security is intricately connected to subsistence; as highlighted by the 1996 World Food Summit statement that 'food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO, 1996, p. 1). This definition highlights the complex factors that contribute to food security (Ingram, 2020), emphasizes preference

as a vital component and opens interpretation on the meaning of sufficient quantity and quality (Gibson, 2012). In this paper, we use the term 'food security' to encompass everything from starvation avoidance to obtaining high quality and preferred food items that improve nutrition and health. With this in mind, we suggest that the term 'subsistence' and by extension 'subsistence fishing' can apply to a wide variety of activities from fishing for imminent survival to fishing for dietary needs and preferences (Berkes, 1990; Branch et al., 2002). Macinko and Schumann (2007) outlined four distinct conceptualizations of subsistence fishing as (a) economic activities sustaining a basic level of livelihood, not profit, (b) economies based on sharing, not selling, (c) social and cultural institutions supported by non-market distribution and (d) culturally significant food producing activities. The first two definitions characterize subsistence in economic terms, while the latter two position subsistence within traditional or cultural values. In this paper, however, we conceptualize subsistence fishing from an economic rather than cultural perspective. We recommend that future work could consider this topic from a cultural perspective that includes a rights and freedoms focus as well as exploring the mixed economies of traditional foods.

# 1.2 | The fuzzy boundary

Although there are cases where a given fishery falls neatly within the recreational or subsistence definitions, the boundary is not always clear. Examples include fisheries in some low- and middle-income countries (Butler, 2019; Potts et al., 2019), low-income fishers in both urban and rural areas of high-income countries (Burger, 2002; Burger et al., 1999: Dickinson et al., 2015), and immigrant fishers that carry cultural practices from their countries of origin and may be lower income than national resident people (Quimby et al., 2020). In these communities, fishers may rely on recreational fisheries to enhance their economic well-being, reduce their reliance on the cash economy (Dickinson et al., 2015; Glass et al., 1990) and contribute to their nutritional security (Cooke et al., 2018). Divisions between recreational and subsistence are further muddied because people who fish for sustenance often target similar species and have overlapping motivations with people who fish purely 'for fun' with no or limited interest in fish consumption (Butler, 2019; Cooke et al., 2016, 2018; Glass et al., 1990). For example, recreational fishers may be as motivated by being in nature and connecting with others while fishing as they are to contribute to their own nutritional security (Butler, 2019; Dickinson et al., 2015). Conversely, some fishers might retain catch for legal reasons that have nothing to do with subsistence or food security (Arlinghaus et al., 2007). In addition, comparable gear types are used in both recreational and subsistence sectors, and some gear types (e.g. spears, arrows, gillnets) make harvest and consumption the norm (see Cooke et al., 2018 for further details on gear types).

We suggest that, when examined in detail, the fuzzy boundary between recreational and subsistence fisheries is common in inland systems and that the degree to which those recreationally harvested fish are consumed for food security or nutritional supplementation purposes is likely to be much higher than is currently understood (Cooke et al., 2018). Quantifying how much recreational harvest contributes to consumption on a global scale is impeded by lack of data on harvest and consumption rates and by poor definitions as outlined above. In many regions, inland fisheries tend to be spatially dispersed and largely unmanaged and/ or unregulated, and most jurisdictions fail to monitor even basic characteristics of the recreational sector (Arlinghaus et al., 2019; Cooke et al., 2016; Post et al., 2002). The recreational sector of low- and middle-income countries' fisheries is sometimes entirely unrecorded and lacking in any licensing or registration system (Bower et al., 2020). Reliable records and regulations tend to be limited to wealthier countries with longer histories of recreational fishing and adequate human and economic resources for data management (Arlinghaus et al., 2021). However, even in higher income countries, assessments of consumption omit harvest that occurs under informal circumstances or in regions with insufficient reporting protocols. Similar to commercial fisheries, where illegal, unreported and unregulated fishing is common, there is also significant underreporting in much more numerous and difficult to quantify global recreational fisheries. It is in these informal, unrecorded and unreported fisheries where the fuzzy boundary is likely to be most common. Although confirmation of our suppositions is challenged by lack of available data, this topic warrants investigation to understand how best to evaluate, manage and direct policy to support these fisheries.

While examining fuzzy boundaries is relevant for both inland and marine fisheries, we focus on the inland sector for several reasons. First, inland recreational and subsistence fisheries tend to be informal and less reliant on established infrastructures or networks and are thus less monitored compared to the marine sector (Cooke et al., 2016). Second, inland recreational fisheries occur on a wide range of water bodies and are accessible across diverse spectra of age, ability, socioeconomic status, ethnicity and gender (Hunt & Ditton, 2002; Hutt & Neal, 2010), making them likely to exemplify the fuzzy boundary. Finally, inland recreational fisheries are disproportionately threatened by climate change, catchment disturbances and other non-fishing-related changes (Nyboer et al., 2021), making it essential to recognize the services that they provide and to account for consumption-oriented recreational harvest in management. Greater awareness of these issues can motivate shifts in environmental protection and natural resource management policies.

To draw attention to the fuzzy boundary that can exist between inland recreational and subsistence fishing, we use localized case studies. These case studies illustrate diverse and specific instances from around the globe where recreationally harvested inland fish are captured and consumed for subsistence and food security purposes. They discuss knowledge gaps that exist on the contributions of these fisheries to consumption and nutrition and the implications of such to sustainable management. In keeping with our economic conceptualization of subsistence, our exploration of the fuzzy boundary does not consider fisheries rooted in cultural, religious or spiritual practice, such as many Indigenous fisheries. Although Indigenous FISH and FISHERIES

fisheries may at times be motivated by subsistence, conflating Indigenous fishing practices with recreational fishing is inappropriate (Castañeda et al., 2020; Shamsi et al., 2020). Therefore, while we acknowledge the importance of these fisheries, we do not draw them into our discussion.

We hope that by describing and typifying the fuzzy boundary we can highlight the importance of inland recreational fishing for subsistence and food security and provide insight into how to best direct policy to assess, monitor and manage these fisheries. We encourage that the old paradigm of recreational fishing considered as only for pleasure (e.g. Pitcher & Hollingworth, 2002) be expanded to a broader concept that includes food objectives as is common in lowand middle-income countries but is also evident in some high-income countries. We aim to reinforce the awareness that such stereotypes must be questioned when devising policy and management actions that seek to improve sustainability of the inland fishery sector.

# 2 | FUZZY BOUNDARY CASE STUDIES

Below, we describe six case studies from around the globe that demonstrate the existence or emergence of the fuzzy boundary between recreation and subsistence in inland fisheries. Each case study describes the target species, gears used and human community involved; each provides information on how the fishery operates and on the social, economic and political contexts under which the fisheries emerged. Details of case studies are summarized in Table 1, by drawing on case studies from countries across a range of social and economic development, we demonstrate that recreational fisheries contribute to subsistence and food security in diverse contexts and thus that the fuzzy boundary is present regardless of economic status.

# 2.1 | Recreational catfish trotline fisheries contribute to food security creating a fuzzy boundary for rural communities in Virginia, United States of America (USA)

In the United States, there is a subculture of recreational fishers who target catfish (large-bodied lctalurid species such as channel catfish (*lctalurus punctatus*, lctaluridae) and blue catfish (*lctalurus furcatus*, lctaluridae) using trotlines (i.e. baited hooks attached to droplines or 'trots', clipped at intervals to a heavy mainline laid horizontally in the water column; Table 1; Figure 1). Recreational trotline fishers are predominantly male, rural and harvest-oriented (Quinn, 1993; Reitz & Travnichek, 2004). They have strong connections to outdoor lifestyles where fishing is one of several subsistence activities conducted within the household, along with hunting, gathering and preserving food (Quinn, 1993; Wilde & Ditton, 1999). Because many trotline fishers operate casually, they tend to be poorly represented in fisheries management processes and estimates of numbers of participants in the fishery and harvest rates across the United States are largely unknown.

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FIGURE 1 Illustration of a fisher using a trotline to capture catfish in the New River, Virginia, USA Illustration by Lakshita Dey.

Dickinson et al. (2015) surveyed the habits, motivations and opinions of trotline fishers on the New River, Virginia, and found that although fishers were driven by both catch-related and noncatch-related factors, sustenance was a key driver for this fishery. Trotline fishers reported eating up to 125 catfish meals per year and were unaware of any size or bag limits on consumption of these fish (Dickinson et al., 2015). Harvest for consumption was the most common motivation stated by trotline fishers; however, many of the same fishers were equally motivated by the thrill of the catch (Dickinson et al., 2015) indicating that the sport aspect of fishing is likely to maintain fishers' interest in fishing for food provisioning. The boundary between subsistence and recreation is blurred in rural communities such as these, and this fishery can neither be classified as strictly a recreational fishery nor a subsistence fishery (Wilde & Ditton, 1999).

It is important to note this fuzzy boundary in a management context that treats these subsistence-oriented fisheries as primarily recreational. The New River trotline fishery is marginalized, and fewer people engage in this fishery now compared to several years ago (Dickinson et al., 2015). Given limited resources, management does not prioritize monitoring or regulating this fishery; consequently, most of the trotline fishers had a limited understanding of current regulations and consumption advisories, which is troubling as some trotline fishers ate New River fish in excess of the recommended limits (Dickinson et al., 2015). The fishery is currently governed by recreational fishing policies but a reframed focus on sustenance may be more appropriate.

# 2.2 | New management approaches are required to accommodate fuzzy boundary fishers in South Africa

Recreational fishing in southern Africa's inland waters normally conjures images of high-value foreign tourist fisheries in wilderness areas. However, some countries (e.g. South Africa, Zimbabwe) have large local recreational fisheries that incorporate a subsistence element and compete with the subsistence fisheries sector for resources (Britz et al., 2015; Walsh & Williams, 1993). A recent survey of South Africa's angling sector found that of the country's ~750,000 recreational fishers, at least 25% were from the low- or low-middle income brackets, and that of the ~4000 tonnes of inland fish harvested annually (Appendix A), most (72%) were eaten (W. Potts, unpublished). Additionally, estimates of numbers of low-income fishers, harvest and consumption rates are likely to be higher than reported as the survey was predominantly conducted online and filled out by respondents from high-income brackets (Potts et al., 2022).

The evolution of the recreational and subsistence sectors in South Africa plays a role in the fuzziness of the boundary between these sectors. Local recreational fishers emerged from a growing middle-class as the economy developed. However, fishing simultaneously became important as an adaptive livelihood strategy as the traditional means of food production (i.e. livestock, crop production) became insufficient to support growing populations (Britz et al., 2015). Subsistence fishing in most of South Africa is not rooted in Indigenous fishing traditions (except for some communities such as the Thonga people in Maputaland), and at first these subsistence fishers used gillnets and traps. However, because these gears are illegal in most of South Africa's inland systems, subsistence fishers have had to rely on recreational fishing techniques (e.g. rod and reel) to catch fish for food (Table 1, Figure 2) (Britz et al., 2015). Participation in angling by poor fishers has in many cases evolved into recreational fishing (Britz et al., 2015). Consequently, there is a continuum of recreational fishers ranging from low-income individuals who rely heavily on their catch for food to the middle- and upperincome individuals who release all or most of their catch. Between these extremes is a fuzzy boundary where it may be difficult to classify an individual as a recreational or a subsistence fisher.

South Africa's national inland capture fisheries policy is nearing promulgation. A central tenet will be equitable access to inland



FIGURE 2 Illustration of recreational/subsistence fishers using rod and reel at the Makuleke Dam, South Africa. Illustration by Lakshita Dey.

resources to those marginalized from customary resource access during the Apartheid and Colonial era. The policy also calls for categorization of participants into sectors (i.e. small-scale, traditional and recreational) and implementing a permit system. Given that the criteria for categorization of individuals into the small-scale and traditional sectors will be complex, it is highly likely that many subsistence-oriented individuals will be categorized as recreational fishers by default (see Sowman & Sunde, 2021). There have been increasing tensions between the growing subsistence sector and recreational fisheries in South Africa (Britz et al., 2015). While this has been attributed to a lack of policy, it can also be ascribed to the increasing reliance on fish resources to meet the nutritional needs of the families of subsistence fishers and increasing numbers of poor recreational fishers. While the promulgation of the new inland fisheries policy and division of the angling population into sectors may alleviate some tension, the likely increase in the ambiguity of what constitutes a recreational fisher may lead to inter- and intra-sectoral tensions and may warrant close monitoring.

# 2.3 | Inequalities in China's rapidly growing recreational sector signal an emerging fuzzy boundary

Traditionally, inland fisheries in Asia are small scale and subsistenceoriented with little large-scale commercial fishing, except perhaps in China (Funge-Smith et al., 2018; Funge-Smith & Bennett, 2019). Only recently has recreational fishing become prominent in some Asian countries, with the industry growing rapidly as wealth and leisure time increase (Cooke et al., 2016). The recreational fishery sector in China typifies this transition, with a major shift away from traditional capture fisheries because of dwindling fish stocks in natural waters (Kang et al., 2017; Zhao et al., 2015) towards a more recreation-oriented inland sector (Zhang et al., 2020). Over the past two decades, harvest rates from inland waters declined from around 2.2 million tonnes in 1998 to around 1.9 million tonnes in 2019 (Hu et al., 2021). However, the contribution of recreational angling to this catch is unknown despite the rapid growth of this sector (Hu et al., 2021), and continues to be excluded from management considerations (Zhang et al., 2020). Today, estimates suggest that there are between 90 million (Arlinghaus et al., 2019) and 220 million (China Society of Fisheries, 2018) recreational fishers in China, however, the term 'recreational fishing' encompasses a variety of activities including fishing, aquaculture, shell and algae collection, and fish viewing. Nevertheless, much emphasis is placed on harvesting and consuming recreationally caught fish (Chen & Zhou, 2021; Yang et al., 2017), so the sector also supports the nutritional needs of the country. Although no data are available on the volume of fish consumed, the economic value of recreational fisheries is estimated to be ~13.5 billion USD, accounting for 3.7% of the total fishery value in 2019, including marine, inland and aquaculture (Hu et al., 2021) (Table 1).

These statistics suggest that recreational fisheries are an important activity in China. However, growth of the industry is currently FISH and FISHERIES

more prominent in the wealthier eastern and southern provinces of Shandong, Hubei and Guangdong (Ding et al., 2021). In those provinces, the government has provided guidance on promoting sustainable recreational fishing (Ying, 2014) and is planning to build leisure infrastructure (e.g. piers, boat sheds) to facilitate the development of the industry (Huang & Tang, 2019; Zhang, 2015). In addition, there are plans to re-allocate large open waters into 'fishing fields' (Figure 3), where a key goal is to provide a source of food and recreation to local people (Ying, 2014). These developments are concentrated and monitored in some regions more than in others, and western provinces with lower economic development and higher reliance on these resources for food security have not kept pace. Such inequalities exacerbate the problem of evaluating the contribution of recreational fisheries to food security or understanding boundaries between recreational and subsistence fishing (Ding et al., 2021), especially for regions that are likely to use inland waters recreationally to contribute to nutritional requirements of households.

# 2.4 | Diverse recreational fishing attitudes in Europe exemplify the complexities underlying fuzzy boundaries in the inland fisheries of Germany and the Czech Republic

Recreational fishing is a common pastime across much of Europe, but attitudes towards harvest and consumption vary among countries and communities (Arlinghaus et al., 2021; Cooke et al., 2018). In Germany, for example, recreational fishing developed as a leisure activity for the working class and prominently after the two world wars. Consumption and generation of fish for food has thus always been a key motivation for German recreational fishers and remains one of the few accepted reasons to engage in recreational fishing in the country (Arlinghaus, 2007; Ferter et al., 2020). Recreational fishers are prolific, landing ~45,000 tonnes of fish per year (Arlinghaus, 2004) outweighing commercial inland yield, which is ~3,000 tonnes per year. In Germany, voluntary catch-and-release happens but is often only practiced if fish are unpalatable or undersized (Jendrusch & Arlinghaus, 2005) or by highly specialized anglers; fishes traditionally judged as having high culinary value include zander (Sander lucioperca, Percidae), pike (Esox lucius, Esocidae) and eel (Anguilla Anguilla, Anguillidae), while bony cyprinids such as roach (Rutilus rutilus, Cyprinidae), bream (Abramis brama, Cyprinidae) or common carp (Cyprinus carpio, Cyprinidae) and in some regions also pike, are regularly released at high fractions (Arlinghaus, 2007; Arlinghaus et al., 2015, 2021; Arlinghaus & Mehner, 2004; Beardmore et al., 2011). Nevertheless, the debate over whether it is ethical to engage in voluntary catch-and-release is heated in both political and social spheres (Riepe & Arlinghaus, 2014).

In the Czech Republic, voluntary catch-and-release and fishing for consumption are both common and depend entirely on the fishers' preferences so long as harvest rates fall within allowed limits. Recreational fishers in the Czech Republic harvest 2,781 tonnes of inland fish annually (Lyach & Čech, 2018), and preferred species for 1288

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Case study	Scale	Target species in case study	Description of species	Techniques
USA	State (Virginia)	<ul> <li>channel catfish (<i>Ictalurus punctatus</i>, Ictaluridae)</li> <li>blue catfish (<i>Ictalurus furcatus</i>, Ictaluridae)</li> </ul>	Large-bodied catfish species; some introduced	Trotlines
South Africa	Country	<ul> <li>common carp (Cyprinus carpio, Cyprinidae)</li> <li>brown trout (Salmo trutta, Salmonidae)</li> <li>rainbow trout (Oncorhynchus mykiss, Salmonidae)</li> <li>smallmouth bass (Micropterus dolomieu, Centrarchidae)</li> <li>spotted bass (Micropterus punctulatus, Centrarchidae)</li> <li>largemouth bass (Micropterus salmoides, Centrarchidae)</li> </ul>	Variety of mid-sized introduced species	Shore fishing; handlines; homemade rod and line; rod and reel; bait angling; artificial lure angling; spearfishing
China	Country	<ul> <li>common carp</li> <li>black carp (Mylopharyngodon piceus, Cyprinidae)</li> <li>crucian carp (Carassius carassius, Cyprinidae)</li> <li>black bream (Megalobrama amblycephala, Cyprinidae)</li> <li>goldfish (Carassius auratus, Cyprinidae)</li> <li>silver carp (Hypophthalmichthys molitrix, Cyprinidae)</li> </ul>	Fish species differ by region, dependent on economic conditions and available aquatic resources. Cyprinids are the major freshwater species targeted, mainly in ponds, reservoirs and lakes. Little fishing in large rivers, although fishing in cages is prominent. Also includes mollusk and algal collection	Rod and line; bow and arrow; nets; traps
Germany / Czech Republic	Two countries	<ul> <li>zander (Sander lucioperca, Percidae)</li> <li>eel (Anguilla Anguilla, Anguillidae)</li> <li>roach (Rutilus rutilus, Cyprinidae)</li> <li>bream (Abramis brama, Cyprinidae)</li> <li>pike (Esox Lucius, Esocidae)</li> <li>catfish (Silurus glanis, Siluridae)</li> <li>common carp</li> </ul>	Variety of piscivorous and non- piscivorous species; some introduced (mainly common carp)	Shore and boat fishing; rod and reel fishing
Argentina	Basin (Parana River basin)	<ul> <li>catfish (Parapimelodus valenciennis; Pimelodus maculatus; Pimelodus albicans)</li> <li>tetra (Astyanax spp.)</li> <li>boga (Megaleporinus obtusidens, Anostomidae)</li> <li>trahira (Hoplias malabaricus, Erythrinidae)</li> <li>pati (Luciopimelodus pati, Pimelodidae)</li> </ul>	Indiscriminately targeted; species that range in body size and value	Shore fishing; simple, homemade rods; live bait; multiple poles
Australia	Territory (Northern Territory)	• barramundi (Lates calcarifer, Latidae)	Large-bodied diadromous predator	Shore fishing; boat fishing; Rod and reel

TABLE 1 Case studies 'at a glance'. Key features of the case studies including: (i) the scale of the fisheries (country, state/territory, basin); (ii) species/taxa of interest, (iii) features of these species and (iv) fishing gear used

consumption include zander, pike, catfish (*Silurus glanis*, Siluridae) and common carp (Horký, 2016). Anglers require licenses, and there are strictly enforced size and bag limits for all species. Reporting protocols are willingly complied with by most fishers (Horký, 2016).

In both nations, nuances in attitudes towards certain species can fuel conflicts between more release-oriented recreational anglers and more subsistence-oriented fishers, highlighting how the fuzzy boundary has emerged in Europe. In Germany, one species group that causes these conflicts is cyprinids. These fishes, especially bream and roach, tend to be abundant in eutrophic waters and can offer high catch rates for fisheries. Given that they were traditionally perceived to be of low culinary value, overabundant cyprinids were targeted during the 1970s and 1980s primarily for fishing club competitions that involved catching high quantities of fish and then releasing them. Although this practice was eventually banned for animal welfare reasons, the competitions have continued under the banner of 'management fishing' (Meinelt et al., 2008), with the fish typically removed after the catch to be fed to animals or dispatched. More recently, due to reduced nutrient inputs through improved water purification the standing stock of cyprinids has declined in many lakes and rivers affecting the quality of fishing competitions. Managers began to stock cyprinids in lakes to maintain





FIGURE 3 Illustration of a typical fishing field serving for both aquaculture and recreational fishing purposes in southern China. Illustration by Lakshita Dey.



FIGURE 4 Illustration of a group of subsistence-oriented migrant recreational fishers harvesting cyprinids along an urban river in Germany. Illustration by Lakshita Dey.

appropriate fishing successes for competitions. However, selected recreational fisher groups, particularly immigrants from Eastern Europe or Russia, consider cyprinids to be excellent food and remove these species intensively from local lakes and rivers (Figure 4). These groups' motivation is primarily subsistence, often salting and drying the fish and sharing them in extended family networks. Although their harvesting behaviour is fully in line with Germany's Animal Welfare Law, conflict has arisen among the immigrant and club recreational fisher who desire abundant cyprinids to fuel competitions (Meinelt et al., 2008).

Similar tensions exist in the Czech Republic. Czech rivers and reservoirs are primarily recreational destinations where fishers come to rest and relax with their families and fish for fun. However, numerous groups of people use these reservoirs to harvest fish for profit. While purely recreational fishers generally respect fishing rules and



**FIGURE 5** Illustration of recreational/subsistence fishers carrying their catch along the Paranà River, Argentina. Illustration by Lakshita Dey.

restrictions, non-resident fishers often exceed quotas (Lyach, 2021). Despite attempts at regulation and control, fishing for illegal consumption and profit still exists (Vehanen et al., 2020). Immigrant fishers in the Czech Republic do not conform with local norms of catch-and-release fishing and intensively harvest fish (Lyach & Čech, 2018). Both the German and Czech cases exemplify the fuzzy boundary between recreation and consumption, and illustrate how conflicts can arise when fishing regulations, motivations to fish, ethical considerations and evaluations of palatability are at odds among different communities (i.e. resident vs. immigrant fishers) who use and access the same resource base. Such situations necessitate agreement-building and negotiation among user groups and improved communication between resource users and managers. Similar developments have been reported from other European areas, for example from United Kingdom (UK) stillwater fisheries (Booth, 2015).

# 2.5 | Fuzzy boundaries do not create conflict in the fisheries of the Paranà River, Argentina

In Argentina, recreational fishers outnumber artisanal fishers. The recreational fisheries of the Paranà River extend throughout the entire Paranà basin and, although the recreational fisheries in this region have never been adequately evaluated, fishers can be broadly categorized into those who engage in 'typical' recreational angling motivated by leisure or competition and those who fish primarily for consumptive purposes. Despite some efforts to characterize recreational fisher demographics (e.g. Baigún, 2003; Iwaszkiw, 2001; Vigliano et al., 2010), the diffuse and informal consumption-oriented group has received little attention.

Unlike the leisure-oriented recreational fisheries geared towards specific target species, the informal consumption-oriented group is WILEY-FISH and FISHERIES

less regulated because it primarily targets smaller species that are not incorporated in the regulations or are not targeted by sport or artisanal fisheries (Figure 5). Furthermore, management agencies do not consider that this type of fishing merits regulation because it is not based on species of high commercial value or social importance. Because the aim of these fisheries is to supplement the nutrition of local people, the preferences of this group are much less selective. These fishers take advantage of the high species richness of the basin (López et al., 2008), including species of low commercial value (e.g. catfish species such as Parapimelodus valenciennis, Pimelodidae; Pimelodus maculatus, Pimelodidae; and Pimelodus albicans, Pimelodidae) (Figure 5), species that only have value as bait (e.g. tetras, Astyanax spp.), and occasionally species with high value for commercial and recreational fisheries (e.g. large-bodied fishes such as boga (Megaleporinus obtusidens, Anostomidae), trahira (Hoplias malabaricus, Erythrinidae) and pati (Luciopimelodus pati, Pimelodidae). Consumption-oriented recreational fishers prefer close and easy access to the river and fish exclusively from the shore using simple rods, which may be just a pole and line with live bait. A distinctive characteristic of this type of fishing is the use of more than one fishing pole and line (Table 1, Figure 6).

These fishers are generally unlicensed, and numbers increase notably on weekends with densities of 50 to 300 fishers per kilometre of coastline (C. Baigún, unpublished). Estimates suggest that informal, consumption-oriented recreational fishing in the Paranà corridor could extract about 7,500 tonnes of fish per year and generate an annual per capita consumption of 2.24 kg (C. Baigún, unpublished), representing 35–45% of the export fishery of *Prochilodus lineatus*, Prochilodontidae (Baigún et al., 2013). Such estimates highlight the potential importance of the fuzzy boundary in Argentinian inland fisheries. Despite their magnitude, Paraná's consumptionoriented recreational fisheries are not in conflict with other types of fisheries, primarily because they target distinct species, operate in different sites and use only simple rods or hand lines, setting them apart from leisure-oriented recreational fishers and artisanal fishers.

The lack of information available on subsistence-oriented fisheries is consistent with the lack of importance that management agencies assign to them. Recreational fishing is mistakenly considered an



FIGURE 6 Illustration of an Australian Indigenous youth fishing for Barramundi from a river in the Northern Territory, Australia. Illustration by Lakshita Dey.

activity that is practiced only for pleasure, ignoring that it can also represent a livelihood for people and a valuable food supplement. This inadequate vision is not only a weakness of fishery management agencies but also of the scientific sector in evaluating the true impact of this fishery considering its social and fishing value as it is based on species that are not included in the fishing regulations.

# 2.6 | Remote community and travelling fishers in the Northern Territory of Australia embody a fuzzy boundary

The remote tropical region of the Northern Territory (NT) in Australia has a long history of participation in recreational fishing and a high participation rate with 32% of the population engaged in recreational fishing, and 19% of this happening in inland systems (Matthews et al., 2019). Long travel distances to these remote areas provide important context for this case study. Food prices are ~ 60% higher in remote communities than the NT capital city of Darwin (Ferguson et al., 2016), and perishable foods are often in poor condition by the time they arrive in markets (Dietitians Australia, 2020). Consequently, remote communities have higher rates of food supplementation by wild harvest, especially for lower-income residents and remote area fishers. However, harvest and consumption rates are unknown for most of the ~20 recreationally harvested inland fish species in the NT (Jackson et al., 2014), and few studies document subsistence-oriented harvest. However, the diadromous barramundi (Lates calcarifer, Latidae), a charismatic species that is highly sought by recreational fishers, has received some attention in fisheries assessments and regional surveys (Table 1). Routine catch assessments of barramundi (Matthews et al., 2019) and surveys of aquatic fauna harvested by recreational fishers and Indigenous households (Henry & Lyle, 2003; Jackson et al., 2012, 2014) have provided reliable sources of information.

These datasets highlight four distinct but spatially connected fishing groups including resident recreational fishers, tourist sport fishers (West et al., 2012), 'grey nomads' (elderly Australians living cheaply by travelling and camping around the country) (Onyx & Leonard, 2005, 2007), and remote Indigenous communities (Jackson et al., 2014). To varying extents, these groups embody the fuzzy boundary between leisure- and subsistence-oriented recreational fishing in NT. For example, grey nomads, who currently comprise >2% of Australians (Cridland, 2008), are known to supplement their food with recreational fishing (Onyx & Leonard, 2005, 2007) and recreational harvest of barramundi is key to this community's intake of fresh food. Although grey nomads' annual barramundi harvest is smaller (24 tonnes) than resident recreational fishers (96 tonnes) and tourist sport fishers (66t) (West et al., 2012), this group tends to have higher consumption rates than the other fishers, especially those with tight budgets and those who stay in remote areas for long periods (Cridland, 2008). The value of barramundi recreational harvest is estimated at 7.4 M AUD per annum based on a retail price of 40 AUD per kg

(O'Brien, 2018) highlighting the significant economic function of this harvest. Recreational fish harvesting and sharing is also of social importance to grey nomad lifestyles (Cridland, 2008). Fish thus provide an affordable, healthy source of food for this groups, and simultaneously contribute benefits for mental and physical health. However, we acknowledge that this group's consumption is likely to fall closer to the 'preference' rather than the 'requirement' end of the subsistence/food security spectrum described in the Introduction.

The Indigenous population of the NT comprises 30% of inhabitants (West et al., 2012). Indigenous fishers were included in the above-mentioned recreational fishing surveys (Henry & Lyle, 2003; Jackson et al., 2012, 2014) and are known to catch and consume Barramundi for subsistence purposes. However, Indigenous communities' constitutional rights to access fish and their cultural and historical connections to fishing (Palmer, 2004) mean that many of their fishing activities cannot be considered 'recreational' (Shamsi et al., 2020), and thus do not exemplify the fuzzy boundary discussed in this paper. Nevertheless, discussions with a fisheries manager of Indigenous heritage from NT (Dr. Thor Saunders) and a Barkindji Traditional Owner (via Sarah Martin, pers. comm.) revealed that many individuals of Indigenous heritage in NT engage in recreational fishing that is not connected to traditional or cultural harvest (Figure 6). While such distinctions add a layer of complexity (and may even highlight a second fuzzy boundary), ignoring the contributions of this demographic to recreational harvest and consumption may overlook a critical part of the overall picture (Thor Saunders, pers. comm.). Recreational participation by the Indigenous population is expected to be higher than the 32% NT average (Thor Saunders, pers. comm.; Jackson et al., 2012). Household surveys undertaken on the remote Daly River catchment estimate that the total annual value of inland fish harvested in NT remote communities would total 7.3 M AUD per annum (Jackson et al., 2014). However, it is important to recognize that economic costs are more complex than just the commercial value. Fish provide affordable, healthy food that may otherwise be inaccessible to remote communities and provide a recreational activity with benefits to mental and physical health (Sarah Martin, pers. comm.).

Regional, social and climatic differences mean that this case study cannot be extrapolated across the whole of Australia. For example, Australia has an overall inland recreational participation rate of 19% although higher in regional areas (Henry & Lyle, 2003); and tourist populations and participation rates vary spatially. Despite this, it is worth considering that the NT constitutes only about 1% of the Australian population (25,750,000 in 2021; www.abs.gov. au/statistics/) suggesting that value of the subsistence recreational inland fish harvest would be much higher than estimated above. These components of subsistence recreational harvest by grey nomads and other remote community recreational fishers (e.g. some Indigenous community members) are likely to be underestimates given that many species apart from barramundi are harvested but not recorded. The lack of valuation of harvest and consumption of



FIGURE 7 Illustration of an 'idealized landscape' incorporating all the case studies in one image. This illustration highlights the similarities among subsistence-oriented recreational fishers around the world in terms of consumptive motivation, but similarly emphasizes the heterogeneity in technique, locale and context. Illustration by Lakshita Dey.

Australian recreational fisheries diminishes their worth and lessens attention to policies impacting their management. This impacts subsistence fishers, who are often in low-income or remote communities. Including the economic evaluation of subsistence harvest for all species in all Australian regional recreational fishery assessments would reveal considerable additional value within the Australian economy (e.g. Zander et al., 2013).

# 3 | DISCUSSION

Many practitioners and managers are aware of the diversity of participant motivations and overlapping sub-cultures within and among inland fishery sectors, as exemplified in the deliberately ambiguous UN definitions of recreational and subsistence fisheries. This paper contributes to understanding and typifying the inherently fuzzy boundary that exists between recreational and subsistence fisheries and highlights the hidden contributions of inland fish to global food security and subsistence. The concept of a fuzzy boundary is evident in the case studies we presented, highlighting the vast under-reporting of inland recreational harvest consumption across the globe. Although in some instances empirical data were lacking, the case studies reveal several gaps in our understanding of the contribution of inland recreational fisheries to subsistence and food security. In addition, this paper further highlights both the congruence and the heterogeneity that exists within the recreational fishing community (Figure 7) (Aas & Ditton, 1998; Beardmore, 2013). An individual fisher's orientation towards harvest may vary depending on the target species, where and when the fisher is operating, and among regions, their socio-economic status and cultural heritage.

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Documenting these patterns can be useful for generating better estimates of fish consumption and fully understanding this fuzzy boundary.

The case studies collectively demonstrate important gaps that exist in both understudied and well-monitored recreational fisheries. Common information gaps among case studies included lack of data on numbers of participants, biomass of fish harvested and consumed, and guantification of the nutritional deficits that recreationally harvested fish potentially fill. There is also missing information regarding the attitudes towards subsistence-oriented recreational fishers from overlapping resources users. Furthermore, complete characterization of the human demographics comprising these fisheries and the diversity of species consumed are also lacking. Each instance is situated within unique histories of development of the recreational fishing industry, which inform fisher attitudes. While management agencies have concentrated mainly on analysing attitudes and motivations of recreational fisheries (Aas & Ditton, 1998), much less effort has been put into addressing the unique sociopolitical and economic contexts that inform and structure these fuzzy boundary fisheries.

Recognizing the reality of fuzzy boundaries thus demands looking at this issue through lenses of intersectionality and equity. From a gender perspective, for many decades recreational fisheries have been viewed by the public, researchers and professionals as a primarily wealthy, male activity. Although most survey-based research in wealthier countries indicates that participation in the sector is overwhelmingly male (e.g. see Arlinghaus, 2004; Bower, 2018; Brownscombe et al., 2014; Jones, 2009), it is likely that many more women participate in the sector than currently understood because of the lack of gender-oriented data (Szymkowiak & Rhodes-Reese, 2020; Wadiwel, 2019). This is relevant to the fuzzy boundary because female fishers may be more food oriented. For example, female fishers in Minnesota related more strongly to catching fish for food than men, were less likely to release their catch, and more likely to keep all legal fish (Schroeder et al., 2006). In such cases, women are less likely to view themselves as recreational fishers if their interests lean more towards subsistence (Quinn & Davis, 1997).

Additionally, explorations of race, socio-economic status and culture in recreational fisheries are limited despite a growing understanding that motivations and experiences differ greatly among communities, ethnicities and cultures (Hunt et al., 2007; Toth Jr. & Brown, 1997). The fuzzy boundary is frequently associated with immigrant groups who do not conform with local norms and carry cultural practices from their countries of origin or individuals who have a higher need to combine leisure time with activities that can contribute to livelihood sustainability, particularly in remote regions with high food prices (Quimby et al., 2020). However, in some countries where the prime reason to go fishing is associated with harvest, such as Germany, subsistence maybe the norm among many fishers, although the expression of the norm will vary by species and the degree of which one depends on fish or can be selective in what is harvested for dinner. Our work thus echoes Cooke et al. (2018) in that harvest is a very important component of the global recreational

fishing sector and somewhat underappreciated in the literature, who often focuses on fishing 'for fun' and catch-and-release type fisheries, specifically in inland fisheries from North America. However, when harvest is significant and poorly known to managers, the lack of consideration of subsistence type recreational fisheries raises potentially uncomfortable issues for conservation and management (including the public image of angling), especially in wealthier countries with non-consumptive environmental values (Arlinghaus et al., 2012) or in countries where prejudice and racism motivate the introduction of regulations that limit harvest of primarily migrant groups (Booth, 2015). These tensions warrant further exploration. Situations where race, socio-economic status and culture exemplify the fuzziness of the boundary between recreational and subsistence fisheries highlights the importance of representing the contribution of recreational harvest for nutrition and wellbeing of families across the globe.

Intersectional approaches that consider wealth status, race and gender can inform our understanding of risk and equity issues as they relate to recreational fisheries development and conflict. For example, there is potential in many areas of the world for recreational fisheries development that could support seasonal livelihood transition (e.g. see Diedrich et al., 2019; Mozumder et al., 2018; Sheaves et al., 2016). However, if we consider this issue using perspectives of justice and equity, many questions emerge for which we currently have no answers. In considering economic equality and leakages, Butler et al. (2020) asked: who will own these developing [recreational] fisheries and where will the profits go? Whether or not the majority of developing recreational fisheries are tourism-based, understanding equity and power issues in ownership, job security, and evaluating the potential for increased resource and social conflict will all need to be made research priorities in the sector, and not just when considering recreational fisheries as a potential alternative livelihood (e.g. see Babali et al., 2018; Kadagi et al., 2020, 2021; Potts et al., 2022). The economic value of fisheries for consumption by the poor and food insecure is a substantial knowledge gap in this discussion. Studies on recreational fisheries have largely focused on their economic impact under the assumption that this value reflects the motivation to fish for pleasure or sport, or the ancillary industries to support this type of recreational fishing. What about recreational fishers being generally motivated by food?

As global environmental stressors (e.g. climate change) continue to impact food security (Gregory et al., 2005; Loring et al., 2019), reliance on consumption of recreationally harvested fish for food security will likely grow. Many low- and middle-income countries in the global south where food security is already a concern are being disproportionately affected by climate change (Myers et al., 2017), which could drive them to use recreational fisheries for subsistence more so than the global north. Climate change will also place extra pressure on water resources, which, in turn, can impact these fisheries and their participants or alter their form and functioning. Similarly, the COVID-19 pandemic as well as the recent start of the war by Russia in the Ukraine has potentially increased the fuzziness of the 'food/fun nexus' (*sensu* Cooke et al., 2018), for example by rising fuel and gas prices in Europe. Many recreational fishers altered their behaviours due to COVID-19 (Midway et al., 2021) and, in some cases, pandemic job loss or rising general costs of living have been associated with more fishing to put food on the table (Potts et al., 2022). With uncertainty regarding the suite of complex consequences of COVID-19 (Cooke, Soroye, et al., 2021, Cooke, Twardek, et al., 2021) and the invasion by Russia in Ukraine on freshwater ecosystems and fisheries, and what appears to be uninformed and uncoordinated policy responses, there is a need to develop new policies that are transformational. In that sense, this may be an opportune time to rethink how we value and manage inland fisheries, including those that currently span the fuzzy boundary between recreation and subsistence.

The case studies reinforce the awareness that stereotypes that separate recreational from subsistence are not helpful for devising policy and management actions that seek to improve monitoring and harvest of this sector. Recreational fisheries have long been ignored or forgotten from a governance perspective (Arlinghaus et al., 2019), especially in emerging economies (Bower et al., 2020). This has put the sector at risk through failures in monitoring and active, sciencebased management (Lorenzen et al., 2016). Even in a country like Canada, for example where there are well-established management agencies that actively monitor and manage inland fisheries, some recreational fisheries have collapsed (Post et al., 2002). Although such collapses can have well-documented ecological and socioeconomic consequences, they may also contribute to food insecurity. Recognizing issues of inequity, the potential for intersectoral conflict and the likelihood of higher reliance on subsistence-oriented recreational fishing under global environmental change demands a fresh policy perspective and new management considerations. For example, in South Africa, many subsistence fishers are unlikely to qualify as 'small-scale fishers' under new fisheries policies (Potts et al., 2019), highlighting the need for amendment; without this, it is likely that the proportion of low-income recreational fishers who harvest fish to meet their nutritional requirements will increase and continue to be marginalized. This is critical because evolving policies might disadvantage people who informally exploit these resources.

In this context of equitable governance, recreational fisheries contributing to food security need to be supported by stronger regulatory frameworks and the historic divide among recreational or commercial fisheries be supplemented by a perspective that part of the recreational sector is also food oriented and not oriented to only having non-consumptive fun. Improving regulation, monitoring and evaluation of these fisheries could be enhanced by the development of a metric for measuring or detecting the fuzzy boundary; however, first steps must include documenting (through social-ecological surveys) numbers and demographics of participants, biomass of fish species harvested and consumed, and nutritional deficits that are filled by recreationally harvested fishes. Furthermore, development of a metric will require an understanding of the unique histories and the socio-political and economic context that structure the fuzzy boundary fisheries. Embracing and extending arguments for managing recreational fisheries in a social-ecological framework

(Arlinghaus et al., 2017) can allow for the consideration of food security and involve a recognition and quantification of the inherently fuzzy boundaries between sub-sectors. This represents a departure given that most sub-sectors are often considered discrete and managed in different ways to achieve different objectives. Setting coordinated objectives that are inclusive and equitable would reflect revised priorities for fisheries management bodies. Recognition of the value of the subsistence component of recreational fisheries is vital for inclusion in resource management decisions, such as water resources management and agricultural and urban development that impact freshwater ecosystems and the fishers that depend on them.

# 4 | CONCLUSION

Our analysis reveals the inherently fuzzy boundary between recreational and subsistence fisheries in inland waters. Because recreational fishing has been long regarded as simply fishing for 'fun' (Pitcher & Hollingworth, 2002), the nutritional (and other) benefits of this activity have been largely overlooked. It is our hope that this objective and candid appraisal of the true complexity of recreational fisheries will lead to better efforts to characterize fish harvest and use in inland waters, notwithstanding gear type, motivation and diversity of users. Discrete labels for fishery sectors have little value in complex scenarios where context itself is variable and underpins fisher behaviour. The traditional view of recreational fishing as an activity totally different from subsistence fishing and based only on catching for pleasure prevents us from understanding the diversity of actors and motivations that recreational fishing possesses and the possible impact of harvest on wild fish stocks. We also want to emphasize that the continued underestimation of the role of recreational fishing in inland waters is rooted in complex socio-cultural legacies and biases, whereby it is assumed that recreational fishing is for wealthy people with much disposable income, while subsistence fishing is for marginalized, food-insecure individuals. Moreover, the belief that fishing for food is only an attribute of subsistence fishing has also shielded the possibility of examining recreational fishing as a subsistence activity or as a livelihood. The reality is that stereotypes are not helpful given the fuzzy boundaries between sectors. Moving forward, a focus on improving the monitoring and assessment of all inland fisheries harvest, as well as engaging in more nuanced social science approaches can lead to better characterization of the complex and dynamic ways in which different resource users interact with inland fisheries.

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# CONFLICT OF INTEREST

The authors declare no conflict of interest in relation to this paper.

# DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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### APPENDIX A

Estimation of recreational fisheries harvest in South Africa

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The estimation of harvest was made as the sum of the harvest estimates for the dominant species (groups of species) in the fishery and included common carp (*Cyprinus carpio*, *Cyprinidae*), *Micropterus* spp., (Centrarchidae), African catfish (*Clarias gariepinus*, Clariidae), rainbow trout (*Oncorhynchus mykiss*, Salmonidae), *Labeobarbus* spp., (Cyprinidae), Mozambique tilapia (*Oreochromis mossambicus*, Cichlidae) and African tigerfish (*Hydrocynus vittatus*, Alestidae).

The anglers who primarily target each species were determined based on the responses to the question: 'What is your primary target species?'. For AD, the respondents were categorized based on their primary target species and the mean number of days fish per annum was estimated based on their responses to the question: 'How many days did you go fishing in the last 12 months?'. This survey asked each respondent to estimate the average number of days fished per year for each species. The PH was estimated for each species based on the response to the question: 'What do you do with the fish that you catch?'. The question provided boxes for: (1) eat, (2) release, (3) donate and (4) sell, and respondents were able to select more than one box. Fish were assumed to be harvested if the respondents selected 'eat', 'donate',or 'sell'. Therefore, if respondents only selected 'release', it was assumed that no fish were harvested by the angler, while if they selected 'eat' it was assumed that all the fish that they caught were harvested. If respondents selected 'release' and 'donate', it was assumed that half of their catch was harvested, while if they selected 'release', 'eat' and 'donate', it was assumed that two thirds of the fish that they captured were harvested. The mean proportion harvested was then estimated.

The CR estimates for *Cyprinus carpio* and *Clarias gariepinus* were obtained from competition data for the Free State Province. The CR estimate for *Micropterus* spp. was obtained from McCafferty (2012), who reported on competition data from around South Africa. However, as the CR estimates were from competitive angling data and represent catch of skilled and well-equipped anglers, the CR was divided in half to obtain a more realistic estimate. CR estimates for the remaining species (*Oreochromis* spp., *Onchorynchus mykiss*, *Hydrocynus vittatus*) were based on expert opinion from Mr. M.T. Davis and Prof. Peter Britz.

Total harvest in the South African inland recreational fishery was estimated to be 3947.4 tonnes per annum (Table A1), with *Cyprinus carpio*, *Clarias gariepinus* and *Oncorhynchus mykiss* contributing 73%, 12% and 6% to the harvest, respectively. The potential bias in the estimates, such as the uncertain estimates of catch rate and assumptions about individual harvest rates and the limited knowledge of harvest rates among low-income recreational anglers are acknowledged. Although this may be an underestimate of recreational harvest, it is likely that the true value falls within this order of magnitude.

TABLE A1 Summary of the calculations for the estimation of recreational fisheries harvest in South Africa

Species	Number of anglers <sup>1</sup>	Catch rate (kg/ day)	Mean no. days fished <sup>1</sup>	Prop. catch harvested <sup>4</sup>	Estimated harvest
Micropterus spp., Centrarchidae	20,814	1.48 <sup>2</sup>	49	0.15	226.4
African catfish, (Clarias gariepinus, Clariidae)	100,000	1.65 <sup>2</sup>	23	0.13	493.4
Oreochromis spp., Cichlidae	51,000	0.5 <sup>3</sup>	29.2	0.31	230.8
Rainbow trout, (Oncorhynchus mykiss, Salmonidae)	15,000	0.5 <sup>3</sup>	37.7	0.29	82.0
Common carp (Cyprinus carpio, Cyprinidae)	400,000	1.65 <sup>2</sup>	33.5	0.13	2874.3
Labeobarbus spp., Cyprinidae	5500	1 <sup>3</sup>	42	0.13	30.0
African tigerfish (Hydrocynus vittatus, Alestidae)	5500	0.5 <sup>3</sup>	34.6	0.11	10.5
				Total	3947.4

Note: 1 = Potts et al (in review), 2 = McCafferty, 2012, 3 = Barkhuizen et al., 2017, 4 = Potts, unpublished data.