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The nexus of fun and nutrition: Recreational fishing is also about food

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Abstract

Recreational fishing is a popular activity in aquatic ecosystems around the globe using a variety of gears including rod and line and to a lesser extent handlines, spears, bow and arrow, traps and nets. Similar to the propensity to engage in voluntary catch-and-release, the propensity to harvest fishes strongly varies among cultures, locations, species and fisheries. There is a misconception that because recreational fishing happens during non-work (i.e. leisure) time, the nutritional motivation is negligible; therefore, the role of recreational fishing in supporting nutrition (and thus food security) at regional, national or global scales is underappreciated. We consider the factors that influence whether fish will be harvested or released by examining the motives that underlie recreational fishing. Next, we provide an overview of the magnitude and role of recreational fishing harvest in supporting nutrition using regional case-studies. Then, we address issues such as contaminants and parasites that constrain the ability of fish harvested by recreational fishers to be consumed. Although recreational fishing is foremost a leisure activity, the harvest of fish for personal consumption by recreational fishers has contributed and will continue to contribute to human nutrition by providing an accessible, affordable and generally highly sustainable food source, notwithstanding concerns about food safety and possibly overfishing. Attempts to better quantify the role of fish harvested by recreational fishers and the relative contribution to overall food security and personal nutrition will provide resource managers and policymakers the information needed to guide management activities and policy development.

KEYWORDS
angling, contaminants, harvest, nutrition, subsistence

1 | INTRODUCTION

Recreational fishing occurs around the globe in inland, estuarine and marine waters spanning developed and increasingly developing countries (FAO, 2012). In most industrialized countries, recreational fishing is today the dominant or sole user of many inland fish populations (Arlinghaus, Mehner, & Cowx, 2002; FAO, 2012). Recreational fishing is also prominent in marine waters, recorded in 76% of the world's exclusive economic zones (Mora et al., 2009). Global estimates of recreational fishing are challenging to generate, but participation rates in industrialized nations were estimated as 10.6% of the populace (Arlinghaus, Tillner, & Bork, 2015). Attempts to estimate global fisheries harvest from the recreational sector have relied on simple extrapolations; Cooke and Cowx (2004) used Canadian averages and extrapolated global recreational harvest to be 17 billion fish with a biomass of some 10.86 million tonnes.

The Food and Agricultural Organization of the United Nations (UN FAO) defines recreational fishing 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*" (UN FAO, 2012). Accordingly, using fishing as a *primary* means to secure one's survival is beyond the scope of recreational fisheries. But this does not mean that the catch-and-harvest of fishes is irrelevant or even unimportant to the recreational fishers; in fact, it is quite the opposite in many situations where the satisfaction of the individual recreational fisher is strongly dependent on the qualities of the catch and the ability to harvest and subsequently consume at least a portion of the catch (Arlinghaus, 2006; Dorow, Beardmore, Haider, & Arlinghaus, 2010). Nonetheless, recreational fishing is a leisure activity and presents an interesting case of where "fishing for fun" (Pitcher & Hollingworth, 2002) and fishing-induced nutritional benefits, which collectively contribute to food security, overlap.

Angling with rod and line is the most common recreational fishing technique; however, in some jurisdictions, recreational fishers use gear such as spears, bows and arrows, rifles, traps and gillnets (Arlinghaus & Cooke, 2009). Some of these gears are designed to catch fish for personal consumption. For example, the use of recreationally deployed traps or gill nets is strongly tied to personal fish consumption and is the key reason why people engage in recreational gill netting in Finland and other Scandinavian countries (Salmi, 2012). Consumptive reasons are also key components of most recreational angling fisheries in Central Europe and Eastern Europe. Similarly, even in cultures with a strong affiliation to voluntary catch-and-release in selected fisheries (e.g. largemouth bass [*Micropterus salmoides*, Centrarchidae] angling in the United States), a portion of recreational anglers (e.g. specific ethnic groups; Toth & Brown, 1997 or selected saltwater fisheries) fish entirely for consumptive reasons (Macinko & Schumann, 2007). By contrast, there are locally relevant recreational fishing techniques in some countries, for example bow fishing for common carp (*Cyprinus carpio*) in the United States, where fishes are indeed harvested but usually discarded dead and not eaten; the reason simply relates to cultural nuances as to which species are considered good to eat or a nuisance.

Recreational fishing can target aquatic organisms other than finfish (e.g. lobster, crayfish, frogs) but finfish are the dominant catch throughout the recreational sector. Some recreational fishing methods are inherently lethal (e.g. bow and arrow) with the assumption that the majority of catch is either consumed or wasted (e.g. the carp example above); however, rod and line fishing (i.e. angling) allows for fish to be released (i.e. catch-and-release), either voluntarily as a result of lack of interest in consuming fish or due to private conservation ethic or mandatorily to comply with fishing regulations (e.g. release undersized fishes that cannot be legally retained). Although the definition makes it clear that recreational fishing is not partaken in solely to meet primary nutritional needs, recreational fish can and does contribute to personal consumption of fish and cumulatively to food security, although this perspective has so far not been prominently expressed in the recreational fishing literature. In Germany, fishing for consumption is the only legally accepted reason to fish recreationally, so essentially all legally harvestable fishes are to be retained for personal consumption (Arlinghaus et al., 2007). The same legalities occur in Switzerland, and across much of Scandinavia and Eastern Europe, where recreational fishers maintain a strong harvest and consumption orientation (Aas & Arlinghaus, 2009; Arlinghaus, Schwab, Riepe, & Teel, 2012), except among the most specialized angler groups for specific fisheries (Bryan, 1977; Oh & Ditton, 2006; see Dorow et al., 2010; Dorow & Arlinghaus, 2012; for an exception where highly specialized eel, *Anguilla anguilla*, anglers were strongly consumption-oriented). Although it is difficult to generalize, saltwater anglers seem to be more harvest- and consumption-oriented than freshwater anglers (Salz & Loomis, 2004), but there are increasingly specific fisheries for target species that are mostly about voluntary catch-and-release (e.g. largemouth bass or muskellunge [*Esox masquinongy*, Esocidae] in the United States).

People engage in recreational fishing to reap a range of expected psychological outcomes (Hendee, 1974; Manfredo, Driver, & Tarrant, 1996). There are a range of psychological, health and nutritional benefits that arise for each individual recreational fishing participant, and collectively, the participation in recreational fishing generates high socio-economic, social and cultural benefits that serve broader society (Arlinghaus et al., 2002; Parkkila et al., 2010; Tufts, Holden, & DeMille, 2015). Aside from acknowledging that recreationally captured fish are harvested in almost all localities and countries and thereby provide nutritional benefits to people (e.g. FAO, 2012), to date there have been few attempts to consider the extent to which recreational fishing actually contributes to nutrition and the challenges associated with food safety that would reduce the potential for the sector to contribute to health and physiological well-being. In this study, we explore the nexus of fishing for fun (Aas, Thailing, & Ditton, 2002) and nutrition in the context of recreational fishing. We submit that the role of recreational fishing in nutrition at regional, national or global scales is understated and underappreciated. We begin by first describing the motivations behind recreational fishing with a focus on understanding consumptive aspects. We then collate relevant statistics to characterize the scope and magnitude of harvest and the role of those fish in food and nutritional security. Next, we explore the constraints on recreational fishing for food with a focus on food safety issues. We conclude with a forward-looking perspective on the future of recreational fishing for food. For the purpose of this study, we inherently restrict our activities to finfish with a particular focus on gamefish (Donaldson et al., 2011) but acknowledge the role of other taxa, and indeed, our review includes "pan fish," "coarse fish" and any other species of finfish that is targeted or captured by recreational fishers. Our approach is inherently global but we recognize biases in the literature focused on developed countries.

2 | MOTIVATIONS FOR FISHING AND PERSONAL CONSUMPTION OF SELF-CAUGHT FISHES

Studying fishing motivations can help in understanding whether and to what degree fish harvest and relatedly consumption is of importance for people to engage in recreational fishing (we acknowledge that people catch fish during leisure time, harvest them and subsequently discard them as unwanted, but given lack of data on the fraction of fish that are harvested and discarded dead we will confine our discussion to the assumption that harvested fish are also consumed in most of the cases). A rich literature has shown that one must be careful when generalizing fishing motivation results at the angler population level because this obscures important contextual and angler subgroup-specific motivations. Fishing motivations have been defined as "expected psychological outcomes" (Manfredo et al., 1996), essentially representing the desired benefits of people engaging in recreational fishing compared to any other recreational pursuit. Recreational fishers are motivated by both catch- and non-catch-related aspects of the fishing experience (Fedler & Ditton, 1994), where the catch motives have undergone much less research compared to the non-catch ones (Finn & Loomis, 2001). Generally, however, fishing motivations probably represent the most intensely researched topic in the so-called human dimensions of recreational fisheries.

When motivations are assessed at the most general level possible (i.e. which factors are generally important to you when you choose to fish), a typical finding is that recreational fishers are motivated by at least four sets of basal motives: temporary escape, achievement, exploration and experiencing nature (Knopf, Driver, & Basset, 1973). Catching fish is part of this overarching motivation (e.g. when desiring achievement motives), but dozens of previous studies mainly from the United States have reported a relatively low general importance attached to catching and keeping fishes as opposed to non-catch motivations (e.g. Beardmore, Haider, Hunt, & Arlinghaus, 2011; Burger, 2002; Fedler & Ditton, 1994; Ross & Loomis, 2001). This finding has frequently been misinterpreted as if catching and keeping fish were unimportant to anglers (Matlock, Saul, & Bryan, 1988), which has created immense tension among fisheries managers and human dimension researchers (summarized in Arlinghaus, 2006). When angler motivations for the activity as a whole at the aggregate level are assessed, relaxation-related or nature-experience-related motives feature higher than catch motivations because recreational fishing is in the first place a recreational pursuit that is not primarily directed at meeting physiological or nutritional needs (see definition in the Introduction). That said, the high level of abstraction of general motivation research also means that such motivations provide very little or even no information about how specifically a fisher will behave on-site in a given situation (Schramm, Gerard, & Gill, 2003, summary in Arlinghaus, 2006).

The apparently low importance of catch and consumption aspects of fishing in general motivation assessment has turned opposite when one asks recreational fishers about the prime motivations at a specific context (e.g. when fishing at a particular site for a particular species; Beardmore et al., 2011). Beardmore et al. (2011) pursued such research in Germany finding that context-specific angler motivations could be grouped into five motivational types: trophy-seeking anglers (not necessarily practising catch-and-release), challenge-seeking anglers (that did not seek trophies, but placed great importance on achievement-oriented catch motivations), nature-oriented anglers, social anglers and consumption- or meal-sharing-oriented anglers. The latter angler group comprised 13% of all German anglers that were surveyed. Although this fraction of primarily consumption-oriented anglers appears low, it was noteworthy that the five angler types did not vary substantially in the harvest rates (proportion of the catch that was retained for personal consumption) of the species they targeted (Beardmore et al., 2011). In fact, although the meal-sharing anglers exhibited a tendency to retain some fish species to a greater extent than the other four angler types (e.g. common carp *Cyprinus carpio*, Cyprinidae; Atlantic cod *Gadus morhua*, Gadidae; or Pleuronectiformes flatfishes), there were other species for which the non-meal-sharing anglers exhibited substantially greater retention and consumption rates than the meal-sharing anglers (e.g. European perch *Perca fluviatilis*, Percidae; northern pike *Esox lucius*, Esocidae; zander *Sander lucioperca*, Percidae). In other words, primary motivation and motivations in general do not differentiate well among anglers that vary in their tendency to keep fish for personal consumption, and even if an angler primarily fishes for trophies, competition or challenge or for relaxation in nature, the same angler can actually exhibit high or low consumption rates depending on local culture and target species.

Because motivations are not well suited to understand the basal propensity and interest of anglers to keep fishes for nutritional reasons, human dimension researchers devised other ways of measuring the importance attached by angler to catch and keep aspects of fishing. Of particular importance is the concept of "consumptive orientation," which is a construct measuring the attitude of recreational fisheries towards the catch and keep dimensions of fishing. Note that the term consumptive orientation is confusing here because the concept measured the attitude of people to both consumptive and non-consumptive catch components. Thus, the construct has been relabelled as catch orientation, where consumption of fish is a subdimension (Anderson, Ditton, & Hunt, 2007).

Originally devised by Graefe (1980), over the years the catch (consumptive) orientation scale has seen much development and testing in various countries of the world (e.g. Aas & Vittersø, 2000; Anderson et al., 2007; Beardmore, Haider, Hunt, & Arlinghaus, 2013). Research has shown that the "catch dimension" has at least four subdimensions, the attitude towards catching "something," the attitude towards the catch of many fish, the attitude towards the catch of large fish and the attitude towards the personal consumption of the catch. Every person scores differently on each of these subdimensions, and there is abundant variation in the consumptiveness aspect across different angler populations, regions and countries (Aas & Kaltenborn, 1995). Hutt and Neal (2010) reported that urban anglers in Arkansas did not vary significantly in their various catch/consumption orientation scores, although there was a trend (p = .06) for urban anglers to have a stronger harvesting and consumption orientation than rural anglers. A meta-analysis by Hunt, Floyd, and Ditton (2007) also revealed important ethnic differences in both consumption and general catch orientation, with African Americans holding more positive attitudes towards catching a large number of fish, catching large fish and retaining the fish for consumption compared to Anglos. Similarly, there is abundant anecdotal evidence from Europe that the consumption orientation is variable across cultures, with Scandinavians, Germans and Eastern Europeans exhibiting a stronger tendency to retain fish compared to anglers in the Netherlands or the UK (Arlinghaus et al., 2007). Aas and Kaltenborn (1995) found Norwegian anglers to be more catch-oriented and generally more highly consumptive than North American anglers, while Fedler and Ditton (1994) found that anglers from Texas were more likely to rate catching fish for consumption as an important motivator than any other subgroup studied. Toth and Brown (1997) found that anglers were more likely to view “harvesting fish” and “holding a fish fry (cooking fish for friends and family)” as important depending on the culture they identified with, although there were significant differences in income levels among groups represented in the study. Burger (2002) did not find any such cultural links, but noted that harvest behaviour occurred more frequently in anglers from lower income brackets. There is no comparative study available that has devised the same measurement constructs in different parts of the world to allow generalizable insight, but comparative work on some of the catch and consumption orientation scores revealed that Norwegian anglers were much more catch-oriented than German anglers (Arlinghaus, 2004). This does not, however, say anything about the actual retention decisions, which are known to be extremely high in German anglers (Beardmore et al., 2011) and equally high for some Norwegian recreational fisheries, for example for Atlantic cod (Ferter, Borch, Kolding, & Vølstad, 2013; Ferter, Weltersbach, et al., 2013).

A further opportunity to assess the importance of the harvest aspects of fishing is to analyse the contribution of different components of the angler experience to angler satisfaction. Satisfaction is the difference between the desired (motivation) and the realized experience (Arlinghaus, 2006). Several studies across the world have all revealed that in most angler populations insufficient catches are the prime contributor to angler dissatisfaction (summarized in Arlinghaus, 2006), which again does not say much about how important the consumption of fishes is. However, in studies from Germany (Arlinghaus, 2006; Arlinghaus, Bork, & Fladung, 2008; Arlinghaus & Mehner, 2005), it was found that (i) the quantity of consumable fishes was the most important contributor to angler satisfaction for German anglers as a whole (Arlinghaus & Mehner, 2005) and the only relevant factor of angler satisfaction for high-catch-oriented anglers (Arlinghaus, 2006); (ii) the quantity of consumable fish was even a key determinant of angler satisfaction (ranked fourth) for people classified as low catch-oriented (Arlinghaus, 2006); and (iii) that the relevance of the quantity of consumable fishes for angler satisfaction varied by residence and preference of fishing waters along an urban-to-rural gradient; it was particularly relevant for urban dwellers that fished outside urbanities in rural sites. A study on Arkansas anglers residing in urban environments (and fishing both urban and rural sites), however, failed to find evidence for the number of eating-size fish captured to relate to angler satisfaction (Hutt & Neal, 2010), suggesting that country- and site-specific variation in the importance of “consumption” for angler satisfaction has to be expected.

Finally, the importance of the harvest dimension can be derived from utility-based choice models, which assess the preferences of fishers as well as from fisher reactions to harvest regulations that constrain the opportunity to harvest (which in most cases will be done for personal consumption). Many studies have shown that the type of harvest regulation affects angler well-being and choice (Beard, Cox, & Carpenter, 2003; Johnston, Arlinghaus, Stelfox, & Post, 2011; Johnston, Beardmore, & Arlinghaus, 2014; Lennox, Falkegård, Vøllestad, Cooke, & Thorstad, 2016). Most choice-based studies suggest that different angler types vary in the acceptability of harvest regulations and that moderately strict harvest regulations are preferred over no harvest regulations and too strict regulations that limit the possibility to harvest at all (Carlin, Schroeder, & Fulton, 2012; Dorow et al., 2010). Similarly, observational data in some fisheries, for example for walleye (*Sander vitreus*, Percidae) in the United States, have shown that the implementation of overly restrictive harvest regulations led to strong effort responses and a shift towards fisheries where the harvesting opportunities remain more liberal (Beard et al., 2003; Johnston et al., 2011). Cumulatively, such shifts suggest that anglers have a desire to harvest at least some fish for personal consumption (see Figure 1 for photograph of walleye shore lunch being prepared by fishing guides). Obviously, the situation varies among fisheries and cultures, and there are also examples of some fisheries developing into total voluntary catch-and-release where anglers have no desire whatsoever in keeping fish for harvest (e.g. many muskellunge *Esox masquinongy*, Esocidae or largemouth bass *Micropterus salmoides*, Centrarchidae fisheries in the United States). There is also abundant within-fishery heterogeneity that needs to be accounted for. For example, American catfish (*Siluriformes* sp.) anglers have very distinctive preference structures ranging from consumption-oriented anglers to size-oriented anglers less interested in keeping fish (Hutt, Hunt, Schlechte, & Buckmeier, 2013). The same finding has been found in American walleye anglers, where walleye anglers with a stronger retention orientation showed more aversion to low bag limits and to protected slot limits (Carlin et al., 2012).

Angler populations retain heterogeneity in expectations relating to harvesting fish, and almost all angler populations occasionally or

FIGURE 1 Photograph related to recreational fishing and food. In some cases, anglers or fishing guides will cook fish immediately after capture on the shore of the waterbody in what is commonly called a “shore lunch” (photograph courtesy of NOTO). [Colour figure can be viewed at wileyonlinelibrary.com]

exclusively harvest legally retainable fish for personal consumption. These results agree with a large body of literature on angler heterogeneity that can be summarized in the concept of angler specialization (Bryan, 1977). Bryan (1977) inductively showed that in American trout anglers a continuum of commitment and specialization exists that moves from the general to the particular. With increasing degree of specialization, the commitment to the activity rises, and attitudes and preferences shift from consumption of self-caught fishes to voluntary catch-and-release, and from a reliance on stocking to habitat management (Bryan, 1977). According to this multidimensional classification, the most specialized anglers are the least consumption-oriented. This seems to be the case in Red Drum (*Sciaenops ocellatus*) fisheries of North Carolina where anglers and commercial fishermen are disputing over ethical use of the resource (Boucquey, 2017). Although this finding generally seems to hold, there are ample exceptions reported in the literature, where one can find, even among the most specialized anglers, groups that harvest regularly for personal consumption vs. those that voluntarily practice catch-and-release (Hutt & Bettoli, 2007). Ultimately, the propensity to engage in catch-and-release vs. catch-and-kill seems to follow strongly from cultural tradition, religious backup and major life change events, for example experience of economic shortage during the raise-up phase. For example, while the German recreational fisheries mainly developed after the Second World War where subsistence needs were important, recreational fisheries in the UK evolved as a field sport conducted by aristocrats that could afford to engage in recreation without taking the fish for dinner, which is why coarse fishing is today almost exclusively voluntary catch-and-release in the UK (Locker, 2014), while consumption motives prevail in Central Europe, including Germany. There are also gender components; Schroeder, Fulton, Currie, and Goeman (2006) found that female anglers were more likely to exhibit harvest behaviours than male anglers of the same age group (see also Toth & Brown, 1997). Cultural norms and traditional reliance on fish as a staple food source contribute to differences in fishing release behaviour (Aas & Kaltenborn, 1995), and nationality and culture is believed to play an important role in the propensity to harvest recreationally captured fish (Aas et al., 2002).

The tendency to harvest can also vary per external factors such as social context, species captured and location fished. Anglers in northern Ontario were more likely to exhibit harvest behaviours when fishing within group of friends than with family members (Hunt, Haider, & Armstrong, 2002). Fishing site choice and target species have been linked to the harvest decisions of anglers. The fishing site determines the diversity and abundance of fish species available to the angler, as well as the amount of time spent fishing (also linked to individual and social behaviours). These factors can lead to catch deprivation (not catching enough fish for the angler to feel satisfied) or catch satiation (catching fish on every angling occasion; Finn & Loomis, 2001). Catch deprivation may be more likely to occur when anglers expend high effort for low catch, catch fewer of their target species than expected and/or catch fewer acceptable substitute species (Finn & Loomis, 2001; Hunt et al., 2002). The target species plays a separate role, irrespective of catch satiation and deprivation. Steelhead (*Oncorhynchus mykiss*, Salmonidae) and salmon (*Oncorhynchus* spp., Salmonidae) anglers reported that fishing for food was a major motivator for fishing in Oregon (Smith, 1980), as did black drum (*Pogonias cromis*, Sciaenidae) and catfish anglers described by Fedler and Ditton (1994). Anglers targeting walleye and northern pike were more likely to harvest than those targeting smallmouth bass (*Micropterus dolomieu*, Centrarchidae) if they were highly catch-oriented (Hunt et al., 2002).

Of note is that very few studies examine the relationship of nutrition-based motivation for harvest behaviour (Hunt et al., 2002), and there is no study that has looked at substitution behaviours among self-caught fishes and the reliance on other animal protein. However, from a cultural and traditional perspective, harvesting a fish can extend beyond a simple "reward" for an angler's efforts, because keeping a fish that was caught in the wild can provide a connection to nature that is often lost or overlooked with common store-bought food items. Similarly, recreational fishers may also choose to harvest fish to provide a more natural, unprocessed, food source that is believed to be free of chemical additives and preservatives that can be used in agriculture/aquaculture applications. Anglers may also choose to harvest fish to provide a more subsistence-based lifestyle. Therefore, subgroups exist within the recreational angling community, which report different perceived reward and punishment for harvest and consumption, highlighting how different anglers perceive fish harvest (Stensland & Aas, 2014). Although the motivations and perceptions are likely to differ significantly among fishers, the existence of angler subgroups with different tendencies towards harvest and catch-and-release is likely consistent across the globe.

Importantly, the definition of recreational fishing stipulates that fish caught must not represent the dominant source of protein in the fisher's diet (see Introduction). Yet, this suggests that on the scale of angling behaviours (ranging from total harvest to total catch-and-release), there may be fishers who, while not catching sufficient amounts of fish to constitute their main source of dietary protein, still subsidize their overall diet in a significant way (Macinko & Schumann, 2007). This may be particularly relevant to any segment of the angling population where food or employment insecurity is high, for example low-income recreational anglers or anglers living in highly food-insecure areas. It may also reflect a difficulty in procuring certain dietary macronutrients in remote or lower income regions that are readily available from wild fish. Alternatively, it may represent a perception of wild-caught or locally produced food as inherently more healthy and sustainable (Tidball, Tidball, & Curtis, 2013; but see Edwards-Jones, 2010 for an assessment of this concept). Ultimately, the question of whether such harvest and consumption behaviours can play a role in alleviating either acute (transitory) or chronic (long-term) food insecurity remains unstudied. In areas where the ability of recreational fishing to contribute to alleviation of acute or chronic food insecurity is likely to be more pronounced, there is a dearth of research examining recreational fishing behaviours in a culturally appropriate context.

3 | SCOPE AND MAGNITUDE OF HARVEST

Although there are some locations (lakes or river systems) that require anglers to release all their catch (i.e. regulatory total catch-and-release), the predominant state of fisheries is to incorporate some harvest. All recreational fisheries are therefore consumptive to some extent (i.e. catch-and-release mortality can occur in addition to harvest; Arlinghaus et al., 2007). Although the rates of harvest are difficult to quantify, jurisdictional surveys (administered nationally, provincially/statewide or in a given waterbody) illuminate the harvest tendencies in various fisheries. The availability and accuracy of such surveys inevitably differ among jurisdictions and may be biased towards developed nations with the best statistical infrastructure. Here, we focus on some case-studies from countries that have reported recreational harvest and release and examine some of the key figures in the magnitude of harvest, comparing them among nations and systems (i.e. inland or marine), and important species that ostensibly contribute to food security.

Anglers in the marine environment are sometimes perceived as being more likely to harvest fish than in inland systems (Ross & Loomis, 2001; Veiga et al., 2013). According to NOAA, American marine fisheries along the Atlantic coast attracted more than 6.1 million resident participants in 2014 and accounted for over 55% of the national marine recreational catch (NOAA, 2014). NOAA (2014) estimated that recreational anglers captured 392 million fish in 2014, 40% of which were released. In Portugal, where coastal marine anglers are considered to be highly motivated to fish for consumption (>90%), 77% of fish are harvested (Veiga, Ribeiro, Goncalves, & Erzini, 2010). A national survey of Australian marine and freshwater recreational fisheries counted over 60 million fish harvested and estimated about 43.9% release (Lyle et al., 2003). Interestingly, Jones (2009) found that recreationally captured fishes in South Australia tended to be released more frequently in marine fisheries (40.6%) than in freshwater (30.5%). High rates of release (>50% of total marine recreational catch) have also been documented throughout several European countries (Ferter, Borch, et al., 2013).

Whether anglers are residents or non-residents probably plays an important role in harvest behaviour (Aas & Kaltenborn, 1995). Non-residents may feel less affinity for local ecosystems or have less knowledge of the local fish conservation needs, which would make them more likely to harvest. However, Brownscombe et al. (2014) found that Canadian resident anglers tended to harvest more than non-resident anglers did, perhaps because tourists would be less likely to have access to facilities for cleaning or cooking their catch. This may also represent a fundamental difference in the motivation to fish, with residents being more committed to using resources as sources of local food, while tourist anglers that are more specialized tend to release more fish (Ferter, Weltersbach, et al., 2013; Margenau & Petchenik, 2004).

Economic, demographic and geographic factors play an important role in whether a fish will be harvested in a recreational fishery; however, the species captured is also significant (Ferter, Weltersbach, et al., 2013). Target species are an important factor contributing to the scope of recreational harvest, because anglers will selectively target species based on their own desired catch or harvest outcomes. Harvest-oriented anglers would preferentially fish for species of high table quality, whereas many species are considered exclusively sport species not targeted by the commercial sector (Clarke & Buxton, 1989). Brownscombe et al. (2014) identified muskellunge and bass (*Micropterus* spp., *Morone saxatilis*, Moronidae) as fisheries with a tendency towards catch-and-release behaviour, whereas smelt (*Hypomesus olidus*, Osmeridae; *Osmerus mordax*, Osmeridae) and cod (*Gadus morhua*, Gadidae; *Microgadus tomcod*, Gadidae; *Ophiodon elongatus*, Hexagrammidae) fisheries were more harvest-oriented. Interestingly, the tendency to harvest fish may differ greatly among nations. Common carp, for example, is largely released in some specialized fisheries of Europe (Arlinghaus & Mehner, 2003) but is commonly harvested in other fisheries (e.g. Australia, Germany; Jones, 2009; Beardmore et al., 2011). These traits would also influence the sizes of fish targeted by the angler and by extension the location fished. In Brazil, Shrestha, Seidl, and Moraes. (2002) described anglers as being more likely to take fishing trips when they were permitted to harvest more fish. However, even among popular food fish, there can be substantial release (Ferter, Weltersbach, et al., 2013; Lennox et al., 2016; Meyer, 2007). Attempts to balance the exploitation of some economically important recreational species have yielded trends towards both regulatory and voluntary catch-and-release angling, in which targeted species are released. For example, Goodyear and Prince (2003) found that the harvest of white marlin (*Kajikia albidus*, Istiophoridae) drastically declined from 1981 to 2001. This tendency to release trophy species is now common among most specialized recreational anglers (Oh & Ditton, 2006).

Recreational fish harvest can negatively affect fish populations and communities via similar mechanisms as commercial fisheries (Post et al., 2002). Data on recreational fisheries are difficult to compile because of the large number of participants and locations, meaning that many fisheries do not have accurate data to calculate the extent of fishing effort, fish exploitation or harvest in each waterbody (Lester, Marshall, Armstrong, Dunlop, & Ritchie, 2003). Nevertheless, where established, fisheries management agencies recognize the potential for damage associated with destructive fishing practices such as overharvest, and therefore, they impose regulations (e.g. spatial or temporal closures) and restrictions (e.g. size limits, quotas and total harvest bans) to reduce the potential for fish harvest to impact resource sustainability (Arlinghaus et al., 2007; Cooke & Schramm, 2007; Cox, Beard, & Walters, 2002; Lennox et al., 2016; Radomski, Grant, Jacobson, & Cook, 2001). Ultimately, these regulations aim to be effective in accomplishing specific management objectives (Lennox et al., 2016) and that they will be complied with (Gigliotti & Taylor, 1990).

4 | RECREATIONAL FISHING AND NUTRITION, POSSIBLY CONTRIBUTING TO FOOD SECURITY

Food security is achieved when all people have physical, social and economic access to sufficient nutritious food that provides the dietary requirements needed to sustain an active and healthy life (World Food Summit, 1996). The capacity for recreational fishing to contribute to food security is extensive given that the world's surface is over 70% water (CIA, 2016). Access to water means access to potential fish habitat, and accompanying fish as a food source, although productivity and diversity of marine food webs will differ by region (Saporiti et al., 2015). Regions will also vary on their level of access to water. Urban areas may have limited access to waterbodies and corresponding fishing opportunities, indicating the need for shore-based fishing facilities to increase access.

Recreational fishing is highly accessible to people of varying economic statuses (Milon, 2000) as there are a variety of tools recreational fishers can use (pole and line, pots, nets, longlines). Generally, recreational fishing is a means of food gathering where cost does not limit access, but economic boundaries to recreational fisheries do exist. Costs of tackle as well as depletion of highly accessible locations may bias catches towards more mobile anglers including those capable of travelling outside urban centres or those with access to boats for fishing offshore areas. Indeed, fisheries in accessible waters tend to be depleted relative to remote areas (Post, Persson, Parkinson, & Kooten, 2008) and there may also be contamination concerns in urban centres that limit the accessibility of fish for food security in some cases (see below).

Money spent to participate in recreational fisheries can vary greatly. In developed countries, anglers may spend considerable amounts of money on fishing gear, licences, trips, accommodation and other fishing related expenses that can be costly relative to the food generated from this activity (Arlinghaus, 2004; Fisheries and Oceans Canada, 2012; Henry & Lyle, 2003; United States Department of the Interior, 2012). In the United States, $41.8 billion was spent by an estimated 33.1 million anglers, an average of over $1200 USD per angler (United States Department of the Interior, 2012). Recreational fishing may also provide access to food for people of varying cultural backgrounds including people identified as part of a minority (Burger, 2002; Hunt et al., 2007) who seek access to traditional food sources (Egeland, Feyk, & Middaugh, 1998; Toth & Brown, 1997). Recreational fishing allows fishers to continue food gathering traditions (Prosser, 1997) while providing for family and friends (Burger, 2013). Regulatory challenges also exist to limit access or bias efforts in recreational fisheries. For example, many marine fisheries around the world (e.g. the United States and Canada) do not have a licensing programme, rendering them more accessible to recreational anglers. The majority of North America's inland waterbodies may also be accessed by (licensed) anglers, whereas the provision of riparian rights (landowners vs. river owner organisations) in some European nations can limit access of fishers to inland watercourses (e.g. Stensland, 2012). This is overcome by the formation of angling clubs/associations which use membership income to lease waters for their members. Using the UK as an example, this results in the vast majority of waterbodies being accessible to recreational anglers, meaning fisheries management and harvest may be regulated by individual or a combination of multiple stakeholders (e.g. angling clubs, landowners and government environmental bodies).

The role of recreational fishing in food security and nutrition varies in magnitude across different parts of the world. The following includes several case-studies assessing the contribution of recreational fishing towards food security and nutrition for North America, Scandinavia, Europe, Asia, Africa, South America and Oceania (Australia). Although the distinction between recreational and subsistence fishing can be minute, particularly in less developed countries, all sources of data reported were claimed as recreational harvest in the respective publications. In the few cases that multiple data sources were available, we present the data from the most reliable source. We considered national resource agencies to have the highest reliability, followed by literature syntheses and modelling, then intergovernmental reporting bodies (OECD). Where available and appropriate multiple estimates are presented for total recreational harvest. Because catches were typically reported as live mass, the edible portion of a fish (skinless filet) was considered to be 40% of total live mass based on the average nutritional yield for nearly 100 commercially important species (FAO, 1989). This number is comparable to the value used by the U.S. Department of Agriculture of 45% edible portion of total body mass. Food that was not consumed was not considered in the calculations below; however, fish/seafood waste certainly occurs at the commercial scale (Buzby & Hyman, 2012). Seafood waste can occur at any point in the food chain from harvest, to processing, to distribution, to consumption and may be as high as 40%–47% in the United States (Love, Fry, Milli, & Neff, 2015). Although recreational harvest removes food waste associated with processing (aside from cleaning fish), and distribution, there is still potential for harvested fish not to be consumed by anglers as consumption waste contributes the greatest portion of total waste (51%–63%; Love et al., 2015). The recreationally caught fish consumption stage may produce less waste however, as anglers often take pride in providing self-caught food for family and friends (Burger, 2013; Prosser, 1997). The rate of recreationally captured fish waste is also likely to differ across regions as North America and Oceania appear to have the greatest seafood and fish waste at the consumption stage (33%) than Europe (11%), industrialized Asia (8%), Africa (2%–4%), Latin America (4%) and South and South-East Asia (2%; Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011). Although the data do not exist to provide estimates of recreationally caught fish waste by country, available data suggest it could be moderate in developed countries but is likely negligible in developing countries.

4.1 | North America

In Canada and the United States, fishing is a popular recreational activity (Brownscombe et al., 2014; Cooke & Murchie, 2015). Participation in recreational fishing is similar across Canada and the United States (7.5 vs. 9.3%) and is primarily conducted using rod and reel (Arlinghaus et al., 2015). Canada and the United States have abundant freshwater resources, with the Great Lakes contributing much of the continents total freshwater (9% and 7% area by water respectively; CIA, 2016). Both Canada and the United States have extensive coastline and therefore access to marine resources from both the Atlantic and Pacific Oceans. Both countries harvest many trout (Salmonidae), walleye, perch and bass (*Micropterus* spp.) from freshwater (Fisheries and Oceans Canada, 2012; Cooke & Murchie, 2015) and smelt (*Osmerus* *mordax*), and Atlantic cod from the ocean (Fisheries and Oceans Canada, 2012; NOAA, 2015). Recreational fisheries harvest in North America is considerably greater in lakes and rivers compared to that of the ocean, and total recreational harvest is nearly 14 times higher in the United States than in Canada (Cooke & Murchie, 2015; Fisheries and Oceans Canada, 2012; NOAA, 2015). Recreational harvest also provides 59% more edible fish per capita in the United States than in Canada, although Canadians eat more fish per capita (all sources) than Americans, suggesting Canadians have greater reliance on other fishing methods (commercial, subsistence) to provide fish (Table 1). Compared to North America, Central American countries such as Cuba and Mexico have little surface water (CIA, 2016). In Cuba, estimated per capita consumption of recreationally caught fish is 90 g/person (Au et al., 2014; NOAA, 2015) and in Mexico, 32 g/person (Cisneros-Montemayor, Cisneros-Mata, Harper, & Pauly, 2015; NOAA, 2015).

4.2 | Europe

Scandinavian nations have especially high participation rates in recreational fishing, including ice fishing due to the long winter season (Aas, 2008). Norway has the greatest participation (32%), followed by Finland (27%) and Sweden (17%) (Arlinghaus et al., 2015). Sweden and Finland have a higher freshwater catch than marine (Statistics Sweden 2013; The The Finnish Game and Fisheries Institute, 2015), whereas Norway has a higher marine than freshwater catch (FAO, 1989; Hallenstvedt & Wulff, 2004). These harvest percentages are consistent with the fact that the area of freshwater is greater in Sweden and Finland (9%–10%; CIA, 2016) than in Norway (6%; CIA, 2016) and that Norway has considerably more coastline. Catch-and-release rates can be relatively high in Scandinavia with Norway having the greatest proportion of fish released (Ferter, Borch, et al., 2013). Scandinavian countries are permitted to use a variety of recreational fishing gear including rod and line, nets, longlines, otter boards (see McHugh, Broadhurst, Sterling, & Millar, 2015), handlines and pots (FAO, 1996; The Finnish Game and Fisheries Institute, 2015). Important freshwater species include pike, perch, zander, roach (*Rutilus rutilus*, Cyprinidae), salmon (*Salmo salar*, Salmonidae) and brown trout (*Salmo trutta*, Salmonidae; Navrud, 2001; Statistics Sweden, 2013; The Finnish Game and Fisheries Institute, 2015), whereas mackerel, trout, cod, Pollock (*Pollachius* spp.), halibut (*Hippoglossus* spp.), tusk (Brosme brosme), perch and herring are harvested most in marine environments (Statistics Sweden, 2013; Vølstad et al., 2011). Per capita fish consumption from recreational sources is greater in Scandinavia than in other areas of the world and contributes a moderate amount of the total fish consumed by the entire population (Table 1).

The European countries of Germany, Italy, Poland, Greece, France, Estonia, Iceland, Hungary, Czech Republic, Slovakia, Holland, England/Wales and Croatia had participation and harvest rates evaluated for their recreational fisheries. Participation in recreational fishing varied considerably in these countries from 0.2% to 11.2% (Table 1). Access to freshwater is relatively consistent between these countries comprising <1%–6% of total area (CIA, 2016). Many countries in Europe are landlocked (e.g. Czech Republic, Hungary, Slovakia) and therefore have little to no commercial fisheries landings. Harvest in these countries is therefore primarily from recreational fishers in inland waters (Table 1). In these landlocked countries, the common carp is the main target of recreational fisheries, although salmonid species are also targeted frequently (FAO, 1990, 2005a; Novomeská & Kovác, 2015). In Italy, the top three species caught by marine recreational fishers were tuna (*Thunnus* spp.), bogue (*Boops boops*) and Atlantic bonito (*Sarda sarda*; Piroddi et al., 2015). According to recreational fisheries surveys, the most commonly targeted species in German and Polish marine fisheries were cod and herring (Arlinghaus, 2004; Bale, Rossing, Booth, Wowkonowicz, & Zeller, 2010), whereas carp, salmonids and pike were most important in lakes and rivers in Germany (Arlinghaus, 2004). In the United Kingdom (England/Wales), mackerel, whiting (*Merlangius merlangus*, Gadidae) and European bass (*Dicentrarchus labrax*, Moronidae) had the greatest total retention, despite over 80% of whiting and bass being released (Armstrong et al., 2013). These species are also coveted by the 125,000 sea anglers in Scotland (Fishpal, 2017; Scottish Government, 2009). In the freshwater fisheries of the UK (including Scotland), anglers harvest primarily migratory salmonids (salmon and sea trout), stocked trout and some coarse fishes (Environmental Agency, 2017; Freshwater rod fishing rules, UK; Scottish Government, 2016). In Scotland, migratory salmonids are released at rates exceeding 80%, so despite catches exceeding 27 tonnes, only 5.5 tonnes are retained (Scottish Government, 2016). Stock enhancement of freshwater fish species such as rainbow trout (*Oncorhynchus mykiss*, Salmonidae) is standard in European countries (Cowx, 1997). In Croatia, European hake (*Merluccius merluccius*, Gadidae), sardines and mullet (Mugilidae spp.) are a considerable component of the recreational harvest, whereas Greece harvests a majority of seabream (Sparidae spp.; Moutopolous, Tsikliras, & Stergiou, 2015). In Holland, Atlantic cod, European sea bass and European eel (*Anguilla anguilla*, Anguillidae) were retained most (van der Hammen, de Graaf, & Lyle, 2015), while pike-perch, perch and bream are popular in Estonia (FAO, 2005b). In some cases, the recreational landings can be equivalent to commercial landings as is the case for European sea bass in France (Herfaut, Levrel, Thébaud, & Véron, 2013). Recreational fishing provides the most fish per capita in Greece (Moutopolous et al., 2015), while fish per angler is greatest in Croatia (Matić-Skoko et al., 2014). Across all European countries listed here, very little food security is provided to the population by recreational fishing (≤625 g per person per year) but recreational fishing contributes substantially to the fish consumption of individual anglers in most of these countries (Table 1). Overall, recreational fish provide less food per capita in these European countries than in North America and Scandinavia (Table 1).

4.3 | Asia

Japan and South Korea have roughly 3% of their inland area as water (CIA, 2016), although only South Korea catches the majority of its recreational fish inland (Lee, 2010; Ministry of Agriculture, Forestry, and Fisheries, 2014; Shon, Harper, & Zeller, 2015). The total recreational harvest in South Korea is nearly three times that of Japan (Table 1), followed by the Russian Far East and Thailand,

TABLE 1 Recreational fishing harvest data for countries in North America, Scandinavia, Europe, Asia, Africa, Latin America and Oceania

Country	Total harvest (t)	Inland harvest (t)	Marine harvest (t)	Total (commercial, industrial, recreational, subsistence_ harvest (t)	Proportion of total harvest (%)	Participation rate (%)	Edible fish/angler/year (g)	Edible fish/per capita (g)	Per capita fish consumption (all sources; g)	Recreational fish in per capita fish consumption (%)	Year of estimate
North and Central America											
The United States	500,021	396,242	103,779	4,995,418	10.0	9.3	7,300	677	4,600	14.7	2004
Canada	35,941	22,758	–	979,521	3.7	9	4,700	425	6,500	6.5	2010
Mexico	3,800*	–	3,800*	1,528,280	0.2	–	–	32	4,600	<1	2010
Cuba	2,500*	–	2,500*	23,996	10.4	–	–	90	3,200	2.9	2010
Scandinavia											
Norway	33,040	10,000	23,040	2,291,295	1.4	32.2	9,000	2,900	21,200	13.7	2003
Finland	22,005 (19,551)	16,132	5873	167,853	13.1	27.0	5,900	1,600	10,200	15.7	2013
Sweden	16,000 (15,211)	9,000	7,000	187,304	8.5	17.0	4,000	670	21,000	3.2	2013
Europe											
Germany	45,000	–	–	221,772	20.3	4	5,500	220	6,200	3.5	2002
Italy	29,800* (386)	–	29,800*	236,062	12.6	2.7	7,447	201	10,320	1.9	2010
Greece	17,390*	–	17,390*	71,035	24.5	0.9	6,900	625	10,000	6.3	2010
Poland	17,021* (13,800)	1,021	16,000*	151,820	11.2	0.2	5,200	180	4,920	3.7	2007
France	12,300*	–	12,300*	473,178	2.6	5.1	1,469	75	13,600	0.6	2012
Holland	7,728	1,626	6,102	386,942	2.0	10.2	1,830	465	9,360	5.0	2009
Croatia	4,800*	–	4,800*	52,867	9.1	1.8	24,000	435	3,200	13.6	2010
Hungary	4,742	4,742	–	6,717	70.6	3.7	5,165	191	2,040	9.4	2012
Czech Republic	3,812	3,812	–	3,812	100	2.8	5,083	145	3,680	3.9	2014
England/Wales	3,684	69	3615	627,000	0.6	11.2	427	25	8,200	0.3	2015
Slovakia	1,936	1,936	–	1,936	100	2.2	6,644	144	3,200	4.5	2011
Iceland	213 (176*)	–	–	1,095,196	<0.1	7.3	3,565	260	36,760	0.7	2014
Estonia	197	–	–	68,284	0.3	3.9	1,549	60	5,880	1.0	2014

(continued)

TABLE 1 (Continued)

Country	Total harvest (t)	Inland harvest (t)	Marine harvest (t)	Total (commercial, industrial, recreational, subsistence_ harvest (t)	Proportion of total harvest (%)	Participation rate (%)	Edible fish/angler/year (g)	Edible fish/per capita (g)	Per capita fish consumption (all sources; g)	Recreational fish in per capita fish consumption (%)	Year of estimate
Asia											
South Korea	151,752	98,942	52,810*	1,734,908	8.7	13.3	9,235	1,229	16,640	7.4	2010
Japan	38,434	12,268	26,166	4,418,233	0.9	8.9	3,380	120	16,900	<1.0	2008
Russia Far East	19,679*	17,711*	1,968*	4,177,071	0.5	5.8	64,536	1,819	8,960	20.3	2010
Thailand	15,180*	–	15,180*	1,810,620	0.8	9.1	1,004	91	13,160	<1.0	2010
Taiwan	852*	–	852*	851,908	0.1	0.3	12,000	15	14,900	<1.0	2010
Pakistan	120*	–	120*	453,264	<0.1	<0.1	47,012	<1	2,000	<1.0	2010
Africa											
Morocco	29,755*	–	29,755*	1,166,539	2.6	–	–	375	3,000	12.5	2010
South Africa	6,943	900	6,043*	640,089	1.1	1.5	3,600	55	3,040	1.8	2010
Senegal	1,650*	–	1,650*	409,715	0.4	–	–	51	10,040	<1	2010
Algeria	1,038*	–	1,038*	93,442	1.1	–	–	30	2,000	1.5	2010
Ghana	850*	–	850*	367,058	0.2	–	–	14	11,440	<1	2010
South America											
Argentina	105,877	15,077	90,800*	811,749	13.0	–	–	1,000	3,160	31.6	2010
Oceania											
Australia	27,000	4,060	22,940	277,094	9.7	19.5	3,200	565	8,100	6.9	2001
New Zealand	19,000	988	18,022	452,522	4.2	17.1	26,027	1,780	10,600	16.8	2008

[a]When inland and marine captures were from different years, the edible fish per capita (g) was calculated using the population from the most recent year.
[b]Total harvest section includes the consumption of invertebrates.
*Indicate the estimate has been derived from a reconstructed catch that accounts for illegal, unreported and unregulated captures.

with particularly low harvest in Taiwan and Pakistan (although sufficient data is lacking for harvest of fish inland). In both Japan and South Korea, seabream and mackerel are important marine recreational fish (Lee, 2010; Ministry of Agriculture, Forestry, and Fisheries, 2014; Shon et al., 2015), whereas eel (*Anguilla japonica*, Anguillidae) and trout are highly retained from freshwater fisheries (FAO, 2003; Ministry of Agriculture, Forestry, and Fisheries, 2014). In Thailand, king mackerel (*Scomberomorus cavalla*), skipjack tuna (*Katsuwonus pelamis*) and barracudas (*Sphyraena* spp.) are important recreational species (Teh, Zeller, & Pauly, 2015), whereas yellow croaker (*Larimichthys polyactis*), yellow drum (*Nibea albiflora*) and seabream are popular in Taiwan (Ditton, Divovich, Färber, Shon, & Zylich, 2015). In Far East Russia, white spotted char (*Salvelinus leucomaenis*, Salmonidae) and various salmon and flounder dominate the recreational catch (Soboloveskaya & Divovich, 2015). Pakistan recreational catch is primarily species within the Serranidae (e.g. sea basses and groupers) as well as the Sphyraenidae (Barracudas; Hornby, Khan, Zylich, & Zeller, 2014). The participation rate in recreational fishing is higher in South Korea (13.3%; Lee, 2010) than in Japan (8.9%; Arlinghaus et al., 2015), Thailand (9.1%; Teh et al., 2015), the Russian Far East (5.8%; Soboloveskaya & Divovich, 2015), Taiwan (0.3%; Divovich et al., 2015) and Pakistan (<0.1%; Hornby et al., 2014). Due to the small number of fishers in Taiwan and Pakistan, each fisher can gather a significant amount of fish (12 and 47 kg/year respectively; see Table 1), as can anglers in the Russian Far East (65 kg/year). The annual per capita supply of recreational fish in South Korea is 1.2 and 1.8 kg in the Russian Far East (Table 1). The contribution of recreational fish to nutrition in South Korea and the Russian Far East is comparable to that in Scandinavia, whereas the contribution of recreational fish in Japan, Thailand, Taiwan and Pakistan is relatively low.

4.4 | Africa

Many of the Northern African countries such as Morocco and Algeria have very little water surface area (CIA, 2016), resulting in most of the recreational fishing taking place off the coast. In Morocco, sole, mullet and sea bass are harvested frequently (Belhabib, Harper, Zeller, & Pauly, 2013a), whereas grouper, barracuda and common dentex (*Dentex dentex*) are commonly retained in Algeria (Belhabib, Pauly, Harper, & Zeller, 2013b). In Southern Africa, the African Great Lakes support immense aquatic diversity (Salzburger, Van Bocxlaer, & Cohen, 2014), providing opportunity for recreational fishing. For example, South Africa has extensive access to freshwater resources in lakes, reservoirs and rivers with the common carp, yellowfish (*Labeobarbus* spp.) and Nile perch (*Lates niloticus*) as popular fisheries in freshwater (Ellender, Weyl, Winker, & Booth, 2010; Schindler, Kitchell, & Ogutu-Ohwayo, 1998). Nile perch are caught by fishers using both gill nets and small hooks on longlines and have recently undergone population decline due to overharvest (Mkumbo & Marshall, 2015). Yellowfish also support sport fisheries in South Africa, increasing angling tourism (Smit, Gerber, O'Brien, Greenfield, & Howatson, 2011). Herring and mackerel are harvested frequently in the ocean by South Africans (Gordon, Finegold, Charles, & Pulis, 2013). Popular recreational fisheries in Senegal include the swordfish (*Xiphias gladius*), marlin and tuna fishery (Ngom Sow & Ndaw, 2009), while Ghana has a popular barracuda fishery (Nunoo, Asiedu, Amador, Belhabib, & Pauly, 2014). Africa also has many recreational fisheries for species such as tigerfish and yellowfish that attract tourists from around the world. These fisheries benefit local economy and therefore a person's ability to obtain food; however, this contribution to nutrition is indirect. The per capita contribution of recreationally caught fish is similar in South Africa, Senegal, Algeria and Ghana (i.e. <100 g; Belhabib, Pauly, et al., 2013b; Belhabib, Koutob, et al., 2013c; Baust, The, Harper, & Zeller, 2015; Nunoo et al., 2014; Table 1), although the supply of food from recreational fishing in Morocco is comparatively high (Belhabib, Harper et al., 2013a; 375 g) and similar to the recreational fish contribution in European countries (Table 1).

4.5 | South America

Countries such as Argentina have some important inland fisheries including established populations of non-native rainbow and brown trout (Vigliano et al., 2000), as well as perch, dorado and patí (FAO, 1980). In addition, the Amazon River and its tributaries support important freshwater sport fisheries such as that of the peacock bass (*Cichla spp.*; Thome-Souza, Maceina, Forsberg, Marshall, & Carvalho, 2014). Overall, recreational fish provide a significant per capita contribution to food consumption in Argentina (1,000 g/person; FAO, 1980; Villasante et al., 2015). Based on the available data, recreational fishing in Argentina seems to contribute the greatest proportion towards per capita fish consumption of all countries in this report (Table 1).

4.6 | Oceania

Australia and New Zealand have access to a variety of marine resources including the Indian Ocean, Timor Sea, Coral Sea, Tasman Sea and South Pacific Ocean that are exploited by recreational fisheries. Recreational fishing participation is relatively high in both Australia (19.5%; Henry & Lyle, 2003) and New Zealand (17.1%; Aas, 2008; Aas & Vittersø, 2000; van Aalst, Kazakov, & McLean, 2003) but is below the participation rates of Scandinavian countries (Table 1). In both countries, most captures occur by rod and reel (85% in Australia; Henry & Lyle, 2003). In Australia, the most commonly harvested species include King George whiting (*Sillaginodes punctatus*, Sillaginidae), flathead, Australian herring (*Arripis georgianus*, Arripidae) and Australian salmon (*Arripis trutta*, Afrripidae) in marine environments, whereas European carp, golden perch (*Macquaria ambigua*, Percichthyidae), barramundi (*Lates calcarifer*, Latidae) and trout/salmon are important fisheries in freshwater systems (Henry & Lyle, 2003). In New Zealand, marine recreational catch is dominated by snapper (Lutjanidae), kahawai (*Arripis trutta*) and blue cod (*Parapercis colias*; Wynne-Jones, Gray, Hill, & Heinemann, 2014), whereas brown trout, rainbow trout and chinook salmon (*Oncorhynchus tshawytscha*, Salmonidae) are most popular for freshwater anglers (Unwin, 2009). The annual contribution of harvested fish to nutrition of the average person is estimated to be 1,780 g (Hartill & Davey, 2014; Ministry of Fisheries, 2008), indicating that recreational fishing contributes extensively to nutrition compared to many other countries (see Table 1). In Australia, recreational fishing provides an average of 565 g per person, which is comparable to the rates in North America (Table 1).

4.7 | On the magnitude of recreational fish consumption

The estimates of food consumption based on the recreational fish harvest reveal that in many cases this source of food serves to subsidize diets of people in both developed and developing countries. Reflecting the inherent variation in motivation for recreational fishing and orientation towards harvest, the extent to which recreationally harvested food contributes to food security is also quite variable. What is clear is that recreationally harvested fish should be considered when evaluating the relative contribution of the different fisheries sectors. Catch-and-release remains a tenet of many recreational fisheries (Cooke & Cowx, 2004) but harvest can still be substantial. Harvest surveys vary in their level of detail and in most cases the data simply do not exist. This makes estimates of the contribution of the recreational harvest challenging or impossible in many cases. Nonetheless, we were able to assemble relatively accurate statistics from a selection of countries from around the globe. The confidence level for these statistics is greatest for countries that have national angling surveys conducted and is lowest for countries that have statistics developed using modelling techniques (see Supporting Information for a description of how each statistic was calculated).

The contribution of the recreational harvest of fish to total country-specific harvest for fish ranges from a low of 0.1% in Taiwan to a high of 24.5% in Greece (see Figure 2). However, even within a region (e.g. Europe and Scandinavia) these values can vary severalfold (e.g. 1.4% in Norway and 2% in Holland compared to 13.1% in Finland and 20.3% in Germany). The edible recreationally harvested fish per capita (in grams) ranges from a low of 14 g in Ghana to a high of 2,900 g in Norway (Figure 3). Perhaps the most interesting statistic is the contribution of recreational fish to the total per capita fish consumption (%). Estimates ranged from lows of <1% in many Asian (e.g. Japan, Thailand, Taiwan) and African (e.g. Ghana, Senegal) countries with highs of 31.6% in Argentina, 20.3% in the Russian Far East, 16.8% in New Zealand and 15.7% in Finland (Figure 4). Clearly no single statistic clearly reflects the importance of recreational fish harvest to diets. This is perhaps most evident in the data for Norway where the recreational harvest is almost negligible when compared to total harvest (i.e. 1.4%) yet per capita consumption of recreationally harvested fish is the highest of all countries listed in Table 1 (2,900 g). The fact that 13.7% of total fish consumption in Norway is from the recreational harvest, however, emphasizes that much of the total commercial harvest in that country is exported such that the relative role of the recreational sector in the diet of Norwegians is relatively high. For the first time, statistics on the value of the recreational harvest to food security and diets have been amassed in a single report (Table 1; Figures 2 to 4).

5 | RECREATIONAL FISHING AND HEALTH

Aside from the cultural and traditional values associated with catch-and-harvest (see above), increasing the proportion of fish in one's diet can also have a suite of positive health benefits. Fish are considered excellent sources of protein, minerals, monounsaturated fats and polyunsaturated fatty acids (PUFAs; Sidhu, 2003). Compared to other meats such as chicken breast, eggs and pork, fish offers considerably higher levels of PUFAs, magnesium and vitamin D, providing similar levels of other micronutrients such as iron, potassium and zinc (Health Canada, 2016a, 2016b). PUFAs may be the most valuable nutritional component of fish, as they include the essential omega-3 fatty acids that must be ingested, as the human body cannot synthesize these

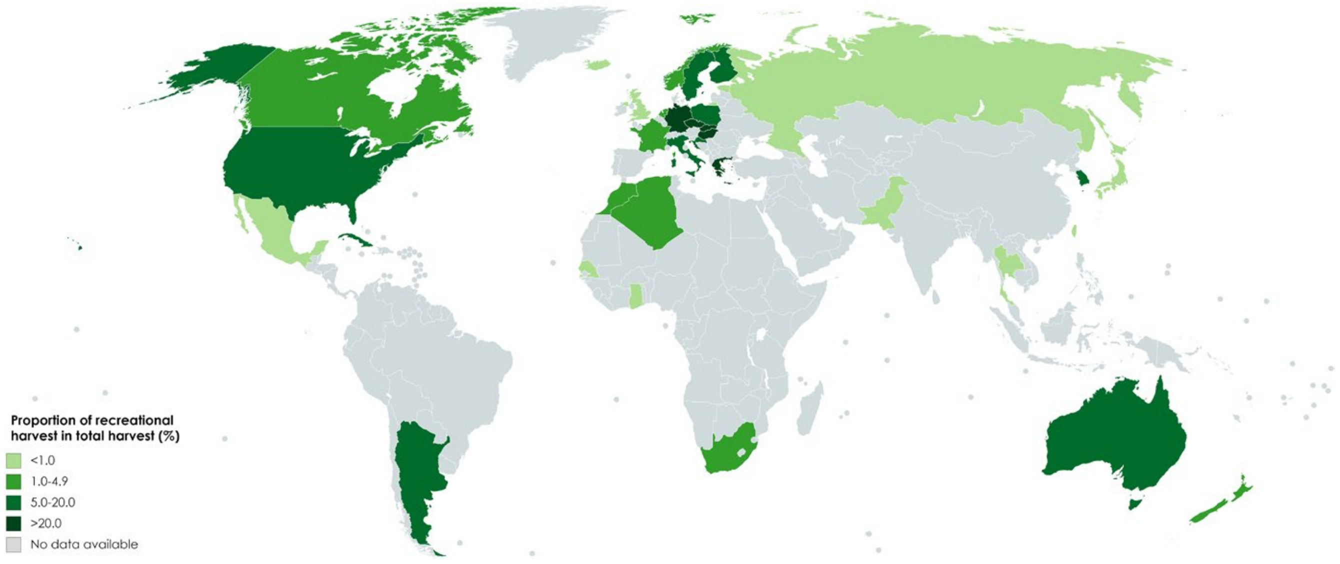

FIGURE 2 The contribution of recreationally harvested fish to total fish harvest for various countries around the world (%). Data sources and details are available in Table 1 and Supporting Information. [Colour figure can be viewed at wileyonlinelibrary.com]

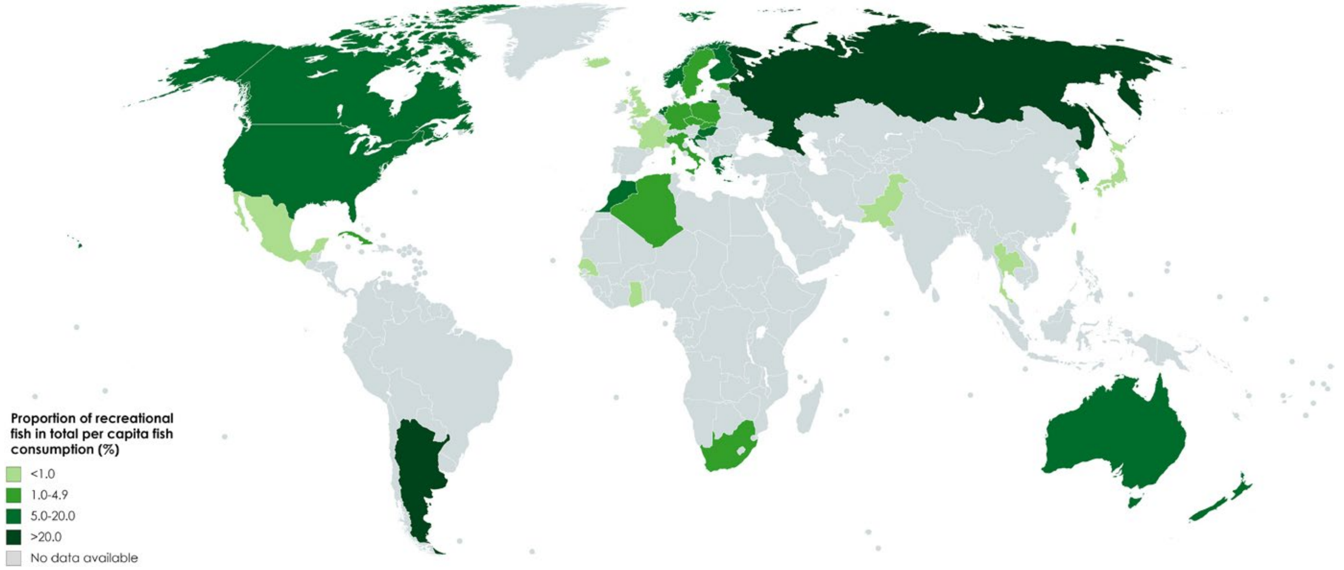

FIGURE 3 The contribution of recreationally harvested fish to total per capita fish consumption for various countries around the world (%). Data sources and details are available in Table 1 and Supporting Information. [Colour figure can be viewed at wileyonlinelibrary.com]

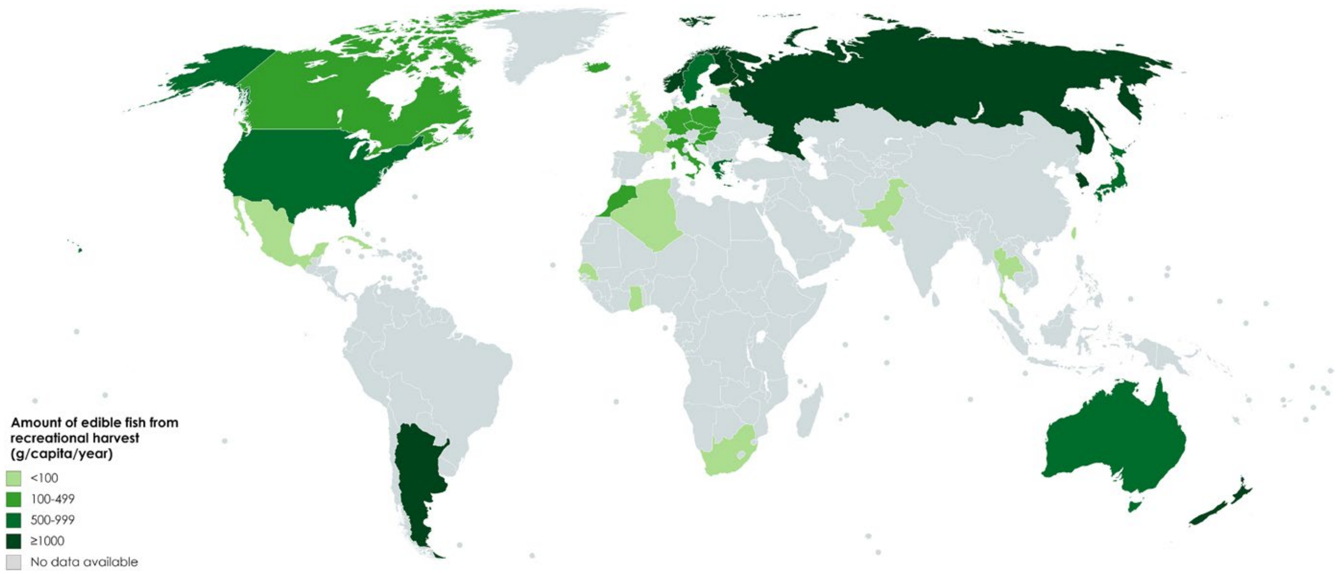

FIGURE 4 The amount of edible fish provided by recreational harvest (g/capita/year) for various countries around the world. Data sources and details are available in Table 1 and Supporting Information. [Colour figure can be viewed at wileyonlinelibrary.com]

compounds naturally (Davidson, 2013). Fish consumption and the associated omega-3 fatty acids can have substantial health benefits including, but not limited to, improved cardiac function, neurological health and development, growth and immunity (Knuth, Connelly, Sheeshka, & Patterson, 2003; Mergler et al., 2007). Recently, the polyunsaturated fatty acid known as docosapentaenoic acid (DPA) was shown to benefit prenatal and postnatal development, and it is suggested fish oils are added to infant formula to increase the intake of DPA (Li, Yin, Bibus, & Byelashov, 2016). Considering the many benefits of fish consumption, it has been recommended by Canada's Food Guide that Canadians consume a minimum of 150 g of fish per week (Health Canada, 2016a, 2016b). Based on this recommendation (i.e. 7,800 g/year), it appears countries within Scandinavia, Asia and Oceania are eating a healthy amount of fish, whereas countries within the Americas and parts of Europe and Africa are not attaining this recommended level of consumption (see Table 1).

Consumer perceptions of "health risks" have influenced the extent to which fish has contributed to nutrition (Lucas, Starling, McMahon, & Charlton, 2016), despite being a healthier option than red meats (Becerra-Tomas et al., 2016). Barriers to fish consumption may be related to the location of capture, obtaining method or storage conditions of the fish (Claret et al., 2012). For example, consumers may prefer wild fish to farmed fish owing to perceived health benefits, and quality, compared to farmed fish (Claret, Guerrero, Gartzia, Garcia-Quiroga, & Ginés, 2016). These preferences exist regardless of any differences in the taste or nutritional value between farmed and wild fish (Cahu, Salen, & de Lorgeril, 2004; Claret et al., 2016). Similar preferences exist for fresh fish compared to frozen fish (Claret et al., 2012; McManus, Hunt, Storey, & Hilhorst, 2014), with fresh fish typically being considered as a "healthier" option as water soluble vitamins and minerals are not lost in the thawing process associated with consumption of frozen fish. This preference for fresh fish may promote the consumption of fish following recreational capture as it is a source of wild or stocked fish that can be eaten fresh, because it does not require the packaging and transport that commercially captured fish often does. The capacity for recreational fishing to provide nutritious food is immense across the world and can make up a considerable component of the total fish consumed in an area (see Table 1). Although there are great nutritional benefits to fish consumption, below we discuss several health risks associated with the consumption of recreationally caught fish.

6 | FOOD SAFETY ISSUES WITH RECREATIONAL FISHING FOR FOOD

Constraints on fish harvesting from recreational angling are diverse in scope ranging from accessibility challenges to contamination and parasite issues. For the purposes of this section, we focus on issues of fish contamination from natural and anthropogenic sources including chemical contaminants and parasites that render fish unsafe or undesirable for human consumption. Various forms of consumption guidelines (see Figure 5a) or signage indicating areas where fish are unsafe (see Figure 5b) are used to communicate safety issues with the public. However, many impoverished communities in developing countries would lack the environmental protection to develop these guidelines.

To date, one of the largest fish contamination issues is caused from a broad range of chemical compounds that enter aquatic environments naturally (atmospheric deposition) or through anthropogenic activities (industrial and agricultural effluent discharge). There is a vast number of chemical compounds in aquatic environments (Howard & Muir, 2010), but this section focuses on several notoriously problematic chemicals that are known to contaminate sportfish and jeopardize human health upon exposure through consumption.

One of the largest and most prolific groups of chemical contaminants in fish include the organochlorine compounds (OCs), which are synthetic chemicals that have been widely used throughout the world for various agricultural (pest control) and industrial (lubricants and coolants) applications (Bard, 1999; Mackay & Fraser, 2000; Niewiadowska, Kiljanek, & Semeniuk, 2015). OCs are highly problematic in aquatic ecosystems due to their chemical structure and

FIGURE 5 Photograph related to recreational fishing and food. (a) Some jurisdictions produce and distribute guides (either online or in hard copy) to the safe consumption of sportfish where they specify species- and waterbody-specific safe consumption guidelines. This particular example is from the Ontario government in Canada (see https://www.ontario.ca/document/guide-eating-ontario-fishwileyonlinelibrary.com]). (b) Example of a sign displayed near a river in Massachusetts where fish (and other wildlife) have unsafe levels of PCBs. Fishing is still permitted, but fish should be released (photograph courtesy of MA DNR). [Colour figure can be viewed at wileyonlinelibrary.com]

behaviour. Specifically, OCs are very stable and persistent chemicals that resist degradation in nature (half-life >2 years). OCs are generally lipophilic and are known to bioaccumulate, bioconcentrate and even biomagnify within upper trophic levels of a food web (Baumann & Whittle, 1988; Chattopadhyay & Chattopadhyay, 2015; Jones & de Voogt, 1999). Furthermore, OCs can induce negative toxicological effects upon acute and chronic exposure in both fish and humans (Falk et al., 1999; Hanrahan et al., 1999; Knuth et al., 2003). A large portion of OCs were developed and used for pest control applications and include such pesticides as aldrin, chlordane, dichlorodiphenyltrichloroethane (DDT), dieldrin, endrin, heptachlor, mirex and toxaphene. Other notorious OCs including polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB) and polychlorinated dioxins and furans were used in a variety of industrial applications (Niewiadowska et al., 2015; Sharma, Rosseland, Almvik, & Eklo, 2009; Simonich & Hites, 1995). As OCs were predominantly used in agricultural and industrial settings, large quantities of these chemicals entered waterways (lakes, rivers, oceans) through rainwater run-off, effluent discharge and waste disposal (Lohmann, Breivik, Dachs, & Muir, 2007; Muir et al., 1992; Simonich & Hites, 1995). As a result, areas of highest concern for contamination by OCs include waterbodies within close proximity to urban development, agriculture, industry and resource extraction sites. Fish can be directly exposed to OCs through various uptake pathways including respiration (passing of chemicals over the gill filaments during oxygen exchange), ingestion (consumption of contaminated prey) and absorption through the dermal layer; which can culminate in the uptake and storage of OCs in various organ, muscle and fat tissues (Burreau, Zebühr, Broman, & Ishaq, 2004; Mackay & Fraser, 2000; Vives, Grimalt, Ventura, Catalan, & Rosseland, 2005).

Fish contamination burden can also vary depending on the species, trophic position and age. Generally, fish that contain higher lipid concentrations (i.e. salmon), occupy higher trophic positions (i.e. Thunniformes, Coryphaenidae, Esocidae) and are long-lived (i.e. lake trout; *Salvelinus namaycush*, Salmonidae) have a higher contamination risk due to greater exposure potential (McIntyre & Beauchamp, 2007; Smylie, McDonough, Reed, & Shervette, 2016; Vives et al., 2005). These phenotypic and life-history characteristics are often associated with the most common and highly sought after predatory sportfish that anglers choose to target. As such, humans that consume contaminated sportfish are at risk of developing increased body burden levels of OCs (Falk et al., 1999). In humans, the main toxicological effects of OCs have largely been observed within the skin, thyroid gland, liver, immune system and reproductive system; with varying levels of exposure resulting in adverse effects to neurological development, reduced thyroid and immune function, dermatological effects and chloracne development (Baumann & Whittle, 1988; Longnecker, Rogan, & Lucier, 1997; Falk et al., 1999; Hanrahan et al., 1999; Carpenter, 2011). Considering the negative health impacts associated with exposure to OCs, these chemicals have largely been banned throughout much of the world; however, residual concentrations of these chemicals still persist in nature (Lohmann et al., 2007), creating legacy contamination impacts on fish and the recreational angling community. Due to the chemical nature and toxicity of OCs, extensive chemical monitoring and consumption limits are applied to fish harvested from contaminated waterbodies.

Another notoriously problematic chemical contaminant that can accumulate in fish is mercury (Hg; Watras et al., 1998; Hammerschmidt & Fitzgerald, 2006; Smylie et al., 2016). Although Hg is a naturally occurring inorganic substance, this chemical can be highly toxic to fish and humans (Reyes, 2016). Hg is also readily produced through anthropogenic activities (i.e. fossil-fuel-fired power plants). When Hg is released into aquatic environments, it is transformed into methylmercury (MeHg) by sulphate-reducing anaerobic bacteria (Compeau & Bartha, 1985). MeHg is the most common and toxic form of organic mercury and is readily taken up by living organisms (Harris et al., 2007; US EPA, 2001). In fish, exposure to MeHg occurs through respiration, ingestion of contaminated food and water, and absorption through the dermal layer (Sindayigaya, Cauwenbergh, Robberecht, & Deelstra, 1994). Similar to OCs, MeHg is a persistent chemical in nature and can biomagnify within upper trophic levels of a food web. MeHg concentrations in fish can also vary depending on the species, trophic position, age and size, resulting in higher MeHg concentrations in older, larger, predatory sportfish (Guardiola et al., 2016; McIntyre & Beauchamp, 2007; Niimi, 1983; Smylie et al., 2016; Trudel & Rasmussen, 2006; Watras et al., 1998). MeHg poisoning in humans can cause severe toxicological effects that can severely disrupt neurological health and development (i.e. Minamata disease), immunity and disease resistance, cardiovascular and respiratory performance, and gastrointestinal function. Chronic MeHg exposure can also lead to paralysis, coma and death (Carpenter, 2011; Holmes, James, & Levy, 2009; Lepak et al., 2016; Zahir, Rizwi, Haq, & Khan, 2005). Unlike OCs, Hg is largely released into the atmosphere where it can travel great distances prior to deposition, resulting in elevated Hg concentrations in remote areas that are devoid of industrial activities (i.e. northern inland lake systems; Bard, 1999; Pirrone et al., 2010). Furthermore, MeHg is not lipophilic and consequently can accumulate in equal concentrations throughout the organs, muscle and fatty tissues of fish (Mieiro, Pacheco, Pereira, & Duarte, 2009). Higher concentrations of MeHg in the muscle tissue of harvested fish can increase the risk of developing higher body burden levels of MeHg through contaminated sportfish consumption. As such, chemical monitoring and consumption limits are often imposed on fish harvested from contaminated waterbodies.

Recently, new analytical techniques have become available to analyse fish and aquatic environments for perfluoroalkyl and polyfluoroalkyl substances (PFASs), which are also known as perfluorinated compounds (PFCs; Lau et al., 2007). PFASs are a family of fluorine-containing chemicals that have unique hydrophobic and lipophobic properties. Owing to the chemical uniqueness of PFASs, these compounds have been integrated into a wide array of consumer and industrial products dating back to the 1950s (Bhavsar et al., 2016; Lau et al., 2007). PFASs and their derivatives are persistent chemicals that do not breakdown easily. Consequently, high chemical concentrations have been detected within fish in contaminated waterbodies (e.g. the Great Lakes), resulting in consumption restrictions to ensure human safety. Other chemical contaminants of concern that may accumulate and biomagnify in fish to levels that pose human health risks include certain heavy metals (i.e. lead, arsenic, selenium, copper, cadmium and zinc; Barwick & Maher, 2003). However, the availability of metals to fish is dependent on many physio-chemical and biological factors (see Dallinger, Prosi, Segner, & Back, 1987).

In addition to various chemical contaminants that may render fish unsafe for dietary consumption, other biological factors such as parasites may also cause human health issues. Furthermore, the visual presence of unsightly parasite infestations on/in fish may also act as a deterrent influencing an angler's decision on whether to harvest of release an infected fish. Several common parasites (i.e. worms, leeches, grubs, cysts, nodules, larval round worm, protozoa) that are found in freshwater and marine sportfish do not present a health hazard to humans if the fish is properly, and thoroughly, cooked prior to consumption (Adams, Murrell, & Cross, 1997). Ciguatera is a foodborne illness that can occur from eating certain tropical reef fishes that are contaminated by a ciguatoxin (Kirkpatrick et al., 2004). The ciguatoxin is produced by dinoflagellates that live on and around tropical reef systems in tropical and subtropical waters. These dinoflagellates can biomagnify within the upper trophic levels of a food web, which can increase the likelihood of highly desirable predatory sportfish becoming contaminated with this ciguatoxin (Chinain et al., 2010; Dickey & Plakas, 2010; Roeder et al., 2010), resulting in increased health and exposure risks to anglers that catch-and-harvest contaminated reef fishes. In humans, ciguatera can have adverse effects on gastrointestinal and neurological systems. Specifically, people suffering from ciguatera can exhibit symptom of nausea, vomiting, diarrhoea, headaches, muscle pains, paraesthesia, vertigo and hallucinations. More severe symptoms can include cold allodynia (Dickey & Plakas, 2010; Kirkpatrick et al., 2004). The ciguatoxin cannot be destroyed or denatured through conventional cooking methods. As such, care should be taken by anglers to not consume fish that have ciguatera. There are a number of commercially available test kits that can be used by anglers to assess whether fish are safe for consumption but we are unable to comment on their reliability.

Recently, various global and regional actions have been taken to protect human health and the environment from contamination by OCs, MeHg, PFASs, heavy metals and biological contaminants. There has been international recognition and cooperation to develop intergovernmental action plans including international treaties such as The Stockholm Convention on Persistent Organic Pollutants and The Convention on Long-Range Transboundary Air Pollution to combat the use and distribution of persistent organic pollutants and toxins (i.e. OCs and PFASs). More specifically, these international treaties have been established to curtail the production and use, monitor chemical concentrations and distributions and to evaluate the biological effects of various OCs and PFASs in the environment. Local action plans and initiatives at the national and regional level are also undertaken by a multitude of nations to monitor and evaluate local levels of OCs, PFASs, MeHg, heavy metals and various biological contaminants in economically valuable water systems (i.e. the Great Lakes). As such, chemical and biological monitoring, combined with consumption limits, are often imposed on fish harvested from contaminated waterbodies to reduce any potential health risks that may occur from consuming unsafe fish products.

Contamination issues may be overlooked, as safety advisories can limit or restrict angling opportunities. If some fish stocks are not healthy to be eaten because some threshold contaminant levels are reached (which happened in several places in lipid-rich species such as anguillids), there is a risk of a complete angling ban because the reasonable reason of angling can no longer be fulfilled if the fish cannot be taken home (e.g. Germany). Thus, under certain situations, contaminants can actually lead to a complete ban on fishing.

7 | THE FUTURE OF RECREATIONAL FISHING FOR FOOD

Fish have long been a significant source of protein in many societies and the act of fishing an important instrument for relaxation, recreation and stress reduction. As noted above, the harvest of recreationally captured fish is acutely driven by current motivations and constraints, but the literature and public perception about recreational fishing is less about harvest and more about catch-and-release. We hope to have accumulated evidence that angling is as much about harvest than it is about catch-and-release and that the harvest component is important and contributes to human well-being. That said, the fact that anglers harvest many fish can also lead to important political and economic conflict with other stakeholders that depend on harvest for survival, in particular commercial fisheries, as currently evidenced in the European Fisheries Policy where coregulation of recreational fishers together with commercial fisheries is on the agenda of policymakers (Strehlow, Schultz, Zimmermann, & Hammer, 2012). Evolving economic conditions that influence the amount of free time and disposable income available could lead to more clashes between commercial fishing enterprises and recreational fishers for access to sites, areas and resources as is the case in North Carolina's Red Drum fisheries (Boucquey, 2017). Recreational black-, grey- or barter-market catch exchanges might gain prominence, which could lead to demand by the commercial enterprises or need from management agencies to monitor, regulate and manage recreational fisheries to a greater degree. We posit that some motivations may remain ingrained into local fishing and societal culture, while others may be more flexible and adapt to population changes (e.g. socio-economic status, immigration and demographic shifts). Constraints to fish consumption, such as the presence of biotoxins, may also change as policymakers and regulators improve water quality and by extension the quality of fish meat. Here, we draw from current motivations and constraints and offer a projection for the future of recreational fishing for food.

Among the motivations for people to consume fish is its high nutritional value in comparison with other food products (reviewed in Tacon & Metian, 2013). Fishers often rate highly the health benefits of fishing for food. Ethnic background often but not always factors into the reasons listed for consuming self-caught fish (Burger, 2002; Burger et al., 2014, Dawson et al., 2008). Given that the per capita rate of aquatic food production and ingestion are related to cultural and socio-economic conditions (Dawson et al., 2008; Tacon & Metian, 2013; Toth & Brown, 1997), it follows that future motivations will be driven by concurrent changes in local societies. However, as suggested Moya, Itkin, Selevan, Rogers, and Clickner (2008), recreational harvest trends will likely only be discernible through local population surveys rather than those acquired at the national level (unless both local and national scales are combined; see freshwater fisheries in the UK; Environmental Agency, 2017). In Ontario, Canada, mail-in surveys conducted every five years consistently show that the number of fish and species harvested depends largely on the local management zone (e.g. Hogg, Lester, & Ball, 2010). Furthermore, fish consumption in the United States has been shown to depend not only on ethnicity but also on the state in which the survey was completed (Moya et al., 2008). Given recent immigration boom in many countries, it remains to be observed whether local and national shifts in ethnicity will have noticeable effects on fish harvest rates. For example, in Canada, which is among the few countries to collect detailed data on recreational fishing, catch-and-harvest have decreased since 1985, despite immigration comprising much of the population growth (Brownscombe et al., 2014; Statistics Canada, 2016). At least in Canada, a developed nation with modest population growth and a strong economy, self-caught fish will not likely be a well-utilized source of protein in the future. Yet, in some regions where recent immigrants make up a large proportion of the population, recreational fisheries harvest may increase as an affordable source of protein. Overall, affluent nations tend to rely on commercially captured and farm-raised fish and fish products, which is unfortunate given the benefits afforded by sustainable recreational fishing (Burger, 2002). Again, reliable data are not available to discern whether immigration will affect harvest rates at the local levels where such trends may be noticeable (Moya et al., 2008).

Uncertainty related to the level of contaminants in fish should also influence consumer decisions in the future (Burger & Gochfeld, 2006; Pieniak, Verbeke, & Scholderer, 2010). Fish living in polluted waters can be prone to the accumulation of environmental contaminants, including lipophilic heavy metals and organocontaminants (Islam & Tanaka, 2004; Pieniak et al., 2010). It has been shown that most anglers, regardless of whether they fish to harvest or simply for recreation, are strongly in favour of fisheries management actions that reduce pollution (Aas & Kaltenborn, 1995, Dorow & Arlinghaus, 2012; Dorow, Beardmore, Haider, & Arlinghaus, 2009). However, many surveys appear to indicate that even when provided information about contamination in their catch, many consumptive anglers continue to harvest fish for food (Dawson et al., 2008; see Motivations, this paper). For example, rather than relying on local officials or the media, consumptive anglers in the industrialized Calumet region of north-west Indiana and south-east Chicago rely on their senses, personal experiences, judgement and information from friends, family and other anglers (Westphal, Longoni, LeBlanc, & Wali, 2008). This poses a challenge to managers, scientists and policymakers to reach a consensus on the risks of fish consumption (Burger et al., 2001). Consumptive fishers possess a diverse array of beliefs regarding the risks associated with consuming fish. In the Laurentian Great Lakes region, Dawson et al. (2008) surveyed a range of Asian-born and Euro-Canadian groups and found that many dismiss the risks either as negligible or not worth worrying over (Dawson et al., 2008). With respect to knowledge about contaminated fish, some Great Lakes anglers would rather "ignore the future" given the apparent uncertainty of negative health effects, the minimal information available on potential effects, and the likelihood that negative effects would be felt many years later instead of worry about issues that may never arise and ruin a good way to spend time (Dawson, Sheeshka, Cole, Kraft, & Waugh, 2008). However, in the same survey many respondents demonstrated they understood the fish consumption risks to pregnant women and their unborn foetuses. Unless the consumer is a pregnant woman, it would seem that in North America, contamination will not be a salient factor in determining whether recreational fishers will consume their catch. Given the global nature of the fish trade, the paucity of information that is required in labelling, and challenges related to inspections for contaminants, consumers may indeed gamble when eating fish that they cannot reliably source (Jacquet et al., 2009).

Over the last several decades, the local food movement has grown in response to challenges and risks associated with globalized food production and distribution systems (Schnell, 2013). Alternative food networks that reduce the spatial proximity between the producer and consumer, such as community supported agriculture and the 100-mile diet (Jarosz, 2008; Schnell, 2013), as well as the organic food movement (Seyfang, 2006), essentially make it easier for consumers to assess the risks associated with their diet. The global to local food movement has also included sourcing of fish, whether from the wild (Tidball et al., 2013) or from aquaculture (Wurts, 2000). Locally available wild fish and game are also beginning to be linked to the "locavore movement" as a means to source environmentally friendly, nutritionally beneficial foods (Tidball et al., 2013). Recreational fishers that can fish relatively close to home and are motivated by the potential to harvest their catch could be overcoming some of the risks associated with commercially sourced fish products. Recreational fishing does involve a financial investment (e.g. for fishing equipment, transportation, licence) and time commitment; however, the net benefit in terms of a known source of fish for consumption could outweigh such costs. The investments may be minimal in unregulated fisheries where there may not be licensing fees, and fishers use basic tackle such as handlines, although transportation costs may still be present. Recreational anglers still have to contend with pollution and associated contaminants in fish; however, where available, consumption guidelines and restrictions may help reduce health risks when eating wild-caught, local fish (Tilden et al., 1997). Appropriately educated anglers can also overcome risks of eating contaminated fish by making choices related to the specific locations to fish and for what species to fish for (Cole, Kearney, Sanin, Leblanc, & Weber, 2004).

As we progress into the 21st century, policymakers, managers and scientists are confronted with the task of adapting and perhaps predicting how perceptions, motivations and constraints will change how recreational fisheries are utilized as a food source (Elmer et al., 2017). Numerous questions will arise as we move forward. How will the demand for self-caught fish change as local populations grow and the ethnic make-up of local communities change? How will reliance on self-caught fish change in developing nations? How will changing behaviours impact stock sustainability and aquatic ecosystem function? How can we improve data collection on self-caught fish harvest in developing nations? How can fishers be protected from contaminated fish? Is the 100-mile diet a reasonable solution for acquiring locally sourced low-risk fish? These are just some of difficult challenges facing policymakers, managers and scientists whose job is to ensure that self-caught fish are a healthy and sustainable source of protein for future generations. Underpinning the harvest of fish caught by recreational fishers is the assumption that the activity is sustainable, which is beyond the scope of this study. It is conceivable that if a fishery was poorly managed (or poorly assessed, which leads to erroneous management actions) or if there was low compliance with harvest regulations that harvest could become problematic, which could thus lead to significant reductions in harvest or potentially fishery closures. If a future scenario includes more individuals depending on this form of fishing for food, such limits or closures could have significant negative effects on food security if there were insufficient financial resources available to secure protein via other means. This scenario may be most relevant to developing countries with deficient or non-existent fisheries management policy and enforcement, and a greater reliance on locally caught fish.

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