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Recreational fisheries activities and management in national parks: A global perspective

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ABSTRACT

National parks occur in most nations around the globe and tend to have a dual role of protecting natural heritage features while also providing opportunities for the public to interact with natural areas through recreation and leisure. National parks are afforded varying degrees of protection with recreational fishing allowed in some form within the boundaries of some parks. However, little is known about the extent to which recreational fishing occurs in national parks or the types of regulations that govern the activity. Vast differences in data availability exist throughout the world (partly related to language barriers and institutional capacity), limiting our understanding of the various uses of national parks. Acknowledging these limitations, we sought to consider the extent of recreational fisheries activities and their management within national parks around the globe. Using the World Database on Protected Areas, we selected the countries that had International Union for the Conservation of Nature type II areas. Within those countries, we investigated national parks that permitted recreational fishing in freshwater and/or marine systems and cataloged information on fisheries regulations, such as size limits and catch quotas. Overall, an equal number of 195 countries allowed some form of recreational fishing within their national parks as the number of countries which did not report any data on recreational fishing at all. Meanwhile, recreational fishing was forbidden in only a few countries with IUCN II national parks. For countries with information available, we found high adoption of recreational fisheries regulations, with the majority of countries requiring specialized park fishing licenses and that all fish be released (i.e., exclusively catch-and-release), though for many countries this information was not reported. The lack of information retrieved on recreational fishing in national parks may reflect search bias or lack of such regulations. Our study highlights the need for better sharing of approaches for the management of recreational fishing in national parks to improve the collective understanding of management practices associated with this activity in protected areas and to learn from successes and failures in different jurisdictions.

1. Introduction

Recreational fishing is practiced globally by millions of people, with one tenth of the world's industrialized population partaking in the activity (Arlinghaus, Cyrus et al., 2015; Arlinghaus, Tillner, & Bork, 2015). The Food and Agriculture Organization (FAO) of the United Nations (UN) defines recreational fishing as the capture of fish and other aquatic animals that do not provide the fisher's primary source of protein nor are sold for profit in domestic, exportation, or black-market trading networks (FAO, 2012). Global estimates of recreational catch total 47 billion fish, most of which are released (Cooke & Cowx, 2004). Recreational catches are estimated to contribute over $190 billion dollars in direct expenditures annually to the global economy (World Bank, 2012).

There has been a recent shift in attention directed to the ecological

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and socioeconomic impacts of recreational fishing (Embke et al., 2019; Ihde, Wilberg, Loewensteiner, Secor, & Miller, 2011; Mora et al., 2009; Pawson, Glenn, & Padda, 2008). Through a lack of monitoring (Post et al., 2002), and poor or no regulations on angler behavior and activity (Johnson, Arlinghaus, & Martinez, 2009), recreational fishing can have negative impacts on fish stocks (e.g., reduced abundance). As such, there has been much debate about the compatibility of recreational fishing and the conservation goals of protected areas (Bartholomew & Bohnsack, 2005; Cooke, Danylchuk, Danylchuk, Suski, & Goldberg, 2006; Cowx, Arlinghaus, & Cooke, 2010). Where protected spaces can contribute to conservation of particular fish species, these efforts may be compromised by direct or indirect outcomes of recreational fishing (Cooke & Cowx, 2006; Cowley, Brouwer, & Tilney, 2002; Lewin, Arlinghaus, & Mehner, 2006). Protected areas are vulnerable to undesirable effects that may result from recreational fishing, including species overexploitation (e.g., catch-and-release mortality, bycatch of imperiled species), non-native invasions or stocking, habitat destruction and disturbance, and pollution (Cooke et al., 2006; Lewin et al., 2006; Schindler, 2000). Even so, to our knowledge there have been no attempts to assess various regulations surrounding recreational fishing implemented by sovereign states for their protected areas, such as in national parks.

It is widely considered that there is a need for increased protection of the world's aquatic (freshwater and marine) ecosystems (Acreman, Hughes, Arthington, Tickner, & Dueñas, 2019; Agardy et al., 2003; Saunders, Meeuwig, & Vincent, 2002). Aquatic protected areas are one such means of doing so, extending protection to the entire community rather than a single species (Acreman et al., 2019; Agardy et al., 2003; Danylchuk & Cooke, 2011). However, each aquatic protected area faces unique challenges that often involves taking into consideration the desires of local stakeholders, as well as the spatial ecology and essential habitats of the biota (Danylchuk & Cooke, 2011; Filous et al., 2017; Venturini, Campodonico, Cappanera, Fanciulli, & Cattaneo Vietti, 2017). Management of present day aquatic protected areas can be especially complex because of the need to balance two potentially conflicting goals: 1) to conserve and protect native species while, also 2) providing stakeholders and supporters opportunities to enjoy the protected area, often meaning providing opportunities to interact with nature by hiking through it, swimming in it, foraging, and fishing recreationally (Brenkman, Dude, Kennedy, & Baker, 2014). Recreational fishing, in particular, is an activity that has the potential to both generate benefits (Granek et al., 2008) and introduce threats to protected spaces (Cooke & Cowx, 2006; Lewin et al., 2006). Similar to commercial fishing, recreational fishing can promote the overexploitation of fish populations, the degradation of aquatic habitat, increase selection pressure on fish, and alter trophic cascades in aquatic ecosystems (Cooke & Cowx, 2006; Lewin et al., 2006). However, recreational fishing can be beneficial from a conservation standpoint, by engaging recreational fishers in conservation and monitoring programs and advancing the progress of scientific research with the direct and indirect help of recreational fishers (Granek et al., 2008).

Here we examine the diversity and extent of recreational fishing activity and management in International Union for Conservation and Nature (IUCN) category II protected areas (the typical designation for national parks). National parks represent "flagship" protected areas in most jurisdictions since they typically are linked to the cultural history and natural heritage of a nation, elevating their profile in society. Participating countries are free to declare suitable areas as IUCN II parks and manage them according to their own governance structures, however, the intent of focusing on protected areas based on that classification was to enable broad comparison at a global scale and to enable a focus on what are typically "national parks" systems (Dudley, 2008).

2. Methods

2.1. Data collection

For the purpose of this analysis, we defined a country as any UN Member and Non-Member State (n = 195). We used the IUCN protected areas categorization system to define various management approaches and governance types. Within the IUCN, six categories describe the various types of protected areas across the world: strict nature reserve (Ia), wilderness area (Ib), national park (II), natural monument or feature (III), habitat/species management area (IV), protected landscape/seascape (V), and protected area with sustainable use of natural resources (VI) (Dudley, 2008). Because many of the categories are not present in most countries, we opted to assess recreational fishing policies at a national scale exclusively for IUCN category II protected areas (herein referred to as 'IUCN II parks'). IUCN II parks are large natural or near-natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational, and visitor opportunities (Dudley, 2008). We define a nationally designated park to be any park that is identified by the World Database on Protected Areas (WDPA) as a marine national park, commonwealth national park, Aboriginal national park, scientific national park, CCA Zone 1 National Park, National Parks Act Schedule 4 park or reserve (Australia), proposed National Parks Act park and/or park addition (Australia). Although there were some discrepancies between the IUCN nomenclature for category II parks and how individual countries defined a national park, we opted to assess parks that are both IUCN II parks and nationally designated parks following careful review of country-specific national park criteria.

Eighteen variables were extracted for each country, depending on availability of the metrics used. A subset of variables was related to general characteristics of national parks in the country (n = 5) whereas most variables pertained to regulations and policies related to the management of recreational fisheries within parks of each country (n = 13; Table 1). Data pertaining to general characteristics of national parks was collected from the WDPA, which is publicly available online via the Protected Planet website. Recreational fishing management approaches were identified based on the governing authority for IUCN II parks in a given country, as reported by the WDPA (UNEP-WCMC, 2017). We defined three management approaches which are used in IUCN II parks: top-down, bottom-up, and co-management. The top-down management approach includes IUCN II park governance by federal or national ministries or agencies, sub-national ministries or agencies, and/or government-delegated management, as defined by the WDPA (UNEP-WCMC, 2017). The bottom-up management approach includes IUCN II park governance by individual landowners, non-profit and for-profit organization, Indigenous peoples, and/or local communities, as defined by the WDPA (UNEP-WCMC, 2017). Finally, the co-management approach includes transboundary, collaborative, and/or joint governance of IUCN II parks, as defined by the WDPA (UNEP-WCMC, 2017). Recreational fishing regulations are defined as directives made and maintained surrounding licensing, quotas, size limits, enforced catch-and-release, area closures, seasonal closures, gear types permitted, and any directives that control fishing effort. Recreational fishing policies are defined as systems of principles put in place by governing bodies surrounding the implementation of fish stocking, population monitoring efforts, and efforts made to actively encourage angling in IUCN II parks.

Data for variables related to recreational fisheries management were extracted separately for marine and freshwater fisheries. Data related to recreational fisheries management was extracted from the websites of government and non-governmental agencies, via internet searches (e.g., using various key words in Google) conducted between October and December 2018. If reports were not produced in English, the narrative

Table 1
Variables and responses extracted from the World Database on Protected Areas and various agency websites on national parks and management of recreational fisheries in national parks. Sample sizes for each variable are divided into 'YES, 'NO', or 'Unreported' responses unless otherwise specified. Where applicable, responses are separated for the total number of countries, countries with freshwater recreational fisheries in their nationally-designated IUCN II parks, and countries with marine recreational fisheries in their nationally-designated IUCN II parks.

Variable	Number of countries (YES/NO/ Unreported responses)	Number of reporting countries with freshwater recreational fisheries (YES/ NO/Unreported responses)	Number of reporting countries with marine recreational fisheries (YES/ NO/Unreported responses)
IUCN II parks: the total number of IUCN category II parks, according to the above definition, for a given country.	153	–	–
Nationally designated parks: the total number of designated national parks for a given country.	160	–	–
IUCN II and nationally designated parks: the total number of parks designated as both an IUCN II and a 'National' park by the corresponding country.	137	–	–
Area (km^2): the total area of all IUCN II and nationally designated parks (terrestrial and marine) in a given country, according to the GIS_AREA reported by the WDPA (UNEP-WCMC, 2017).	137	–	–
Management approach: the governing authority for IUCN II and nationally designated parks in a given country, reported by the WDPA (UNEP-WCMC, 2017).	111	–	–
Recreational fishing: is the act of capturing or harvesting aquatic animals, mainly fishes, which do not constitute the fisher's dominant source of protein or income and are not sold or traded on markets (FAO, 2012), permitted within the boundaries of any IUCN II parks	YES (56) NO (24) Unreported (57)	YES (47) NO (0) Unreported (71)	YES (30) NO (22) Unreported (85)
Countries with recreational fisheries in nationally-designated IUCN II Parks (n = 56)			
License: is the requirement of a license, certificate, or permit for recreational fishing enforced by the governing authority of the national parks system for a given country	YES (38) NO (6) Unreported (12)	YES (33) NO (4) Unreported (19)	YES (19) NO (4) Unreported (33)
Quota: is a bag limit, possession limit, or any fixed number of fish that an individual can harvest for a specified time period enforced by the governing authority of the national parks system for a given country	YES (27) NO (3) Unreported (26)	YES (23) NO (1) Unreported (32)	YES (13) NO (3) Unreported (40)
Size limit: is a restriction on the size (length) of fish harvested from a water body within the boundaries of a national park enforced by the governing authority of the national parks system for a given country?	YES (25) NO (3) Unreported (28)	YES (20) NO (1) Unreported (35)	YES (14) NO (3) Unreported (39)
Catch-and-release: is the method of recreational fishing where anglers immediately release fish unharmed back into the water where they are caught (NPS) enforced in response to any regulation (e.g. size, species, time of year) by the governing authority of the national parks system?	YES (20) NO (1) Unreported (35)	YES (14) NO (1) Unreported (41)	YES (13) NO (0) Unreported (43)
Area closure: is there limited access for recreational fishing activities in specified areas within the boundaries of national parks enforced by the governing authority of the national parks system?	YES (24) NO (0) Unreported (32)	YES (18) NO (0) Unreported (38)	YES (11) NO (0) Unreported (45)
Seasonal closure: is there limited access for recreational fishing activities during specified periods of time (either species-wise or area-wise) within the boundaries of national parks	YES (20) NO (2) Unreported (34)	YES (18) NO (0) Unreported (38)	YES (7) NO (2) Unreported (47)

(*continued on next page*)

Table 1 (*continued*)

Variable	Number of countries (YES/NO/ Unreported responses)	Number of reporting countries with freshwater recreational fisheries (YES/ NO/Unreported responses)	Number of reporting countries with marine recreational fisheries (YES/ NO/Unreported responses)
enforced by the governing authority of the national parks system?			
Gear: particular fishing gear that are permitted for recreational fishing in a national park by the governing authority of the national parks system. Gears included net, trawl, spear, line, bow, trap, hand, gill net, and chemical. Countries that allowed only a single type of gear are shown in the Permitted/Enforced column, and countries that allowed multiple types of gear are shown in the Not Permitted/Enforced column.	Reported (38) Unreported (18)	Reported (29) Unreported (27)	Reported (23) Unreported (33)
Control for effort: does the governing authority of the national parks system enforce limitations on the amount of recreational fishing that takes place in water bodies within the boundaries of national parks? Control for effort may take the form of limiting the number of licenses an individual can have at a time, etc.	YES (7) NO (3) Unreported (46)	YES (4) NO (1) Unreported (51)	YES (3) NO (3) Unreported (50)
Stocking: is it permitted to introduced to water bodies within the boundaries of a national park to augment fish populations for recreational fishing purposes?	YES (9) NO (3) Unreported (44)	YES (9) NO (3) Unreported (44)	YES (1) NO (3) Unreported (52)
Stocked species: if fish stocking is permitted, are the stocked fish introduced or native to the country in which they are being stocked? *Introduced:* any species that did not historically occur within that water body and was introduced by humans or circumstances that resulted from human activity. Responses shown in the Permitted column. *Nativespecies*: any species that has occurred within that water body or may occur as a result of natural processes and was not introduced by humans or circumstances that are a result of human activity. Responses shown in the Not Permitted column.	Introduced (2) Native (7)	Introduced (2) Native (7)	Introduced (0) Native (1)
Population monitoring: are data regarding fish populations (ex. species richness or abundance; fish stock assessments) that occur in water bodies within the boundaries of a national park collected? If so, countries are recorded in the Permitted/Enforced column. If not, countries are recorded in the Not Permitted/Enforced column.	YES (22) NO (1) Unreported (33)	YES (12) NO (1) Unreported (43)	YES (13) NO (1) Unreported (42)
Active encouragement of angling: does the governing authority of the national parks system or individual parks encourage recreational fishing within national park water bodies? Encouragement may take the form of advertisements or promotions for recreational fishing. If so, countries are recorded in the Permitted/Enforced column. If not, countries are recorded in the Not Permitted/Enforced column.	YES (17) NO (6) Unreported (33)	YES (13) NO (5) Unreported (38)	YES (8) NO (2) Unreported (46)

was translated to English using Google Translator before data extraction. However, given that searches were conducted in English that was relatively uncommon. All results are presented as absolute values or as percentages (%) and refer only to the countries that had information available for that variable, unless otherwise specified. For instance, it

was assumed that all gear types not listed online were prohibited from use in the IUCN II park. For countries with both marine and freshwater recreational fisheries in IUCN II parks, presence of a regulation or activity in either freshwater or marine resulted in a 'present' or 'Yes' score when presenting data at the level of the individual country.

3. Results

We extracted data on recreational fishing in IUCN II national parks from countries (n = 195) across Africa (n = 54), Asia (n = 48), Europe (n = 44), North America (n = 23), South America (n = 12), and Oceania (n = 14), all of which provided information on the presence or absence of IUCN II national parks (Table 2). Of 195 countries, 58 did not have any IUCN II national parks. The median number of nationally designated IUCN II parks for the 137 countries included in our assessment was 6 (minimum = 1; first quartile = 2; third quartile = 16; maximum = 674) with a median national park area of 5927.8 km^2 (minimum = 2.5; first quartile = 999.6; third quartile = 22979.8; maximum = 1487554.4).

Table 2
Continents (number of countries) and a list of countries examined for the presence of IUCN category II parks, and the extent of recreational fishing activities and management approaches in such IUCN category II parks.

Africa (54)	Asia (48)	Europe (44)	N. America (23)	S. America (12)	Oceania (14)
Algeria	Afghanistan	Albania	Antigua and Barbuda	Argentina	Australia
Angola	Armenia	Andorra	Bahamas	Bolivia	Fiji
Benin	Azerbaijan	Austria	Barbados	Brazil	Kiribati
Botswana	Bahrain	Belarus	Belize	Chile	Marshall Islands
Burkina Faso	Bangladesh	Belgium	Canada	Colombia	Micronesia
Burundi	Bhutan	Bosnia and Herzegovina	Costa Rica	Ecuador	Nauru
Cabo Verde	Brunei Darussalam	Bulgaria	Cuba	Guyana	New Zealand
Cameroon	Cambodia	Croatia	Dominica	Paraguay	Palau
Central African Republic	China	Czech Republic	Dominican Republic	Peru	Papua New Guinea
Chad	Cyprus	Denmark	El Salvador	Suriname	Samoa
Comoros	Democratic People's Republic of Korea	Estonia	Grenada	Uruguay	Solomon Islands
Congo	Georgia	Finland	Guatemala	Venezuela	Tonga
Côte d'Ivoire	India	France	Haiti		Tuvalu
Democratic Republic of the Congo	Indonesia	Germany	Honduras		Vanuatu
Djibouti	Iran	Greece	Jamaica		
Egypt	Iraq	Holy See	Mexico		
Equatorial Guinea	Israel	Hungary	Nicaragua		
Eritrea	Japan	Iceland	Panama		
Eswatini	Jordan	Ireland	Saint Kitts and Nevis		
Ethiopia	Kazakhstan	Italy	Saint Lucia		
Gabon	Kuwait	Latvia	Saint Vincent and the Grenadines		
Gambia	Kyrgyzstan	Liechtenstein	Trinidad and Tobago		
Ghana	Lao People's Democratic Republic	Lithuania	United States of America		
Guinea	Lebanon	Luxembourg			
Guinea-Bissau	Malaysia	Malta			
Kenya	Maldives	Monaco			
Lesotho	Mongolia	Montenegro			
Liberia	Myanmar	Netherlands			
Libya	Nepal	North Macedonia			
Madagascar	Oman	Norway			
Malawi	Pakistan	Poland			
Mali	Philippines	Portugal			
Mauritania	Qatar	Republic of Moldova			
Mauritius	Republic of Korea	Romania			
Morocco	Saudi Arabia	Russian Federation			
Mozambique	Singapore	San Marino			
Namibia	Sri Lanka	Serbia			
Niger	State of Palestine	Slovakia			
Nigeria	Syrian Arab Republic	Slovenia			
Rwanda	Tajikistan	Spain			
Sao Tome and Principe	Thailand	Sweden			
Senegal	Timor-Leste	Switzerland			
Seychelles	Turkey	Ukraine			
Sierra Leone	Turkmenistan	United Kingdom of Great Britain and Northern Ireland			
Somalia	United Arab Emirates				
South Africa	Uzbekistan				
South Sudan	Viet Nam				
Sudan	Yemen				
Togo					
Tunisia					
Uganda					
United Republic of Tanzania					
Zambia					
Zimbabwe					

The most comprehensive recreational fishing variable was whether recreational fishing was allowed, which was reported for 59 % of all countries containing IUCN II parks (80/137 countries); Africa (19 countries), Asia (17 countries), Europe (24 countries), North America (12 countries), South America (4 countries) and Oceania (4 countries; Fig. 1). Countries allowing recreational fishing in their nationally designated IUCN II parks were more common (70 %; 56/80) than those explicitly forbidding (30 %; 24/80) recreational fishing. Recreational fishing was most commonly allowed in nationally designated IUCN II parks in countries in Europe (23/24 countries), Oceania (3/4 countries), South America (3/4 countries), North America (8/12 countries), Africa (12/19 countries), and Asia (7/17 countries). Recreational fishing was more commonly permitted in reporting countries with marine systems (30/31) than in reporting countries with freshwater systems (47/66). A total of 80 countries provided data for both freshwater and marine systems. Many of these countries allowed recreational fishing in both freshwater and marine ecosystems (21 countries), while recreational fishing was consistently not allowed in freshwater nor marine ecosystems in 16 countries. Only New Zealand allowed fishing in freshwater ecosystems, but not in marine ecosystems.

It was uncommon (11/80) for countries to have more than one approach implemented to manage recreational fisheries in their nationally designated IUCN II parks. Most (66/80) countries used a top-down approach, whereas co-management (11/80) and bottom-up approaches (4/80) were infrequent. Across all countries, area closures (24/24), seasonal closures (20/22), and licenses (38/44) were commonly reported recreational fishing regulations in nationally designated IUCN II parks, as were quotas (27/30), size limits (25/28), enforced catch-and-release (20/21), and effort control (7/10). In general, freshwater fisheries tended to have more regulations surrounding area closures, licenses, quotas, size limits, seasonal closures, and enforced catch-and-release than marine fisheries (Fig. 2). Gear restrictions varied across recreational fisheries in nationally designated IUCN II parks (n = 38). Across all countries, when recreational fishing was allowed and gear restrictions existed, hook-and-line was the most common gear type, and was allowed in all 38 countries. Other legal gear types were uncommon but included spear (5/38), net (4/38), trap (4/38), and gill net (2/38) with hand, trawl, and chemical all allowed in only 1 country each. Gear restrictions varied across freshwater and marine systems, with greater gear variety allowed in marine recreational fisheries (Fig. 3).

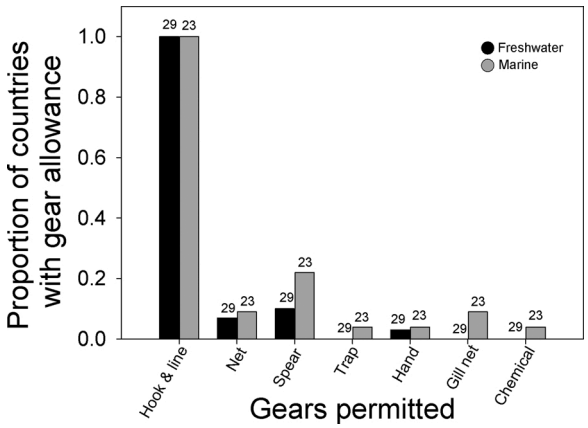

Fig. 2. Proportion of various regulations used in freshwater and marine recreational fisheries located within IUCN II parks worldwide. The number of reporting countries for each variable are indicated above respective bars.

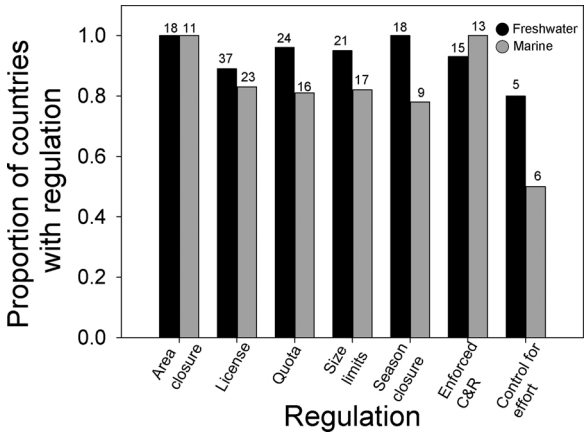

Fig. 3. Proportion of various gears permitted in freshwater and marine recreational fisheries located within IUCN II parks worldwide. The number of reporting countries for each variable are indicated above respective bars.

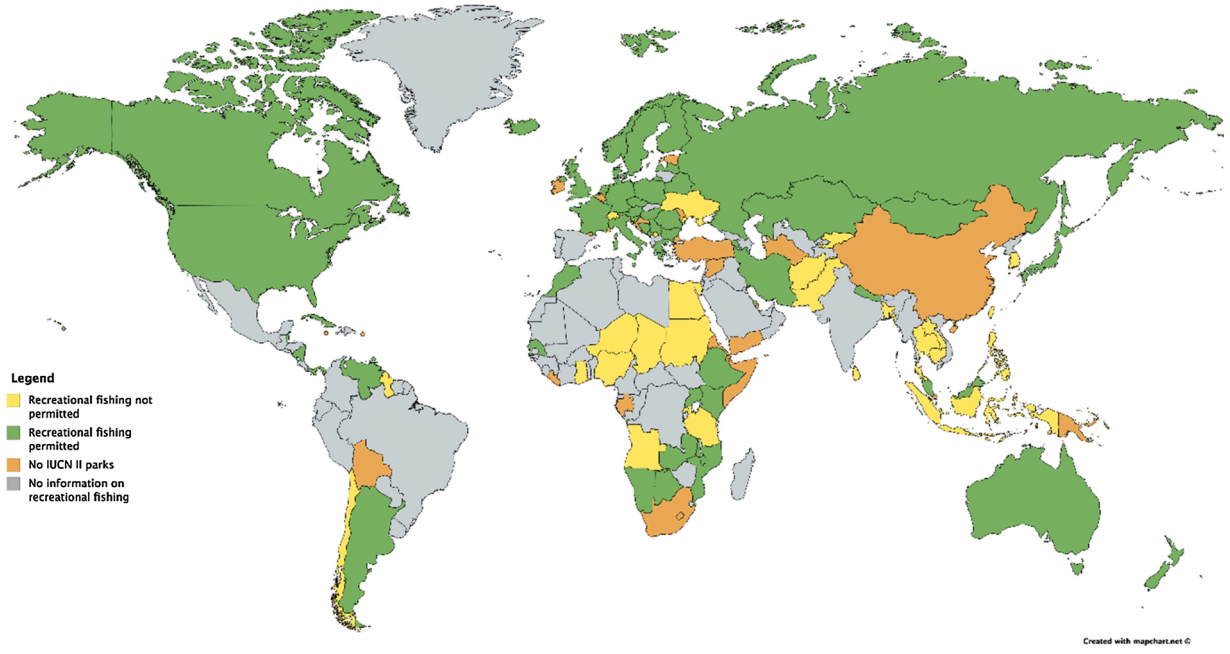

Fig. 1. Global distribution of IUCN type II parks and recreational fishing tendencies in 195 countries.

Reporting on stocking was uncommon, but where reported (n = 12), 9 countries reported stocking and 3 countries reported they did not stock their nationally designated IUCN II parks. When stocking was undertaken, 7 countries reported stocking recreational fisheries with native fish, and 2 countries reported stocking with introduced species. No countries reported stocking both native and introduced species. Stocking was more common in freshwater (9/12) than marine fisheries (1/4) in nationally designated IUCN II parks in reporting countries. Only Finland reported stocking fish in both freshwater and marine fisheries. Population monitoring occurred in most nationally designated IUCN II park recreational fisheries where information was reported (22/23), and governing authorities tended to actively encourage recreational fishing (17/23). There was little difference in population monitoring nor encouragement for recreational fishing between freshwater and marine fisheries.

4. Discussion

This review identified a considerable lack of information related to management and regulations associated with recreational fisheries in IUCN II parks. It is unclear whether this information is merely difficult to access, or simply does not exist, but regardless both scenarios present challenges for harmonizing management frameworks for national parks. It is also possible that there is a bias towards those jurisdictions that allow recreational fishing to have information on management accessible while those that forbid it (or where it is not a social/cultural norm in a given region) simply do not share information about recreational fishing on their websites. Barring these potential biases, this review identified that most countries allow recreational fishing within IUCN II parks, but with varying levels of regulations. Recreational fishing in national parks tended to be most common in Europe and North America which aligns with previous research showing that recreational fishing is more established in developed countries (discussed in Arlinghaus, Cyrus et al., 2015; Arlinghaus, Tillner et al., 2015). Freshwater and marine fisheries were often managed similarly, though generally freshwater fisheries had stronger regulations in place.

4.1. Recreational fisheries management and regulations in IUCN II parks

Management of recreational fisheries in IUCN II parks was generally undertaken using a top-down approach. Top-down approaches are most common in fisheries management, though there is increasing interest to move towards other forms of management such as co-management and bottom-up management (Arceo, Cazalet, Aliño, Mangialajo, & Francour, 2013; Trimble & Berkes, 2015). Given that most national parks are governed by national government agencies, it is not entirely surprising that co-management of recreational fisheries was uncommon. In some cases, however, multiple management approaches were in place. For example, in Australia, fisheries management in IUCN II parks was completed by national, sub-national, or collaborative government agencies (top-down), while other parks were managed by non-profit organizations, Indigenous communities, and individual landowners (i.e., bottom-up). This approach is similar to the approach used in Norway to manage salmon recreational fisheries (Stensland, 2010). While there are benefits to both top-down and bottom-up approaches, it is likely that a combined approach would be most effective (i.e., co-management; Gaymer et al., 2014), though it can be challenging to merge these methods (Jones, 2012).

There was large variation in the degree to which various regulatory measures were implemented in recreational fisheries within IUCN II parks. These measures have the goal of limiting both the type and number of fish taken by anglers (Johnson & Martinez, 1995). Area closures were the most common regulation, indicating that certain portions of parks tend to prohibit angling, while allowing other parts to be exploited. Area closures can lead to increased fish abundance by reducing fishing effort in a localized area, but often this fishing effort is displaced to the boundaries of these areas with mixed outcomes for both the fish and fishery (Kellner, Tetreault, Gaines, & Nisbet, 2007). Seasonal closures were also a commonly used regulatory measure across IUCN II parks. Seasonal closures restrict fishing at times when fish species may be in a more vulnerable life stage such as spawning, potentially increasing population abundance (e.g. Gwinn & Allen, 2010). However, seasonal closures also impact non-fish taxa; reductions in seabird by-catch and benthic invertebrate biomass have been identified in response to seasonally-altered fishing regulations (Croxall, 2008; Dinmore, Duplisea, Rackham, Maxwell, & Jennings, 2003).

Licenses were another commonly implemented management measure in IUCN II parks, which offer several potential benefits, including knowledge on the number of legal anglers as well as an opportunity to engage directly with anglers at point of sale (e.g., to provide information on best practices). Additionally, selling licenses may serve as a source of income for parks. However, the value of licensing systems depends heavily on the corresponding compliance or enforcements strategies used in a given area (Keane, Jones, Edwards-Jones, & Milner-Gulland, 2008). Quota restrictions (i.e., bag limits) and size limits were also widespread in IUCN parks. These types of regulations are commonly used in recreational fisheries management to limit the number of fish taken by a fisher and to protect fish at certain life-history stages (e.g. salmon fisheries in Norway; Lennox, Falkegård, Vøllestad, Cooke, & Thorstad, 2016), though this approach of selective harvesting can lead to undesirable effects at the population level (Garcia et al., 2012). Most IUCN II parks enforced catch-and-release which is typically regarded as a means of reducing rather than eliminating fishing mortality (Cooke et al., 2006). Reducing incidental catch-and-release mortality can be achieved by adhering to 'best practices' that can reduce sublethal impacts and mortality (Brownscombe, Danylchuk, Chapman, Gutowsky, & Cooke, 2017). These practices should be encouraged where fishing is permitted in IUCN II parks.

Gear restrictions for recreational fisheries were common in IUCN II parks. Hook-and-line was the most commonly permitted gear in IUCN II parks which is consistent with global perspectives on recreational fisheries gear use (Cooke et al., 2018). The use of hook-and-line angling also corresponds to the large amount of catch-and-release only fishing, as few other gear types are associated with catching and releasing fish. Furthermore, hook-and-line fishing can be fairly selective of the species that are captured (Lennox et al., 2017), potentially reducing capture of non-target and potentially protected species. Gears such as nets may be less selective of certain species and can capture larger quantities of fish (Glass, 2000), though these gears were not commonly allowed in national parks, although technically they can be deployed in a recreational context (FAO, 2012). Furthermore, hook-and-line gear typically requires the fisher to actively operate the gear (compared to passive methods that can be left alone), which may make monitoring and enforcement of fishing effort throughout the park more feasible and effective. We did not assess limits to fishing vessels because they are also used for other purposes but it is worth noting that noise and disturbance associated with combustion motors may not align with park objectives such that regulations on vessel type are reasonably common (Graham & Cooke, 2008; Jacobsen et al., 2014).

4.2. Promotion of angling

Overall, most management authorities allowing recreational fishing tended to encourage recreational fishing within IUCN II parks (e.g. through web pages or free fishing events). Encouraging angling within national parks may be a means to increase the number of people visiting the park, contributing to park revenue and overall tourism (Ditton, Holland, & Anderson, 2002). We did not assess the extent to which angling promotion was coupled with attempts to educate anglers about strategies to minimize the potential negative effects of recreational fishing. Stocking was implemented in approximately half of all IUCN II parks with available information, likely as a means to promote

recreational fishing opportunities (Knapp, Corn, & Schindler, 2001). Native fish were most frequently stocked, reducing the likelihood of detrimental effects to the aquatic community compared to non-native species. Consequences of stocking introduced fishes are well known, including the loss of reproductive fitness (Milot, Perrier, Papillon, Dodson, & Bernatchez, 2013; Philipp & Claussen, 1995), loss of genetic diversity (Araki & Schmid, 2010), introduction of pathogens, and low survival rates of native fishes. However, there are still countries that stock introduced species, likely to create familiar recreational fisheries in areas that may not have popular gamefish (Ellender, Woodford, Weyl, & Cowx, 2014). Population monitoring was also undertaken in most IUCN II parks with recreational fisheries (where information was available) which we regard as promising as this will presumably ensure that park managers can respond quickly to population declines or changes in community structure (Post et al., 2002). We did not quantify the extent to which fish populations are monitored outside of national parks but in general assessment of freshwater (Lorenzen et al., 2016) and marine (Leslie & McLeod, 2007) fish populations is lacking aside from some notable exceptions (e.g., commercially exploited species).

4.3. Limitations and research needs

Several factors may have limited the quantity of data retrieved during our search, both related to the method of search and existence of the information. For some countries, information was not available in English and had to be translated from its original language. In some cases, translations were garbled and incomprehensible, decreasing our ability to extract information. Moreover, use of search terms to find relevant information on non-English sites was inherently challenging. In other instances, the information was only partly available online, and further details were only provided to visitors physically present at a designated location at the national park. An example of this is the Djerdap (or Derdap) National Park in Serbia where the web materials directed anglers to the entrance booth for information on recreational fishing (Turizam, 2016). We also acknowledge that while our study identified considerable regulatory measures were in place for recreational fisheries in most parks, the availability of information online may have been biased to those countries with more regulations in place. For analytical purposes, we took a conservative approach and made no assumptions when no information could be found online about a given characteristic for a recreational fishery in a nationally-designated IUCN II park. That said, it seems likely that a lack of information or reporting online most likely means that regulation, gear type, or activity is not in place or permitted. In reality, the incidence of various fishing regulations, gear permissions, as well as stocking or monitoring efforts, is likely lower than that reported here. On the other hand, some countries may have regulations in place and simply did not have that information readily available online. That being noted, we also recognize that in many countries (especially low and middle income ones), recreational fisheries are simply not on the policy agenda given that most fishing that occurs is inherently for subsistence and that feeding people is inherently more important than fishing for fun (Cooke et al., 2018). In that context, and given that there over 140 low and middle income countries, it is quite remarkable that we were able to obtain data from as many countries as we did. Building capacity for recreational fisheries science and management in low and middle income countries remains a high priority for the recreational fisheries community (Holder et al., 2020).

This study has demonstrated the need for a universal, harmonized system for tracking recreational fishing policy worldwide in national parks. Though not necessarily readily comparable across countries and cultures, a database would allow researchers to properly assess similarities and differences in management approaches under different circumstances, as well as potential strengths and weaknesses in recreational fishing policies between countries and national parks. Gaining access to this type of information would not only be extremely valuable for researchers, but also for policy-makers who may benefit from having first-hand access to accurate and comprehensive global data surrounding the use of national parks. Although our analysis has limitations, it does provide park managers with insight into the range of tools used in managing recreational fisheries within national parks. This should lead to opportunities for sharing successes and failures across jurisdictions which is an important mechanism to improve recreational fisheries management (Cooke et al., 2019).

Declaration of Competing Interest

The authors report no declarations of interest.

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References

Acreman, M., Hughes, K. A., Arthington, A. H., Tickner, D., & Dueñas, M. A. (2019). Protected areas and freshwater biodiversity: A novel systematic review distils eight lessons for effective conservation. *Conservation Letters*, Article e12684.

Agardy, T., Bridgewater, P., Crosby, M. P., Day, J., Dayton, P. K., Kenchington, R., et al. (2003). Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems, 13*(353-), 367.

Araki, H., & Schmid, C. (2010). Is hatchery stocking a help or harm?: Evidence, limitations and future directions in ecological and genetic surveys. *Aquaculture, 308*, S2–S11.

Arceo, H. O., Cazalet, B., Aliño, P. M., Mangialajo, L., & Francour, P. (2013). Moving beyond a top-down fisheries management approach in the northwestern Mediterranean: Some lessons from the Philippines. *Marine Policy, 39*, 29–42.

Arlinghaus, R., Cyrus, E.-M., Eschbach, E., Fujitani, M., Hühn, D., Johnston, F., et al. (2015). Hand in Hand für eine nachhaltige Angelfischerei: Ergebnisse und Empfehlungen aus fünf Jahren praxisorientierter Forschung zu Fischbesatz und seinen Alternativen. *Berichte des IGB, 28*, 200.

Arlinghaus, R., Tillner, R., & Bork, M. (2015). Explaining participation rates in recreational fishing across industrialised countries. *Fisheries Management and Ecology, 22*(1), 45–55.

Bartholomew, A., & Bohnsack, J. A. (2005). A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries, 15*, 129–154.

Brenkman, S. J., Dude, J. J., Kennedy, P. J., & Baker, B. M. (2014). A legacy of divergent fishery management regimes and the resilience of Rainbow and Cutthroat Trout populations in Lake Crescent, Olympic National Park, Washington. *Northwest Science, 88*(4), 280–304.

Brownscombe, J. W., Danylchuk, A. J., Chapman, J. M., Gutowsky, L. F., & Cooke, S. J. (2017). Best practices for catch-and-release recreational fisheries–angling tools and tactics. *Fisheries Research, 186*, 693–705.

Cooke, S. J., & Cowx, I. G. (2004). The role of recreational fisheries in global fish crises. *BioScience, 54*, 857–859.

Cooke, S. J., & Cowx, I. G. (2006). Contrasting recreational and commercial fishing: Searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation, 128*, 93–108.

Cooke, S. J., Danylchuk, A. J., Danylchuk, S. E., Suski, C. D., & Goldberg, T. L. (2006). Is catch- and- release recreational angling compatible with no- take marine protected areas? *Ocean and Coastal Management, 49*, 342–354.

Cooke, S. J., Twardek, W. M., Lennox, R. J., Zolderdo, A. J., Bower, S. D., Gutowsky, L. F., et al. (2018). The nexus of fun and nutrition: Recreational fishing is also about food. *Fish and Fisheries, 19*(2), 201–224.

Cooke, S. J., Twardek, W. M., Reid, A. J., Lennox, R. J., Danylchuk, S. C., Brownscombe, J. W., Bower, S. D., Arlinghaus, R., Hyder, K., & Danylchuk, A. J. (2019). Searching for responsible and sustainable recreational fisheries in the Anthropocene. *Journal of Fish Biology, 94*, 845–856.

Cowley, P. D., Brouwer, S. L., & Tilney, R. L. (2002). The role of Tsitsikamma National Park in the management of four- angling fish along the South-eastern cape coast of South Africa. *South African Journal of Marine Science, 24*(27-), 35.

Cowx, I. G., Arlinghaus, R., & Cooke, S. J. (2010). Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. *Journal of Fish Biology, 76*, 2194–2215.

Croxall, J. P. (2008). The role of science and advocacy in the conservation of Southern Ocean albatrosses at sea. *Bird Conservation International, 18*, S13–S29.

Danylchuk, A. J., & Cooke, S. J. (2011). Engaging the recreational angling community to implement and manage aquatic protected areas. *Conservation Biology, 25*(3), 458–464.

Dinmore, T. A., Duplisea, D. E., Rackham, B. D., Maxwell, D. L., & Jennings, S. (2003). Impact of a large-scale area closure on patterns of fishing disturbance and the

consequences for benthic communities. *ICES Journal of Marine Science, 60*(2), 371–380.
Ditton, R. B., Holland, S. M., & Anderson, D. K. (2002). Recreational fishing as tourism. *Fisheries, 27*(3), 17–24.
Dudley, N. (Ed.). (2008). *Guidelines for applying protected area management categories*. Gland, Switzerland: IUCN. WITH Stolton, S., P. Shadie and N. Dudley (2013). IUCN WCPA Best Practice Guidance on Recognizing Protected Areas and Assigning Management Categories and Governance Types, Best Practice Protected Area Guidelines Series No. 21, Gland, Switzerland: IUCN.
Ellender, B. R., Woodford, D. J., Weyl, O. L. F., & Cowx, I. G. (2014). Managing conflicts arising from fisheries enhancements based on non-native fishes in southern Africa. *Journal of Fish Biology, 85*(6), 1890–1906.
Embke, H. S., Rypel, A. L., Carpenter, S. R., Sass, G. G., Ogle, D., Cichosz, T., et al. (2019). Production dynamics reveal hidden overharvest of inland recreational fisheries. *Proceedings of the National Academy of Sciences, 116*(49), 24676–24681.
FAO. (2012). *Recreational fisheries. Technical guidelines for responsible fisheries*. No. 13 (p. 176). Rome: FAO.
Filous, A., Friedlander, A., Wolfe, B., Stamoulis, K., Scherrer, S., Wong, A., et al. (2017). Movement patterns of reef predators in a small isolated marine protected area with implications for resource management. *Marine Biology, 164*(1), 2.
Garcia, S. M., Kolding, J., Rice, J., Rochet, M. J., Zhou, S., Arimoto, T., et al. (2012). Reconsidering the consequences of selective fisheries. *Science, 335*(6072), 1045–1047.
Gaymer, C. F., Stadel, A. V., Ban, N. C., Cárcamo, P. F., Ierna, J., Jr., & Lieberknecht, L. M. (2014). Merging top-down and bottom-up approaches in marine protected areas planning: Experiences from around the globe. *Aquatic Conservation: Marine and Freshwater Ecosystems, 24*(S2), 128–144.
Glass, C. W. (2000). Conservation of fish stocks through bycatch reduction: A review. *Northeastern Naturalist, 7*(4), 395–411.
Graham, A. L., & Cooke, S. J. (2008). The effects of noise disturbance from various recreational boating activities common to inland waters on the cardiac physiology of a freshwater fish, the largemouth bass (*Micropterus salmoides*). *Aquatic Conservation: Marine and Freshwater Ecosystems, 18*(7), 1315–1324.
Granek, E. F., Madin, E. M., Brown, M. A., Figueira, W., Cameron, D. S., Hogan, Z., et al. (2008). Engaging recreational fishers in management and conservation: Global case studies. *Conservation Biology, 22*(5), 1125–1134.
Gwinn, D. C., & Allen, M. S. (2010). Exploring population-level effects of fishery closures during spawning: An example using largemouth bass. *Transactions of the American Fisheries Society, 139*(2), 626–634.
Holder, P. E., Jeanson, A. L., Lennox, R. J., Brownscombe, J. W., Arlinghaus, R., Danylchuk, A. J., et al. (2020). Preparing for a changing future in recreational fisheries: 100 research questions for global consideration emerging from a horizon scan. *Reviews in Fish Biology and Fisheries, 30*, 137–151.
Ihde, J. F., Wilberg, M. J., Loewensteiner, D. A., Secor, D. H., & Miller, T. J. (2011). The increasing importance of marine recreational fishing in the US: Challenges for management. *Fisheries Research, 108*, 268–276.
Jacobsen, L., Baktoft, H., Jepsen, N., Aarestrup, K., Berg, S., & Skov, C. (2014). Effect of boat noise and angling on lake fish behaviour. *Journal of Fish Biology, 84*(6), 1768–1780.
Johnson, B. M., & Martinez, P. J. (1995). Selecting harvest regulations for recreational fisheries: Opportunities for research/management cooperation. *Fisheries, 20*(10), 22–29.
Johnson, B. M., Arlinghaus, R., & Martinez, P. J. (2009). Are we doing all we can to stem the tide of illegal fish stocking? *Fisheries, 34*(8), 389–394.
Jones, P. J. (2012). Marine protected areas in the UK: Challenges in combining top-down and bottom-up approaches to governance. *Environmental Conservation, 39*(3), 248–258.
Keane, A., Jones, J. P., Edwards-Jones, G., & Milner-Gulland, E. J. (2008). The sleeping policeman: Understanding issues of enforcement and compliance in conservation. *Animal Conservation, 11*(2), 75–82.
Kellner, J. B., Tetreault, I., Gaines, S. D., & Nisbet, R. M. (2007). Fishing the line near marine reserves in single and multispecies fisheries. *Ecological Applications, 17*(4), 1039–1054.
Knapp, R. A., Corn, P. S., & Schindler, D. E. (2001). The introduction of nonnative fish into wilderness lakes: Good intentions, conflicting mandates, and unintended consequences. *Ecosystems, 4*, 275–278.
Lennox, R. J., Alós, J., Arlinghaus, R., Horodysky, A., Klefoth, T., Monk, C. T., et al. (2017). What makes fish vulnerable to capture by hooks? A conceptual framework and a review of key determinants. *Fish and Fisheries, 18*(5), 986–1010.
Lennox, R. J., Falkegård, M., Vøllestad, L. A., Cooke, S. J., & Thorstad, E. B. (2016). Influence of harvest restrictions on angler release behaviour and size selection in a recreational fishery. *Journal of Environmental Management, 176*, 139–148.
Leslie, H. M., & McLeod, K. L. (2007). Confronting the challenges of implementing marine ecosystem-based management. *Frontiers in Ecology and the Environment, 5*(10), 540–548.
Lewin, W. C., Arlinghaus, R., & Mehner, T. (2006). Documented and potential biological impacts of recreational fishing: Insights for management and conservation. *Reviews in Fisheries Science, 14*(4), 305–367.
Lorenzen, K., Cowx, I. G., Entsua-Mensah, R. E. M., Lester, N. P., Koehn, J. D., Randall, R. G., et al. (2016). Stock assessment in inland fisheries: A foundation for sustainable use and conservation. *Reviews in Fish Biology and Fisheries, 26*, 405–440.
Milot, E., Perrier, C., Papillon, L., Dodson, J. J., & Bernatchez, L. (2013). Reduced fitness of Atlantic salmon released in the wild after one generation of captive breeding. *Evolutionary Applications, 6*(3), 472–485.
Mora, C., Myers, R. A., Cool, M., Libralato, S., Pitcher, T. J., Sumaila, R. U., et al. (2009). Management effectiveness of the world's marine fisheries. *PLoS Biology, 7*(6).
Pawson, M. G., Glenn, H., & Padda, G. (2008). The definition of marine recreational fishing in Europe. *Fisheries Research, 32*, 339–350.
Philipp, D. P., & Claussen, J. E. (1995). Fitness and performance differences between two stocks of largemouth bass from different river drainages within Illinois. *American Fisheries Society Symposium, 15*, 236–243.
Post, J. R., Sullivan, M., Cox, S., Lester, N. P., Walters, C. J., Parkinson, E. A., et al. (2002). Canada's recreational fisheries: The invisible collapse? *Fisheries, 27*, 6–17.
Saunders, D. L., Meeuwig, J. J., & Vincent, A. C. J. (2002). Freshwater protected areas: Strategies for conservation. *Conservation Biology, 16*(1), 30–41.
Schindler, D. W. (2000). Aquatic problems caused by human activities in Banff National Park, Alberta, Canada. *AMBIO: A Journal of the Human Environment, 29*(7), 401–407.
Stensland, S. (2010). Fishing rights and supply of salmon angling tourism in Mid-Norway. *Scandinavian Journal of Hospitality and Tourism, 10*(3), 207–230.
Trimble, M., & Berkes, F. (2015). Towards adaptive co-management of small-scale fisheries in Uruguay and Brazil: Lessons from using Ostrom's design principles. *Maritime Studies, 14*(1), 14.
Turizam. (2016). *Fishing areas*. Derdap National Park. http://www.turizam.npdjerdap.org/?page_id=55&fbclid=IwAR3jKqctZJnowMR_9wHB0mmXk3HbhBD9cX16qd9FC_7qnqAwlSQlJ_qbuqE&lang=en.
UNEP-WCMC. (2017). *World database on protected areas user manual 1.5* [online]: Available at: UNEP-WCMC http://wcmc.io/WDPA_Manual.
Venturini, S., Campodonico, P., Cappanera, V., Fanciulli, G., & Cattaneo Vietti, R. (2017). Recreational fisheries in Portofino Marine Protected Area, Italy: Some implications for management. *Fisheries Management and Ecology, 24*(382-), 391.
World Bank. (2012). *Hidden Harvest: The global contribution of capture fisheries. Report # 66469-GLB* (p. 69). Washington, D.C., USA: World Bank.