Assessment gaps and biases in knowledge of conservation status of fishes

Gaps assessment in fishes

Imanol Miqueleiz[I], Monika Bohm[2], Arturo Hugo Ariño [I] & Rafael Miranda[I]

[I]University of Navarra, School of Sciences, Department of Environmental Biology, Biodiversity Data Analytics and Environmental Quality Group, Irunlarrea 1, E-31008 Pamplona, Navarra, Spain.

[2]Institute of Zoology, Zoological Society of London, London, UK.

Correspondence

Imanol Miqueleiz. University of Navarra, School of Sciences, Department of Environmental Biology, Irunlarrea 1, E-31008 Pamplona, Navarra, Spain. E-mail: imiqueleiz@alumni.unav.es

Abstract

1. More than 33,500 fish species inhabit freshwater and marine environments, according to FishBase database records. The International Union for the Conservation of Nature (IUCN) has assessed the conservation status of approximately half of them, the lowest percentage in any vertebrate group.
2. In order to identify what factors may underlie this assessment gap, we examined several traits related to distribution, life-history, taxonomy, conservation, and the economic relevance of species according to their assessment status. We explored IUCN assessment patterns and included separate analyses for freshwater and marine species.
3. Our results showed that IUCN assessments were biased towards economically developed regions, species with early description dates and species covered by current IUCN specialist groups. Species living in remote areas or habitats were more likely to be unassessed. In particular, South America had low assessment levels. Other traits such as commercial importance did not influence the assessment status of fish species.
4. We therefore encourage assessment in poorly assessed areas and taxonomic subgroups to prompt timely conservation action to prevent species extinctions.

Keywords

Distribution patterns, extinction risk, IUCN Red List, freshwater realm, marine realm, threatened species.

1. Introduction

Throughout the earth's history, aquatic ecosystems have formed both a mosaic and a continuum of habitats ranging from the freshwater springs, rivers, lakes and wetlands of continents and islands to estuaries, shallow coastal habitats, reefs and the seas (Arthington, Dulvy, Gladstone, & Winfield, 2016). Fishes are one of the world's most important natural resources, as they provide humans with various ecosystem services (Olden, Hogan, & Zanden, 2007), contributing to health, well-being, cultural identity and economies of societies (Hughes, 2014). With more than 33,500 species currently described, fishes constitute an important part of the biomass of aquatic ecosystems (Jennings et al., 2008), with slightly more fish species in freshwater than marine ecosystems (Carrete Vega & Wiens, 2012; Fricke, Eschmeyer, & Van der Laan, 2019). However, population declines, mainly caused by habitat loss and degradation, invasive species, overexploitation, pollution and climate change (Dudgeon et al., 2006), are increasing the risk of global or local extinctions of species (Darwall & Freyhof, 2016). Over the current century, marine and freshwater organisms will face a suite of environmental conditions that have no analogue in human history (Garcia-Moreno et al., 2014; Harnik et al., 2012).

Fish continue being described at very high rates, with about 3900 new species described between 2005-2014 (Nelson, Grande, & Wilson, 2016). The most comprehensive database on fish species is FishBase (Froese & Pauly, 2016), which provides information about species distributions, taxonomy and biological traits and indices for species, However, this database does not provide an estimation of species' extinction risk (Miranda, 2017). To evaluate a species' extinction risk, and assess its current, past and future threats, we need to access the reference guide on extinction risk over the last 50 years (Rodrigues, Pilgrim, Lamoreux, Hoffmann, & Brooks, 2006), the IUCN Red List of Threatened Species (IUCN, 2017). Having failed to reduce the rate of biodiversity loss by 2010 (S. H. M. Butchart et al., 2010), the Convention on Biological Diversity determined that during the past decade there was insufficient policy-specific scientific information to aid the decision-making process (Costelloe et al., 2016). Given the global threat to a large proportion of species (Pimm et al., 2014), the IUCN Red List and the Red List Index (Stuart H. M. Butchart et al., 2004) are essential indicators to track progress towards meeting Aichi Biodiversity Target 12: that "by 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained" (SCBD, 2010). In addition, the IUCN Red List directly inputs in a number of conservation and policy instruments, such as the development of Key Biodiversity Areas (KBAs; Langhammer et al., 2007), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Rodrigues et al., 2006) and dissemination of biodiversity and threat information to researchers, conservation planners and business as an environmental impact tool.

Several specialist groups and assessment projects exist under the umbrella of the IUCN's Species Survival Commission (SSC), such as the Marine's Biodiversity Unit's Global Marine Species Assessment (GMSA), several marine fish Specialist Groups and the Freshwater Fish Specialist Group (FFSG), which have so far assessed the extinction risk of half of all known fish species (IUCN, 2017). This is much lower than assessment levels in other vertebrate groups (e.g. almost 99% in mammals and birds) (Meiri & Chapple, 2016), although fish are far richer (e.g. six times the number of mammal species and three times the number of birds). Knowledge of aquatic biodiversity is also lower than that of terrestrial groups due to bias in conservation research toward charismatic terrestrial species (Darwall, Holland, et al., 2011). Assessment processes are currently struggling to catch up with fish discovery rate, resulting in an incomplete knowledge of fish biogeography, population density and threats (Arthington et al., 2016).

In addition, many fish species have cryptic or remote distributions, such as tropical freshwater fishes (Alofs, Liverpool, Taphorn, Bernard, & López-Fernández, 2014), thus lacking sufficient information to assess their extinction risk. An additional consequence of this knowledge gap is the high number of species assessed as Data Deficient (DD). Data deficiency may be caused by a lack of information on population status and trends, outdated information or because a species is known only from the type specimen (Bland & Böhm, 2016). With over 20% of fish species on the IUCN Red List currently classified as DD, there is a dangerous misrepresentation of risk levels in this group and overlooking many species in conservation efforts (Morais et al., 2013) even though they may actually require them. In a context of limited resources and funding for species assessments (with half of it coming from philanthropic sources) (Juffe-Bignoli et al., 2016), many species remain unassessed by IUCN. However, the affordability of assessments when considered at a global scale has been demonstrated (Juffe-Bignoli et al., 2016; Turak et al., 2016) and constitutes a best-value knowledge product into which money should be invested.

Considering that only half of all fish species are assessed, how representative of the broader fish fauna is this subset of assessed species? Complex reasons may account for certain species being systematically overlooked while others are more likely to be assessed. Species presumed to be at high risk of extinction may be assessed first, such as species with small range size, which is one of the main criteria used by IUCN to establish a risk category for a species (Meiri & Chapple, 2016). Other traits like short generation times and small body size associated with fast life histories, should enable species to increase their resilience from the effects of human activities, thereby reducing their extinction risk according to ecological theory (Olden et al., 2007) and becoming less prone to assessments. However, assessment exercises are often driven by funding availability and are often first applied to better-known regions or specific taxa (Bland et al., 2017; Tapley et al., 2018). This will leave some areas or species unevaluated and introduce potential geographical and taxonomic biases. Olden et al. (2007) reported that as larger marine species face higher rates of extinction, they might be likely better evaluated than smaller ones. Knowledge about these biases in assessed species traits may steer conservation and funding decisions, and therefore help focus efforts towards the taxa and regions that are in the greatest need of investigation and determination of their conservation status (Meiri & Chapple, 2016).

Here we assess whether distributional, ecological, life history or taxonomic biases exist in IUCN assessments of marine and freshwater fishes. We hypothesise that higher assessment rates will be found for (1) species inhabiting developed regions with high levels of research activity (*i.e.* Europe, North America, Mediterranean region); (2) larger species in the marine environment because of higher perceived extinction risk (Olden et al., 2007); and (3) species that are easier to study (e.g., large, long-lived), have commercial importance, are considered more vulnerable to threats, and have been longer known (i.e. described earlier). The results should serve as a guide to research efforts, conservation planning and funding to improve the knowledge of species and areas that are in the highest need for research and assessment of their conservation status.

2. Methods

In this study the 2016 version of FishBase was analysed (Froese & Pauly, 2016). This database, a reference tool for fish study, includes information about the extinction risk of the species on the IUCN Red List. The status of the species was updated, where possible, as per the latest IUCN Red List classifications (IUCN, 2017). Old Red List categories were translated into current categories following the latest IUCN standards (IUCN, 2012): therefore, LR/nt was renamed as Near Threatened, NT; LR/lc as Least Concern, LC; and LR/cd was merged into NT. Analyses were performed on the five classes of fishes (Actinopterygii, Chondrichthyes, Myxini, Petromyzontida and Sarcopterygii) as recognised by FishBase.

Data on fish traits and other species information were collected from FishBase and grouped into the following five categories: 1) distributional traits, 2) life history traits, 3) vulnerability index, 4) taxonomic traits, and 5) commercial importance. In terms of distributional traits, the presence of species in each FAO Major Fishing Area (henceforth FAO area) was collected. Preferred habitat for each species was recorded as assigned in FishBase (bathydemersal, bathypelagic, benthopelagic, demersal, pelagic, pelagic-oceanic, pelagic-neritic and reef associated). For life-history traits, there were considered: maximum length (in mm) of the longest individual recorded for the species; maximum weight (in g) recorded for the species; longevity (oldest age recorded for the species); and generation time (time period from birth to average age of reproduction for the species). The vulnerability index (Cheung, Pitcher, & Pauly, 2005), originally developed for marine fishes but now applied to all species in FishBase, is used to establish the vulnerability of a species to fishing pressure. Three relevant taxonomic traits were considered: The phylogenetic index (Faith, Reid, & Hunter, 2004), that uses phylogenetic patterns of evolutionary diversification to predict feature diversity of sets of species, is calculated as a sum of phylogenetic differences present in an assemblage (Tucker et al., 2016) and takes values ranging from 0.5 (low uniqueness of the species) to 2.0 (high uniqueness) (Froese & Pauly, 2016) to check whether the phylogenetic uniqueness of a species could be a trait driving IUCN Red Lists assessments. Secondly fish order according to FishBase to see if there were certain orders which could be potentially over or under-represented in Red List assessments. Finally, in the case of the year of description (based on species authorship), it was assumed that more-recently described species were less susceptible of being assessed than previously described species. FishBase commercial importance reflects whether the species is regularly targeted by fisheries or regularly found in aquaculture activities.

FishBase did not contain data on all of the above traits for all species (Table 1). Rather than inferring data from similar species, species without direct data for a specific trait were classed as non-available (NA) for this trait. Our data were analysed across three groups of species: 1) all species present in FishBase (including species both assessed and non-assessed by IUCN, hereafter referred to as the full dataset), 2) species assessed by the IUCN and included in the IUCN Red List, and 3) species assessed by the IUCN excluding those classified as Data Deficient (DD). Analyses were performed separately for freshwater and marine fish.

We firstly did multiple logistic regression models (glm with binomial errors) where the status of IUCN Red List assessment ("no" or "yes") was the response variable. Sample sizes for different variables were very unequal (Table 1). Only those variables for which data were available for >85% of species were used as predictors: Habitat, length, Vulnerability Index, Phylogenetic Index, description year and order. In these analyses, there were not considered body mass, tightly correlated to length (Froese, Tsikliras, & Stergiou, 2011), longevity and generation time (due to the insufficient percentage of species having data for these traits).

Then differences in assessment were tested (assessed vs. non-assessed) between the three groups through chi-square tests for analyses of frequencies (*e.g.* number of assessed species in the FAO areas, commercial or non-commercial species and orders) and Wilcoxon rank sum test with continuity correction (due to non-normal distributions of the variables) for the numeric data (*e.g.* length, weight, description year), with log transformations for length and weight. All statistical analyses were performed with R software version 3.3.3 (R Development Core Team, 2019). Each trait was analysed twice to identify biases: full dataset vs. assessed species (comparison 1) and assessed vs. assessed non-DD species (comparison 2).

As assessment levels vary across vertebrate groups, with fish potentially being among the least assessed (Hermoso et al., 2017), it was tested whether there was a decline in assessment level over time. The year of species description for fish were contrasted with that from other vertebrate groups (Amphibians, Reptiles, Birds and Mammals) obtained from Catalogue of Life (http://www.catalogueoflife.org/), distinguishing between non-assessed, assessed-DD and non-DD by year to analyse how IUCN evaluations changed with time.

3. Results

The IUCN has assessed 15,029 fish species (7,984 freshwater and 7,457 marine), which is 46% of the species listed in FishBase. Different FAO areas had varying proportions of species assessed, both when comparing all evaluated species and when excluding species assessed as DD (Table 2). South America (19% of species assessed) and Antarctic Ocean (12%-24 % depending on the FAO Area) had the lowest level of assessment, followed by the Arctic and the Pacific Ocean, (Fig. 1, Supporting Information). The Atlantic Ocean (including the Mediterranean and the Black Sea) was the best-assessed area in the marine realm, while Africa and Europe had the highest levels of assessment among inland areas; however, Africa had a higher proportion of DD-species than Europe. Both the Indian and Pacific Oceans remained relatively poorly assessed (24%-40% and 12%-62% respectively). The proportion of species assessed differed significantly among habitats, in both comparisons (Table 2). Bathydemersal and bathypelagic habitats were least assessed, while reef associated-habitats were the best-evaluated habitats and with a relatively low proportion of DD-species. In contrast, in bathydemersal habitats, the proportion of species assessed was reduced from 32% to 18% assessment if DD-species were excluded (Supporting Information).

Commercial importance differed in both comparisons (Table 2): commercial species were not the best-assessed ones, despite having the biggest number of assessed species. Even excluding DD species, species of minor commercial interest were better assessed than other species (56% vs 52%) (Supporting Information).

Regarding biological traits, assessed species tended to be larger than the average of the full dataset (Table 3). Heavier species were better assessed in marine habitats when analysing total and assessed species, but not in the assessed vs non-DD comparison; weight was a non-significant factor for freshwater fish. Assessed species had shorter lifespans when compared to the full species set (marine and freshwater combined), but this difference was not observed when analysing freshwater and marine species separately. Assessed species had longer generation times (Table 3), but this could not be seen in the comparison between assessed and non-DD species in the freshwater environments.

Assessed species had higher vulnerability indices in both freshwater and marine environments (Table 3), with no difference in vulnerability indices when comparing assessed and non-DD species. In terms of taxonomic traits, phylogenetic index values of all fish ranged from 0.5 (low) to 2 (high), although most species had low values (0.5). The only significant difference in this comparison was that assessed species had higher phylogenetic indices compared to the full dataset, in both the full comparison and for freshwater fish only.

The level of assessment varied significantly across different orders, in both freshwater and marine habitats, as well as in the global analysis (Table 2 and Supporting Information). Among the richest orders, Squaliformes and Rajiformes appeared to have most species assessed (90% and 92% species assessed respectively), whilst other orders such as the marine orders Scorpaeniformes (15% assessed) and Gadiformes (21%), were relatively poorly represented in the IUCN Red List. Among freshwater fish, Gymnotiformes (11% assessed non-DD), Characiformes (21%) and Siluriformes (26%) had the lowest assessment levels.

Assessed species had generally been described earlier, both for freshwater and marine species (Table 3). Fish were (together with reptiles) the least assessed vertebrate taxa, with hundreds of species described in recent years but often not yet included in the Red List. When examining the proportion of non-DD vertebrate species according to their description date, it was observed that while all vertebrate groups had a lower proportion of recently-described species assessed, fish described in the last thirty years have generally not been assessed yet on the IUCN Red List. The ratio of species assessed to species described (excluding those years with less than 10 species described) showed that lower percentages of assessment were associated with higher numbers of discovered species in reptiles, amphibians and especially in fish (Fig. 2). Many fish species discovered since 1996 (2,782 freshwater species) occurred in South America and Asia, two areas with relatively poor assessment levels (Fig. 1).

The best model for species assessments among those models for which data on >85% of species were available included the positive effects of length and Vulnerability Index. On the other hand, Phylogenetic Index and description year had a negative influence on species assessment probability, confirming the results obtained in the individual analyses (Tables 2 and 3). Considering fish orders, certain orders were positively associated with the probability of assessing a species (Carcharhiniformes, Chimaeriformes, Squaliformes, Rajiformes and Syngnathiformes) whereas others had a negative association (Characiformes, Gadiformes, Gymotiformes). The full result of this model is presented in Appendix S5.

4. Discussion

Our study highlights certain areas and habitats on Earth where additional assessment efforts for fish are needed to ensure that levels of threat to fish species are adequately represented within the IUCN Red List and that fish feature in subsequent conservation and policy instruments. Longer (but not heavier) species tend to be better assessed, as are short-lived species - but not those with shorter generations, i.e. those that reproduce earlier. Assessed species have a higher vulnerability index (the vulnerability of a species to fishing pressure) than non-assessed ones. Certain fish orders are better assessed, such as sharks and rays (Dulvy et al. 2014), while others lack sufficient assessment (Scorpaeniformes, Gymnotiformes). Species assessed had been described earlier than unassessed ones, resulting in an assessment gap for fish species described during the most recent decades, comparable to a similar gap observed in reptiles (Meiri & Chapple, 2016) and amphibians (Tapley et al., 2018). Finally, no evidence was found to support the hypothesis that assessment rates are higher in species with higher commercial interest or value.

As predicted, fish from developed regions (e.g., Mediterranean, Europe, and Atlantic Sea) had higher rates of assessment. The higher levels of freshwater fish assessment in Europe are due to a comprehensive European assessment programme that exists for freshwater fish (Freyhof & Brooks, 2011). However, such exhaustive assessments are not confined to developed regions only: the higher levels of freshwater fish assessment in Africa compared to other developing regions are the result of an exhaustive assessment by IUCN in 2011 (Darwall, Smith, et al., 2011). South America and Asia, on the contrary, require further attention in freshwater fish assessment efforts (Darwall & Freyhof, 2016), although some Asian regional assessments have focussed on the Western Ghats, and the Indo-Burman and Eastern Himalayan regions (Allen, Molur, & Daniel, 2010; Molur, Smith, Daniel, & Darwall, 2011). These regions might be subject to particularly high extinction risk, as they represent hotspots with high threat status (tropical regions), small species ranges (Albert, Petry, & Reis, 2011), and high data deficiency, especially in South America (Alofs et al., 2014). Around 40% of freshwater fish species occur in the Neotropical region (Albert et al., 2011); given that only 19% of the more than 5,000 South American freshwater fish species are assessed on the IUCN Red List, the definition of key biodiversity areas for freshwaters in South America are likely inadequate for fish, due to a lack of fish representation. (Collen et al., 2014) showed that there was little congruence in the patterns of species richness, endemic species richness and threatened species richness between different groups of freshwater species, so that one freshwater taxon group is unlikely to be an adequate surrogate for another in analyses of priority areas for conservation. Initiatives like the Alliance for Freshwater Life aim to place freshwater species and their associated ecosystems on the global agenda as legitimate targets for conservation action (Darwall et al., 2018).

In the marine realm, it was surprising to see that the Atlantic Ocean was far better assessed than areas of the Indian and Pacific Oceans that belong to economically developed regions, such as the Eastern Pacific (Fig. 1). In this case, we consider that our hypothesis is not truly valid for oceans, as more factors may be affecting fish assessment rates. Similarly, species assessment was not equally distributed among habitats. Coral reefs, which are known to provide several ecosystem services to humans (Moberg & Folke, 1999) were better assessed than other habitats (Table 3). Their ease for survey and charismatic image (Duarte, Dennison, Orth, & Carruthers, 2008) is combined in this case with a high risk, as reef-associated fish face habitat-degrading threats originating from land, such as coastal residential and commercial development (McClenachan, Cooper, & Dulvy, 2016) and coral bleaching induced by climate change (Alvarez-Filip, Dulvy, Gill, Côté, & Watkinson, 2009). Assessments of deep water benthic species are lagging behind that for neritic species, likely due to better information availability for neritic species, and possibly due to lower perceived threats affecting these species (Halpern, Selkoe, Micheli, & Kappel, 2007). However, deep sea habitats are often found in international waters with less restrictions and regulations; areas around hydrothermal vents for example are likely targets for deep-sea mining (Van Dover, 2011) and the impacts of such activities are at present vastly overlooked in conservation planning and policy. Non-assessed marine fish species were consistently smaller than those assessed by the IUCN, but there was no size bias in freshwater fish assessments (Table 3). Threats affect freshwater species in a complex manner, not always related to body size (Dudgeon et al., 2006). An assessment bias towards species of commercial interest was expected, as the most significant threat for marine fishes is associated with direct mortality from human fishing activities targeting large-bodied species (Olden et al., 2007), often with slow population growth (Reynolds, Dulvy, Goodwin, & Hutchings, 2005), and those species may be prioritised for conservation assessment. No evidence of commercial fish being better assessed than other species was found (Table 2). Species of commercial interest were expected to be better assessed as a result of the fishing pressure they are subjects of.

Assessed species generally had higher vulnerability indices (Table 3). Previous studies have compared this index and IUCN Red list categories (Miranda, 2017; Strona, 2014), and Red List categories were found to be more suitable for conservation purposes than the VI (Miranda, 2017). Both measures are equally valid because they are considering different threat processes (VI measures the intrinsic extinction vulnerability due to being fished, based on biological traits of fish species whilst the IUCN Red List evaluates the extinction risk of species considering a wide range of threat processes that are affecting species, and including data on symptoms of extinction risk, such as populations declines, distribution size, population size, etc.). With aquatic systems being affected by a number of different threats (Reis et al., 2017), including emerging threats such as climate change and plastic pollution, the understanding of species vulnerability needs to be expanded to the wide spectrum of threat processes, e.g. through assessment processes such as climate change vulnerability assessments (Chin, Kyne, Walker, & McAuley, 2010). Vulnerability assessments allow to highlight those species potentially vulnerable to a specific threat and act on safeguarding these before the threat may take full effect, i.e. lead to population declines and hence higher extinction risk. On the contrary, IUCN Red List gives an estimate of the extinction risk at present, given the threats already or about to affect a species. Furthermore, previous results of species of commercial interest (more vulnerable to fishing pressure) do not show similar patterns. Therefore, this incongruity in the results may be subject of study in further research about the relationship between VI and commercial interest.

As predicted, the assessment of threat status in fish is taxonomically biased (Table 2). The presence of several Fish Specialist Groups (https://www.iucn.org/ssc-groups/fishes) may skew IUCN efforts towards certain groups or species. The IUCN Shark Specialist Group (http://www.iucnssg.org) published a significant work in 2014 (Dulvy et al., 2014) assessing the conservation status of all sharks, rays and chimaeras, resulting in higher assessment levels than in other orders. Such levels respond to an increasing concern over the past decades on shark conservation, with the change in perception, from one of needing to protect humans from sharks, to that of needing to protect sharks from humans (Simpfendorfer, Heupel, White, & Dulvy, 2011). However, a closer look at these groups showed that there was a large proportion of DD species (51% in sharks, 44% in rays, and 40% in chimaeras), slightly improved in the 2017 Red List. Thus, despite it being better to have a DD assessment than not being assessed, further investigation is required in these and other highly DD orders to obtain data that will allow scientists to classify their extinction risk (Bland, Collen, Orme, & Bielby, 2012).

Regarding marine orders, Scorpaeniformes (10% assessed non- DD) and Gadiformes (15%) had the lowest levels of assessment (Supporting Information), despite including many species of commercial importance in certain areas of the world (Winfield, 2016). In the case of Scorpaeniformes, their low growth rate and long generation time make them especially sensitive to overexploitation, which has resulted in the disappearance of many stocks in the Atlantic (Ricard, Minto, Jensen, & Baum, 2012). Unfortunately, these results are consistent with data obtained for commercial fishes, suggesting that human consumers may be largely unaware of the conservation status of the consumed marine fish. Many of these commercially-fished species may also be of importance to subsistence fishermen, endangering important food stocks and protein availability in areas around the world.

Freshwater tropical species are possibly within the least assessed groups compared to other Red List assessed fish, requiring in-depth research to evaluate their conservation status. Characiformes, freshwater-restricted species distributed in tropical Africa and South America, had a low assessment rate (21% if DD species are excluded). Considering that over 300 of the 2022 characiform species have been described as recently as the 2000-2010 decade (Oliveira et al., 2011), a combination of high description rates and few evaluations has led to a significant assessment gap in this order. Gymnotiformes (11% non-DD) and Siluriformes (26%) from South America, Africa and South-Eastern Asia (only Siluriformes) (Cordiviola, Campana, Demonte, del Barco, & Trógolo, 2009) inhabit extensive and difficult to sample habitats such as deep river channels and flood-plain floating meadows (Albert, 2001), which severely hamper initiatives for their conservation.

In this study, we have demonstrated that most of the non-evaluated species were only recently described (Fig. 2). Since the mid-1990s, IUCN's capacity to provide assessment for newly-described species seems to be decreasing as observed in the time-dependent rates of assessment. As new species are being described in those areas which already have low assessment rates, such as South America, Asia or tropical oceans (Fig. 1; Nelson et al., 2016) the gap between described and assessed species widens. South America is the sole FAO Major Fishing Area where more species were described between 1994 and 2013 than were included in the Red List for that area (Fig 1). Current rates of species discovery and publication suggest there are likely more than 8,000 Neotropical freshwater fishes (Reis, 2013), urging the need for an exhaustive effort to sample and study South American inland waters. This is of particular importance given the threats of naturalised species (e.g. non-native fish; Pelicice, Vitule, Junior, Orsi, & Agostinho, 2014), and damming (Reis et al., 2017), amongst others, which are likely to impact a large number of freshwater species in South America. In addition, these threats have the scope to impact on freshwater community structure, leading to homogenisation of the fauna, loss of genetic diversity, etc. and thus impacting wild fish stocks which may play a major part in protein provisioning along inland waters.

Furthermore, comparing data from fish with other vertebrate groups, fish species have been suffering from an evaluation decline since the 1980s which, combined with an increase in species discovery, result in a large proportion of recently discovered species not being evaluated, a trend shared with reptiles (Meiri, 2016) and amphibians (Tapley et al., 2018). In the case of amphibians, for which previously complete global assessments had been carried out, assessments are now rapidly becoming out-dated with an increasing proportion of non-evaluated species (Tapley et al., 2018). Previous studies with lizards and snakes (Böhm et al., 2017; Meiri & Chapple, 2016) have found that those species easier to study (large range sizes, temperate latitudes) are described earlier and are better assessed, whilst species with small ranges and inhabiting tropical regions remain unassessed or even undiscovered, with higher risk of extinction as a result of their rarity (Pimm et al., 2014). The tropical biodiversity data gap may influence certain indicators established by the Convention on Biological Diversity more than others (Collen, Ram, Zamin, & McRae, 2008) and, despite recent efforts led by IUCN (Tognelli, Lasso, Bota-Sierra, Jiménez-Segura, & Cox, 2016), further research and investment in this area is needed to ensure the effective protection of species dwelling there.

5. Recommendations

Since conservation efforts to date have resulted in only 46% of fish species being formally assessed by the IUCN, completing the assessment for the remaining ones seems a colossal task, complicated by the rate of new species discovery. With a cost of US$38 million, evaluating 160,000 species by 2020 seems hardly feasible in a context of funding shortfalls (Juffe-Bignoli et al., 2016). Thus, we suggest focusing efforts in the following key areas:

1) Develop working groups for under-assessed areas: We strongly recommend the creation of a working group on Central and South American fish species. Several regional initiatives have been developed by IUCN in Europe (Abdul Malak et al., 2011; Freyhof & Brooks, 2011; Nieto et al., 2015), Africa (Darwall, Smith, et al., 2011) and Asia (Allen et al., 2010; Allen, Smith, & Darwall, 2012; Molur et al., 2011). However, only a partial report of North and Central America Chondrichthyans (Kyne et al., 2012) and an assessment in the Andean region (Tognelli et al., 2016) have been carried out on the continent so far. To fulfil this aim, collaboration with local organisations and investment in local institutions is essential to develop the infrastructure and expertise for long-term monitoring (Collen et al., 2008) and study not only individual species but also species assemblages and interactions.

2) Increase knowledge of fish distribution, ecology and life history to combat Data Deficiency: Only 37% of fish species have been assigned an IUCN category, excluding DD species, which are often known from type specimens or type localities only. More resources should be directed to research those Data Deficient species (Hoffmann et al., 2008), where field surveys are likely to bring about an immediate increase in knowledge and hence expedite a non-DD assessment, i.e. species where a lack of population data or knowledge about threats are affecting a DD status. The application of environmental DNA (eDNA) sampling can provide greater probabilities of detection of aquatic species when compared with the use of traditional sampling procedures (Antognazza et al., 2019). Machine-learning techniques may also help to classify the most likely extinction risk category for those DD species that are more difficult to survey (Bland, Collen, Orme, & Bielby 2015). Furthermore, we cannot underestimate the risk of outdated assessments, that combined with unassessed areas should drive conservation priorities (Hermoso et al., 2017).

3) Explore the role played by Protected Areas (PAs) and Key Biodiversity Areas (KBAs) in fish conservation (specially freshwater fish), congruently with Aichi target 11 (SCBD, 2010). The establishment of PAs to benefit fish populations relies on improved knowledge on fish distribution (Hermoso, Abell, Linke, & Boon, 2016) and knowledge on species extinction risk, distribution and endemism is vital to inform at least some of the criteria FOR definition of A KBA (KBA Standards and Appeals Committee, 2019). Up until now, in many regions of the world fish species have played a limited role in the designation of protected areas or KBAs. Thus, further studies on both the ability of the current network of PAs to adequately protect freshwater fish (Abraham & Kelkar, 2012) and on gaps within the PA/KBAs network are urgently needed (Pino-del-Carpio, Ariño, & Miranda, 2014; Pino-del-Carpio et al., 2011). This task is even more urgent in under-assessed areas like the Andean region of South America, where 88% of the species are not adequately represented in any protected area (Tognelli et al., 2019).

4) Enhance the role played by national Red Lists: IUCN Red List and Criteria are being increasingly used for regional and national red lists (Rodríguez, 2008; Zamin et al., 2010). Several measures are proposed to better link national, regional and global Red Lists such as taxonomic uniformity and enhance data transfer between national and the global Red Lists (Brito et al., 2010). The ability to now also submit IUCN Red List Assessments in French, Spanish and Portuguese, is likely to improve coverage of assessments for regions such as South America. In addition, financial investment for national Red List development should favour those countries with richest biodiversity but lower GDP (Zamin et al., 2010). Better linkage of global and national Red List processes also increases the pool of experts available for global IUCN Red List assessments, through increased networking, collaboration and capacity building. The possibility of doing national assessments of endemic species following global Red List standards also increases the value of such assessments and we should not underestimate their possible contribution to the IUCN Red List.

5) Finally, this study goes beyond a simple listing of IUCN Red List gaps. In a context of global threat to fish species, jeopardized by human and climate pressures combined, we consider that the voice of conservation initiatives like IUCN Red List should be extensively heard by other authorities. CBD's Aichi target #12 referred to in the introduction is a call to "improve and sustain species conservation status". The results of the study fully supports this target by pointing out where assessment efforts should be focused. FAO could benefit from improved Red List evaluations, too. There is also room for improved use of IUCN outputs in FAO assessments (especially those subject to intensive fishing). For example, the 2016 SOFIA (State of World Fisheries and Aquaculture) report by FAO did not refer to the IUCN Red List (FAO, 2016) whilst this collaboration is emerging in the 2018 report (FAO, 2018). With

insufficient funds to both expand taxonomic coverage through new assessments, and keep existing assessments up to date (Rondinini, Di Marco, Visconti, Butchart, & Boitani, 2014) a compromise solution should be achieved. This study supports others like Hermoso et al., (2017) to help guide assessments efforts and afterwards, implement conservation actions for such species. We do not want to devaluate conservation actions, but we consider that proper assessments provide not only a status but also valuable information required to achieve successful conservation programs.

Acknowledgements

We would like to acknowledge the Association of Friends of the University of Navarra financial support. M.B is supported by the Rufford Foundation.

Conflict of interests

The authors declare that they have no conflicts of interest.

References

Abdul Malak, D., Livingstone, S. R., Pollard, D., Polidoro, B. a., Cuttelod, A., Bariche, M., … Tunesi, L. (2011). *Overview of the conservation status of the marine fishes of the mediterranean sea*. Gland, Switzerland and Malaga, Spain: IUCN.

Abraham, R. K., & Kelkar, N. (2012). Do terrestrial protected areas conserve freshwater fish diversity? Results from the Western Ghats of India. *Oryx*, *46*, 544–553.

Albert, J. S. (2001). Species diversity and phylogenetic systematics of American knifefishes (Gymnotiformes, Teleosti). *Miscellaneous Publications, Museum of Zoology, University of Michigan*, *190*, 1–140.

Albert, J. S., Petry, P., & Reis, R. E. (2011). Major Biogeographic and Phylogenetic Patterns. In J. S. Albert & R. E. Reis (Eds.), *Historical biogeography of neotropical freshwater fishes* (pp. 21–58). Berkeley and Los Angeles, CA: University of California Press.

Allen, D. J., Molur, S., & Daniel, B. A. (2010). *The status and distribution of freshwater biodiversity in the eastern Himalaya*. Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.

Allen, D. J., Smith, K. G., & Darwall, W. R. T. (2012). *The status and distribution of freshwater biodiversity in Indo-Burma*. Cambridge, UK and Gland, Switzerland: IUCN.

Alofs, K. M., Liverpool, E. A., Taphorn, D. C., Bernard, C. R., & López-Fernández, H. (2014). Mind the (information) gap: The importance of exploration and discovery for assessing conservation priorities for freshwater fish. *Diversity and Distributions*, *20*, 107–113.

Alvarez-Filip, L., Dulvy, N. K., Gill, J. a, Côté, I. M., & Watkinson, A. R. (2009). Flattening of Caribbean coral reefs: region-wide declines in architectural complexity. *Proceedings of the Royal Society B: Biological Sciences*, *276*, 3019–3025.

Antognazza, C. M., Britton, J. R., Potter, C., Franklin, E., Hardouin, E. A., Gutmann Roberts, C., … Andreou, D. (2019). Environmental DNA as a non-invasive sampling tool to detect the spawning distribution of European anadromous shads (Alosa spp.). *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*, 148–152.

Arthington, A. H., Dulvy, N. K., Gladstone, W., & Winfield, I. J. (2016). Fish conservation in freshwater and marine realms: status, threats and management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*, 838–857.

Bland, L. M., Bielby, J., Kearney, S., Orme, C. D. L., Watson, J. E. M., & Collen, B. (2017). Toward reassessing data-deficient species. *Conservation Biology*, *31*, 531–539.

Bland, L. M., & Böhm, M. (2016). Overcoming data deficiency in reptiles. *Biological Conservation*, *204A*, 16–22.

Bland, L. M., Collen, B., Orme, C. D. L., & Bielby, J. (2012). Data uncertainty and the selectivity of extinction risk in freshwater invertebrates. *Diversity and Distributions*, *18*, 1211–1220.

Böhm, M., Kemp, R., Williams, R., Davidson, A. D., Garcia, A., McMillan, K. M., … Collen, B. (2017). Rapoport's rule and determinants of species range size in snakes. *Diversity and Distributions*, *23*, 1472–1481.

Brito, D., Ambal, R. G., Brooks, T., Silva, N. De, Foster, M., Hao, W., … Rodríguez, J. V. (2010). How similar are national red lists and the IUCN Red List? *Biological Conservation*, *143*, 1154–1158.

Butchart, S. H. M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P. W., Almond, R. E. A., … Watson, R. (2010). Global biodiversity: Indicators of recent declines. *Science*, *328*, 1164–1169.

Butchart, Stuart H. M., Stattersfield, A. J., Bennun, L. a, Shutes, S. M., Akçakaya, H. R., Baillie, J. E. M., … Mace, G. M. (2004). Measuring global trends in the status of biodiversity: red list indices for birds. *PLoS Biology*, *2*, e383.

Carrete Vega, G., & Wiens, J. J. (2012). Why are there so few fish in the sea? *Proceedings of the Royal Society B: Biological Sciences*, *279*, 2323–2329.

Cheung, W. W. L., Pitcher, T. J., & Pauly, D. (2005). A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. *Biological Conservation*, *124*, 97–111.

Chin, A., Kyne, P. M., Walker, T. I., & McAuley, R. B. (2010). An integrated risk assessment for climate change: Analysing the vulnerability of sharks and rays on Australia's Great Barrier Reef. *Global Change Biology*, *16*, 1936–1953.

Collen, B., Ram, M., Zamin, T., & McRae, L. (2008). The tropical biodiversity data gap: Addressing disparity in global monitoring. *Tropical Conservation Science*, *1*, 75–88.

Collen, B., Whitton, F., Dyer, E. E., Baillie, J. E. M., Cumberlidge, N., Darwall, W. R. T., … Böhm, M. (2014). Global patterns of freshwater species diversity, threat and endemism. *Global Ecology and Biogeography*, *23*, 40–51.

Cordiviola, E., Campana, M., Demonte, D., del Barco, D., & Trógolo, A. (2009). Conservation state of Siluriformes fishes from the Ramsar site Jaaukanigas (middle Parana river), Argentina. *Gayana (Concepción)*, *73*, 222–232.

Costelloe, B., Collen, B., Milner-Gulland, E. J., Craigie, I. D., Mcrae, L., Rondinini, C., & Nicholson, E. (2016). Global biodiversity indicators reflect the modeled impacts of protected area policy change. *Conservation Letters*, *9*, 14–20.

Darwall, W., Bremerich, V., De Wever, A., Dell, A. I., Freyhof, J., Gessner, M. O., … Weyl, O. (2018). The Alliance for Freshwater Life: A global call to unite efforts for freshwater biodiversity science and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *28*, 1015–1022.

Darwall, W. R. T., & Freyhof, J. (2016). Lost fishes, who is counting? The extent of the threat to freshwater fish biodiversity. In G. Closs, M. Krkosek, & J. D. Olden (Eds.), *Conservation of freshwater fishes* (pp. 1–36). Cambridge University Press.

Darwall, W. R. T., Holland, R. A., Smith, K. G., Allen, D., Brooks, E. G. E., Katarya, V., … Vié, J. C. (2011). Implications of bias in conservation research and investment for freshwater species. *Conservation Letters*, *4*, 474–482.

Darwall, W. R. T., Smith, K. ., Allen, D. ., Holland, R. ., Harrison, I. ., & Brooks, E. G. . (Eds.). (2011). *The diversity of life in African freshwaters: Underwater, under threat. An analysis of the status and distribution of freshwater species throughout mainland Africa*. Cambridge, United Kingdom and Gland, Switzerland: IUCN.

Duarte, C. M., Dennison, W. C., Orth, R. J. W., & Carruthers, T. J. B. (2008). The charisma of coastal ecosystems: Addressing the imbalance. *Estuaries and Coasts*, *31*, 233–238.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z.-I., Knowler, D. J., Lévêque, C., … Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society*, *81*, 163–182.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., … White, W. T. (2014). Extinction risk and conservation of the world's sharks and rays. *ELife*, *3*, e00590.

Faith, D. P., Reid, C. A. M., & Hunter, J. (2004). Integrating phylogenetic diversity, complementarity, and endemism for conservation assessment. *Conservation Biology*, *18*, 255–261.

FAO. (2016). *The state of world fisheries and aquaculture 2016. Contributing to food security and nutrition for all*. Rome.

FAO. (2018). *The state of world fisheries and aquaculture 2018. Meeting the sustainable development goals*. Rome.

Freyhof, J., & Brooks, E. (2011). *European Red List of Freshwater Fishes*. Luxembourg: Publications Office of the European Union.

Fricke, R., Eschmeyer, W. N., & Van der Laan, R. (Eds.). (2019). Eschmeyer's Catalog of fishes: Genera, species, references. Retrieved March 28, 2019, from http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Froese, R., & Pauly, D. (Eds.). (2016). Fishbase. Retrieved from www.fishbase.org

Froese, R., Tsikliras, A. C., & Stergiou, K. I. (2011). Editorial note on weight-length relations of fishes. *Acta Ichthyologica et Piscatoria*, *41*, 261–263.

Garcia-Moreno, J., Harrison, I., Dudgeon, D., Clausnitzer, V., Darwall, W. R. T., Farrell, T., … Tubbs, N. (2014). Sustaining freshwater biodiversity in the Anthropocene. In A. Bhaduri, J. Bogardi, LeentvaarJan, & S. Marx (Eds.), *The global water system in the Anthropocene: Challenges for science and governance* (pp. 247–270). Cham, Switzerland: Springer.

Halpern, B. S., Selkoe, K. A., Micheli, F., & Kappel, C. V. (2007). Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conservation Biology*, *21*, 1301–1315.

Harnik, P. G., Lotze, H. K., Anderson, S. C., Finkel, Z. V., Finnegan, S., Lindberg, D. R., … Tittensor, D. P. (2012). Extinctions in ancient and modern seas. *Trends in Ecology and Evolution*, *27*, 608–617.

Hermoso, V., Abell, R., Linke, S., & Boon, P. (2016). The role of protected areas for freshwater biodiversity conservation: challenges and opportunities in a rapidly changing world. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*, 3–11.

Hermoso, V., Januchowski-Hartley, S. R., Linke, S., Dudgeon, D., Petry, P., & McIntyre, P. (2017). Optimal allocation of Red List assessments to guide conservation of biodiversity in a rapidly changing world. *Global Change Biology*, *12*, 3218–3221.

Hoffmann, M., Brooks, T. M., da Fonseca, G. A. B., Gascon, C., Hawkins, A. F. A., James, R. E., … Silva, J. M. C. (2008). Conservation planning and the IUCN Red List. *Endangered Species Research*, *6*, 113–125.

Hughes, R. M. (2014). Recreational fisheries in the USA: economics, management strategies, and ecological threats. *Fisheries Science*, *81*, 1–9.

IUCN. (2012). *IUCN Red List Categories and Criteria. Version 3.1* (2nd ed.). Gland, Switzerland and Cambridge, UK.

IUCN. (2017). The IUCN Red List of Threatened Species. Version 2017-1. Retrieved from www.iucnredlist.org

Jennings, S., Melin, F., Blanchard, J. L., Forster, R. M., Dulvy, N. K., & Wilson, R. W. (2008). Global-scale predictions of community and ecosystem properties from simple ecological theory. *Proceedings of the Royal Society B: Biological Sciences*, *275*, 1375–1383.

Juffe-Bignoli, D., Brooks, T. M., Butchart, S. H. M., Jenkins, R. B., Boe, K., Hoffmann, M., … Kingston, N. (2016). Assessing the cost of global biodiversity and conservation knowledge. *PLoS ONE*, *11*, 1–22.

KBA Standards and Appeals Committee. (2019). *Guidelines for using a Global Standard for the Identification of Key Biodiversity Areas. Version 1.0*. Gland, Switzerland: IUCN.

Kyne, P. M., Carlson, J. K., Ebert, D. A., Fordham, S. V., Bizzarro, J. J., Graham, R. T., … Dulvy, N. K. (Eds.). (2012). *The conservation status of North American , Central American, and Caribbean chondrichthyans*. Vancouver, Canada: IUCN Species Survival Commission Shark Specialist Group.

Langhammer, P., Bakarr, M., Bennun, L., Brooks, T., Clay, R., Darwall, W., … Tordoff, A. W. (2007). *Identification and gap analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. Gland, Switzerland: IUCN.

McClenachan, L., Cooper, A. B., & Dulvy, N. K. (2016). Rethinking trade-driven extinction risk in marine and terrestrial megafauna. *Current Biology*, *26*, 1640–1646.

Meiri, S. (2016). Small, rare and trendy: traits and biogeography of lizards described in the 21st century. *Journal of Zoology*, *299*, 251–261.

Meiri, S., & Chapple, D. G. (2016). Biases in the current knowledge of threat status in lizards, and bridging the "assessment gap." *Biological Conservation*, *204A*, 6–15.

Miranda, R. (2017). The misguided comparison of vulnerability and conservation status. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *27*, 898–899.

Moberg, F., & Folke, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological Economics*, *29*, 215–233.

Molur, S., Smith, K. G., Daniel, B. A., & Darwall, W. R. T. (2011). *The status and distribution of freshwater biodiversity in the Western Ghats, India*. Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.

Morais, A. R., Siqueira, M. N., Lemes, P., Maciel, N. M., De Marco, P., & Brito, D. (2013). Unraveling the conservation status of data deficient species. *Biological Conservation*, *166*, 98–102.

Nelson, J. S., Grande, J. S., & Wilson, M. V. (2016). *Fishes of the world* (5th ed.). Hoboken, N.J.: John Wiley & Sons.

Nieto, A., Ralph, G. M., Comeros-Raynal, M. T., Kemp, J., Criado, M. G., Allen, D. J., … Williams, J. T. (2015). *European Red List of marine fishes*. Luxembourg: Publications Office of the European Union.

Olden, J. D., Hogan, Z. S., & Zanden, M. J. Vander. (2007). Small fish, big fish, red fish, blue fish: Size-biased extinction risk of the world's freshwater and marine fishes. *Global Ecology and Biogeography*, *16*, 694–701.

Oliveira, C., Avelino, G. S., Abe, K. T., Mariguela, T. C., Benine, R. C., Ortí, G., … Corrêa e Castro, R. M. (2011). Phylogenetic relationships within the speciose family Characidae (Teleostei: Ostariophysi: Characiformes) based on multilocus analysis and extensive ingroup sampling. *BMC Evolutionary Biology*, *11*, 275.

Pelicice, F. M., Vitule, J. R. S., Junior, D. P. L., Orsi, M. L., & Agostinho, A. A. (2014). A serious new threat to Brazilian freshwater ecosystems: the naturalisation of non- native fish by decree. *Conservation Letters*, *7*, 55–60.

Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., … Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science*, *344*, 1246752.

Pino-del-Carpio, A., Ariño, A. H., & Miranda, R. (2014). Data exchange gaps in knowledge of biodiversity: Implications for the management and conservation of Biosphere Reserves. *Biodiversity and Conservation*, *23*, 2239–2258.

Pino-del-Carpio, A., Villarroya, A., Ariño, A. H., Puig, J., Miranda, R., & Villarroya, A. (2011). Communication gaps in knowledge of freshwater fish biodiversity: Implications for the management and conservation of Mexican biosphere reserves. *Journal of Fish Biology*, *79*, 1563–1591.

R Development Core Team. (2019). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Reis, R. E. (2013). Conserving the freshwater fishes of South America. *International Zoo Yearbook*, *47*, 65–70.

Reis, V., Hermoso, V., Hamilton, S. K., Ward, D., Fluet-Chouinard, E., Lehner, B., & Linke, S. (2017). A global assessment of inland wetland conservation status. *BioScience*, *67*, 523–533.

Reynolds, J. D., Dulvy, N. K., Goodwin, N. B., & Hutchings, J. A. (2005). Biology of extinction risk in marine fishes. *Proceedings of the Royal Society B: Biological Sciences*, *272*, 2337–2344.

Ricard, D., Minto, C., Jensen, O. P., & Baum, J. K. (2012). Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. *Fish and Fisheries*, *13*, 380–398.

Rodrigues, A. S. L., Pilgrim, J. D., Lamoreux, J. F., Hoffmann, M., & Brooks, T. M. (2006). The value of the IUCN Red List for conservation. *Trends in Ecology and Evolution*, *21*, 71–76.

Rodríguez, J. P. (2008). National Red Lists: The largest global market for IUCN Red List Categories and Criteria. *Endangered Species Research*, *6*, 193–198.

Rondinini, C., Di Marco, M., Visconti, P., Butchart, S. H. M., & Boitani, L. (2014). Update or outdate: Long-term viability of the IUCN Red List. *Conservation Letters*, *7*, 126–130.

SCBD. (2010). *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its tenth meeting. X/2. The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets*. Nagoya, Japan.

Simpfendorfer, C., Heupel, M. R., White, W. T., & Dulvy, N. K. (2011). The importance of research and public opinion to conservation management of sharks and rays: a synthesis.

Marine and Freshwater Research, *62*, 518–527.

Strona, G. (2014). Assessing fish vulnerability: IUCN vs FishBase. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *24*, 153–154.

Tapley, B., Michaels, C. J. C. J., Gumbs, R., Bohm, M., Luedtke, J., Pearce-Kelly, P., … Rowley, J. J. L. (2018). The disparity between species decription and conservation assessment: a case study in taxa with high rates of species Discovery. *Biological Conservation*, *220*, 209–214.

Tognelli, M. F., Anderson, E. P., Jiménez-Segura, L. F., Chuctaya, J., Chocano, L., Maldonado-Ocampo, J. A., … Villa-Navarro, F. A. (2019). Assessing conservation priorities of endemic freshwater fishes in the Tropical Andes region. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*, 1123–1132.

Tognelli, M. F., Lasso, C. A., Bota-Sierra, C. A., Jiménez-Segura, L. F., & Cox, N. A. (Eds.). (2016). *Estado de conservación y distribución de la biodiversidad de agua dulce en los Andes tropicales*. Gland, Suiza, Cambridge, UK and Arlington, USA: IUCN.

Tucker, C. M., Cadotte, M. W., Carvalho, S. B., Davies, T. J., Ferrier, S., Fritz, S. A., … Mazel, F. (2016). A guide to phylogenetic metrics for conservation, community ecology and macroecology. *Biological Reviews*, *92*, 698–715.

Turak, E., Harrison, I., Dudgeon, D., Abell, R., Bush, A., Darwall, W. R. T., … De Wever, A. (2016). Essential Biodiversity Variables for measuring change in global freshwater biodiversity. *Biological Conservation*, *213*, 272–279.

Van Dover, C. L. (2011). Tighten regulations on deep-sea mining. *Nature*, *470*, 31–33.

Winfield, I. J. (2016). Recreational fisheries in the UK: natural capital, ecosystem services, threats, and management. *Fisheries Science*, *82*, 203–212.

Zamin, T. J., Baillie, J. E. M., Miller, R. M., Rodríguez, J. P., Ardid, A., & Collen, B. (2010). National red listing beyond the 2010 target. *Conservation Biology*, *24*, 1012–1020.

Tables

Table 1: Number of fish species evaluated for each trait in each group. Only FAO (Food and Agriculture Organisation) Area, order and year of description were available for all species. Population refers to the full dataset of all species present in FishBase. Assessed refers to those sopecies assessed by IUCN Red List. Assessed non DD refers to those species assessed by IUCN Red List excluding those classified as Data Deficient.

Trait	Population	Assessed	Assessed non-DD
Distribution			
FAO Area	32568	15029	11931
Life History			
Length	27967	13579	11092
Weight	1737	1104	990
Longevity	1264	865	825
Generation time	25490	12413	10095
Conservation			
Vulnerability Index	32541	14990	11892
Taxonomy			
Phylogenetic Index	32338	14977	11881
Order	32568	15029	11931
Year of description	32568	15029	11931
Commercial			
Commercial importance	7362	4376	3735

Table 2: Chi-square results for the comparisons between global and assessed species included on the IUCN Red List (Total *vs* RL) and excluding Data Deficient species (RL *vs* RL non-DD) for each FAO area, preferred habitat, the number of species assessed in each taxonomic order in all the environments, and commercial categories. Original data can be found in Supporting Information.

	Total *vs* RL			RL *vs* RL non-DD		
	$\chi2$	df	p	$\chi2$	df	p
FAO areas	16894.4	25	< 0.001	801.0	25	< 0.001
Habitats	9521.4	7	< 0.001	706.7	7	< 0.001
Orders	10319.0	61	< 0.001	782.4	61	< 0.001
Orders (Freshwater species)	4476.4	61	< 0.001	393.8	61	< 0.001
Orders (Marine species)	6011.6	61	< 0.001	407.3	61	< 0.001
Commercial importance	1214.8	5	< 0.001	100.2	5	< 0.001

Table 3: Values and biases of life-history traits in the three groups: Total, assessed species included on Red List (RL), and assessed excluding data deficient species (RL non-DD) were compared.. All values are reported as the median and interquartile range in brackets. Wilcoxon rank sum test with continuity correction statistic (W) and associated probability (*p* assoc.) are shown.

Trait	Length (log cm)	Weight (log g)	Longevity	Generation Time	Vulnerability Index	Phylogenetic Index	Year of description
Overall							
Total median	1.1 (0.8-1.5)	3.6 (3.0-4.1)	10.0 (5.0-18.0)	1.8 (1.1-3.1)	21 (10-34)	0.5 (0.5-0.5)	1928
RL median	1.2 (0.9-1.5)	3.7 (3.1-4.3)	8.0 (4.0-15.0)	1.8 (1.2-3.1)	23 (12-36)	0.5 (0.5-0.5)	1917
RL not DD median	1.2 (0.9-1.5)	3.6 (3.1-4.3)	8.0 (4.0-15.0)	1.8 (1.2-3.1)	23 (12-35)	0.5 (0.5-0.5)	1911
Total *vs* RL	177330000	887440	591610	154800000	228120000	245890000	268090000
p assoc.	< 0.001	0.001	0.001	0.001	< 0.001	0.001	< 0.001
RL *vs* RL not DD	74322000	554770	360770	62998000	88381000	88220000	94615000
p assoc.	0.076	0.548	0.693	0.479	0.233	0.138	< 0.001
Freshwater							
Total median	1.0 (0.8-1.3)	3.5 (2.8-4.0)	7.0 (4.0-12.0)	1.5 (0.9-2.6)	15 (10-27)	0.5 (0.5-0.5)	1935
RL median	1.0 (0.8-1.3)	3.5 (3.0-4.1)	6.0 (4.0-11.0)	1.6 (1.1-2.7)	17 (10-30)	0.5 (0.5-0.5)	1927
RL not DD median	1.1 (0.8-1.4)	3.5 (2.9-4.1)	6.0 (4.0-11.0)	1.6 (1.1-2.7)	18 (11-31)	0.5 (0.5-0.5)	1921
Total *vs* RL	48165000	175230	169280	37545000	57670000	64586000	70037000
p assoc.	< 0.001	0.272	0.371	< 0.001	< 0.001	0.004	< 0.001
RL *vs* RL not DD	20605000	108340	134060	17632000	24065000	24640000	26409000
p assoc.	< 0.001	0.788	0.927	0.182	< 0.001	0.222	< 0.001
Marine							
Total median	1.3 (1.0-1.6)	3.7 (3.2-4.2)	12.0 (7.0-25.0)	2.2 (1.3-3.5)	26 (14-39)	0.5 (0.5-0.5)	1918
RL median	1.4 (1.0-1.7)	3.8 (3.2-4.4)	12.0 (7.0-22.5)	2.2 (1.3-3.7)	27 (15-42)	0.5 (0.5-0.5)	1904
RL not DD median	1.4 (1.0-1.7)	3.8 (3.2-4.4)	12.0 (7.0-22.0)	2.1 (1.3-3.5)	27 (15-41)	0.5 (0.5-0.5)	1897
Total *vs* RL	43493000	380090	174280	42631000	59736000	63703000	71410000
p assoc.	< 0.001	0.002	0.197	0.042	< 0.001	0.286	< 0.001
RL *vs* RL not DD	18896000	238810	88981	15984000	22672000	22037000	23622000
p assoc.	0.094	0.714	0.848	0.017	0.049	0.402	< 0.001

Figure Legends

Figure 1: Total number of fish species included on FishBase 2013 (outer black circles), and relative number of assessed species (dark grey circles) and assessed and non-Data Deficient species (light grey circles) in the IUCN Red List, by FAO Major Fishing Area. Grey sectors: Proportion of species described in the Fishing Area after 1994. Full data in Supporting Information.

Figure 2: Number of species described per year assessed by IUCN as non-DD (blue) and DD (orange), and Not Evaluated (grey), in main vertebrate groups.