Putting the fish into inland fisheries – a global allocation of historic inland fish catch.

Authors: Rachel F. Ainsworth[1]*, Ian G. Cowx [1] & Simon J. Funge-Smith[2]

[1]Hull International Fisheries Institute, University of Hull, Hull, UK

[2]Food and Agricultural Organisation of the United Nations, Regional Office for Asia and the Pacific, Bangkok, Thailand.

Corresponding Author: *Dr Rachel Ainsworth, Hull International Fisheries Institute, University of Hull, Hull, UK R.Ainsworth@hull.ac.uk

Global allocation of inland fish catch

Abstract

Inland waters support the livelihoods of up to 820 million people and provide fisheries that make an essential contribution towards food security, particularly in the developing world where 90% of inland fisheries catch is consumed. Despite their importance, inland fisheries are overlooked in favour of other water use sectors deemed more economically important. Inland fisheries are also driven by external factors such as climate change and habitat loss, which impedes our ability to manage them sustainably. Using a river basin approach to allocate fish catch we have provided an integrated picture of how different inland water bodies contribute to global inland fisheries catches. There is a substantial amount of information available on inland fisheries, but it has never been synthesised to build this global picture. Fishery statistics from river basins, lakes, floodplains, hydrobasins and countries covering a time span from 1960-2018 were analysed. Collation of basin-scale fisheries statistics suggests a global inland catch of ≈17.4 million tonnes (PSE= ±3.93 million tonnes) in 2010, considerably more than the 10.8 million tonnes published by the United Nations Food and Agriculture Organization (FAO), but in line with estimates based on household consumption. The figure is considered a likely maximum due to recent reductions in catches because of closures, threats and fisheries declines in the most productive fisheries. It is recommended that sentinel fisheries, which are important for food provision, employment or where threats facing a fishery could cause a deterioration in catch, are identified to provide the baseline for a global monitoring programme.

Keywords: FAO, Fish catch statistics, Inland fisheries, River basin approach, Sentinel fisheries.

Contents

1. Introduction

1.1 Background

Inland fisheries are poorly understood and often overlooked in agricultural, water, environmental and social policy frameworks (Cooke et al., 2016). They are highly dispersed and fragmented, and catch data are often lost in time-bound research projects or initiatives that do not link to larger monitoring programmes (Lorenzen et al., 2016). There are few extended time-series of catches for inland fisheries, with the exception of all but the largest or most intensive fisheries (e.g. African Great Lakes, North American Great Lakes, Tonle Sap '*dai*' fishery in Cambodia, the *Sábalo* fishery in the Amazon, and large stocked reservoirs). Even then, some of the major fisheries (e.g. floodplain fisheries on the major tropical rivers in Asia and Africa) are not regularly or effectively monitored. These weaknesses propagate through to national reporting of inland fish catch statistics constraining effective management of inland fisheries, or undermining the justification of their protection in the face of water resources development schemes, such as hydropower dams, agriculture development, and urban and industrial expansion (Lynch et al., 2017).

The patchy nature of inland fisheries monitoring also perpetuates the impression that it is not possible to build a picture of the world's inland fisheries because they are not well documented, and any data available are either too fragmented (focussing on small areas within a basin), or overly-aggregated to provide an accurate understanding of where inland fisheries catch is occurring and across what scale (Ainsworth et al., 2021). Further, when one drills down into the actual catch statistical reporting procedures, considerable variability is found between institutions in the same country (e.g. Cowx et al., 2003), or in comparison with outputs from independent studies (Schubert et al., 2022).

There have been numerous efforts to estimate missing or unmonitored elements of marine fishery catches (e.g. Froese et al., 2012) and account for these at national and global levels (e.g. Pauly, & Zeller, 2016). However, there have been few systematic attempts to understand the potential gaps in global inland fisheries catches and potential yield, and all of them provided either a global or partial total, rather than downscaled regional or basin estimates (Fluet-Chouinard et al., 2018).

Previous studies have highlighted that total global inland catches could be higher than officially reported, but intrinsic constraints in the methods used to estimate the global catch make it difficult to directly compare such estimates. Welcomme (2011) used lake area and fish catches from tropical lakes to suggest a potential yield (i.e. fish that are potentially there to be caught) in global lakes of 90 million tonnes; however, Welcomme stated that this potential yield was “undoubtedly excessive” as this study assumed similar yields across temperate and tropical regions, did not account for effort and excluded catch estimates from other aquatic habitats. The “Big Numbers Project” carried out by the World Bank, The Food and Agricultural Organization of the United Nations (FAO) and WorldFish (World Bank, 2012) used simple extrapolation based on a limited number of country case studies to estimate that global inland capture fisheries and hidden harvest catch was 13 million tonnes, compared with the 10.8 million tonnes reported by FAO in 2010 (FAO, 2018). The Big Number Project used a general percentage of underreporting to derive the global estimate and did not consider subsistence fisheries as part of the study. Lymer et al., (2016) used an update of Welcomme’s (2011) methodology, estimating the theoretical total annual inland fish harvest could be as much as 72 million tonnes. This method was based on estimates of various inland fishery habitat areas (permanent lakes, reservoirs, rivers, floodplains and wetlands) and average yield estimates from these habitats, but also did not account for accessibility or effort. Deines et al., (2017) used satellite estimates of chlorophyll from 80,012 lakes (larger than 0.1 km^2) globally and attempted to factor for effort using population density around water bodies, to approximate a global lake harvest in the year 2011 at around 8.4 million tonnes. However, this too revealed large country level inaccuracies and also did not include estimates from other aquatic habitats. Fluet-Chouinard et al., (2018), used household surveys to elicit fish consumption and a modelling approach to derive the inland captured fish component, to conclude that global inland catch in the median year of 2008 was more likely 16.6 million tonnes, rather than the 10.1 million tonnes that was reported by the FAO in the same year.

Irrespective of the rising global trend in fish catches, the apparent low proportion of fish provided by inland capture fisheries is misleading, as it does not reflect the sub-national concentrations of inland fisheries and thus misrepresents their local or regional importance. As a consequence, the contribution of inland fisheries to nutritional and livelihood resilience is often overlooked (Cooke et al., 2016; Lynch et al., 2016, 2017; Thilsted et al., 2016). Due to their inherent inter-annual fluctuations, inland fishery catches rarely provide an indication of their status, and aggregated, national statistics only provide an estimate of their contribution to food supply (FAO, 2018). If we are to really understand the contribution of inland fisheries it is imperative to re-examine inland fisheries data and to assess their accuracy (Sorensen and Palomares, 2021) and identify more clearly how catches are distributed globally..

To address some of these constraints, this paper reviews independent information on catches from major inland fisheries in the world using river basins as the unit of aggregation, and establishes a relationship between river basin data and FAO national data to re-estimate historical global inland fish catch for the median year of 2010.

1.2 Background to inland fisheries catch

FAO is the international body responsible for the collation and dissemination of global capture fisheries statistics reported by its member nations. The global fisheries statistics database commenced in 1950, and since then inland fisheries catches have increased between 2 and 3% annually, to 11.5 million tonnes in 2020 (Figure 1), contributing 13% of total global fish catch in 2020 (FAO, 2022). Major growth in inland fisheries catch has occurred in Asia and Africa, which accounted for 63.6% and 28% of the reported catch in 2020 (Figure 2). Fish catches from the Americas, Europe and Oceania are considerably less than the catches from Asia and Africa, accounting for a combined 8.4% of the total inland fisheries catch (FAO, 2022). Reported inland fish catches from these continents have stabilised and have not shown any significant increase in decades, primarily due to the transition from commercial or food fisheries to recreational fisheries in these areas (Figure 1).

In situations where a country does not routinely report fish catch statistic to FAO, the organization estimates catch based on previous reports and available data to preserve the time series. In 2020, 25 countries in Africa did not report fish catches, similarly, 15 countries in Asia, 12 countries in the Americas, 17 countries in Europe and 4 countries in Oceania, (73 countries in total) did not report (FAO, 2022). There are also occasional adjustments to the global catch database, to account for evidence indicating significant under- or over-reporting of catch by individual countries (e.g. global inland fish catches for 2014 were revised downwards to 11.3 million tonnes from the previously reported 11.9 million tonnes, following the replacement of the national inland fisheries estimate for Myanmar with an FAO estimate (FAO, 2020)).

Inland fisheries are distributed globally, but almost 78% of the global reported inland fisheries catch is harvested by only fifteen countries and a further 11% is harvested by an additional 10 countries. Major inland fish harvests tend to be in developing countries, particularly in Asia and Africa, with the notable exceptions of the Russian Federation and Finland. Low Income Food Deficit (LIFD) countries accounted for 31% of the total reported catch in 2020 and Developing Landlocked Countries accounted for 13.4% of total inland fish catch (FAO, 2022). Fish catches are concentrated around productive waters, such as lakes, rivers and floodplains, particularly where there is a large rural population (Funge-Smith, 2018).

1.3 Problems with understanding inland fisheries

Inland fisheries can be characterised as highly seasonal, small-scale, highly dispersed, multi-species, multi-gear fisheries, where fishing is often for household consumption, and part of a diversified household strategy (Bartley et al., 2015; Lynch et al., 2016; Ainsworth, 2020). These characteristics create uncertainty in reporting of inland fisheries contributing to their lack of visibility, which ultimately leads to fish being seen as a by-product of water and being overlooked in food security and nutrition discussions (Cooke et al., 2016). This is despite the inland fisheries sector contributing to the livelihoods of around 820 million people globally (WorldFish, 2015) and having total use valued at USD 43 billion when reported and estimated unreported production are combined (Thorpe et al., 2018).

FAO and others have commented on the spatial and temporal fragmentation of knowledge and research on inland fisheries, and their associated aquatic ecosystems (Coates, 2002; Allan et al., 2005; FAO, 2010; World Bank, 2012; Funge-Smith, 2018). The continuous increases in fish catch, particularly for many poorly developed countries, is also seen by some as inexplicable and contrasts with the declines in global ocean fisheries (Bartley et al., 2015; Pauly and Zeller, 2016; Sorensen and Palomares, 2021).

Traditional methods of single-species stock assessment and management, that have been adapted from marine fisheries, are rare in inland fisheries, and are generally restricted to large lakes or individual commercially important species (Welcomme, 2011). The transboundary and often small-scale diffuse nature of many inland fisheries makes it difficult to assess fish catches and there has been a general lack of fisheries monitoring in areas such as rice fields and floodplains. Fisheries statistical data collection requires investment, but inland fisheries are often not seen as important enough to warrant such investment compared to marine fisheries (Ainsworth, 2020).

Recreational fishing presents an additional challenge to estimating total global catch, as it is generally considered a leisure activity. Despite this generalization and whilst retained recreational catch is rarely required to meet primary nutritional needs, it can contribute to personal food security (Cooke et al., 2018). Recreational fishing is present in 76% of the world’s exclusive economic zones (Mora et al., 2009) and the potential contribution of recreational fisheries to global fish catch could be as much as 5.4% of total reported global fish catch (Funge-Smith et al., 2018). However recreational fishing data are usually aggregated at a national level, are often only available in terms of participation rather than catch (Cooke and Cowx, 2004; Cooke et al., 2018; Funge-Smith et al 2018; Embke et al., 2019; Embke et al., 2022), and where catches are available, these may not be clearly disaggregated between retained and returned catch. The high degree of uncertainty that comes with estimating recreational fishing catches from recreational fishing (Funge-Smith et al., 2018) and their attribution to basins rather than a national figure has meant that we have not attempted to allocate national recreational data to basins. This has only been done where the literature provided a recreational fishing catch value attributable to a basin as outlined in Ainsworth et al., (2021); and Supplementary Material Table S2.

Despite this catalogue of problems and the apparent dearth of usable data, there is a surprisingly large amount of information available on inland fisheries, as they have been studied over many decades; it is just that this information has not been systematically pieced together to build a global picture and is rarely from the same year. Such a synthesis therefore requires us to accept data from a wider timeframe than is typically considered when attempting to report on fishery catches (typically annual figures or figures from within a relatively narrow time frame, e.g. five years).

Although this might be considered to introduce large errors, it must be viewed through the lens of the large, inter-annual variations that occur in many of the largest inland fisheries, typically driven by climatic variables (Harrod et al., 2018).

2. River basin approach to assessing inland fisheries

2.1 River basin selection and data collection

Country-specific fisheries statistics are aggregated within national borders, rather than at the basin scale, and the national figure therefore represents fish catch from a range of habitats (wetlands, lakes, rivers and floodplains), and often multiple basins and fisheries. Very few large basins are wholly contained within a single country boundary and are typically part of transboundary water bodies. Using a basin approach to allocate catches as applied in this study provides an understanding of the importance, in terms of food provision, of an inland fishery that may be shared amongst several countries. The river basin approach carried out here also overcomes many of the issues associated with highly dispersed or aggregated data, or the potential loss of valuable information from independent or national catch assessment programmes.

It is recognised that fish are caught and harvested in most countries around the globe (FAO 2021a; Ainsworth et al., 2021), but countries with the greatest inland fish catches tend to be concentrated in river basins and water bodies in the tropical and subtropical latitudes of the world and developing countries, with the addition of Russian Federation and Finland. To account for this uneven distribution of catches and to limit disproportionate effort focusing on data rich, but relatively insignificant small systems, a priority list of river basins and waterbodies was developed, covering an estimated 94% of global inland capture fisheries statistics, based on the FAO national statistics associated with those countries. Initially 45 river basins and lakes were identified as part of the FAO Circular "A review of major river basins and large lakes relevant to inland fisheries" (Ainsworth et al., 2021). River basins chosen for this study were based on the importance of their fisheries from a commercial, subsistence or recreational perspective, and information regarding river basin characteristics, fisheries management and threats were collected to form river basin profiles. For most basins, data were from the 2000-2018 period, but occasionally data were older (up to 50 years old), however, they were still considered the best available information.

Fish catches from other river basins and hydrobasins known to contribute fish catches for harvest were estimated from the literature and national sources to account for additional inland fisheries catches of these important systems (basin estimates from Ainsworth, 2020 and Ainsworth et al., 2021 used in the study are presented in Supplementary Material Table S2). Catch data from 107 rivers and lakes and fisheries data from countries that are in essence one hydrobasin (e.g. Sri Lanka, Madagascar, Indonesian islands) were also obtained. Search engines such as Google Scholar, Web of Science and ProQuest, were used to find the most recent estimates of inland fishery catches for the chosen rivers and lakes from literature sources. FAO statistical reporting (FishStatJ: https://www.fao.org/fishery/en/topic/18238?lang=en) and official national data were also used.

Inland fishery statistics for China are reported by province, therefore the fish catch from one province could reflect the fish catch from more than one river basin. In this case, a partitioning approach was used to allocate catch to basins. The area that each river basin occupied in each province in China was established using Arc GIS, and the proportional area of each river was applied to the provincial fish catch on a pro rata basis (based on 2015 fisheries data from *A Statistical Analysis of China's Fisheries in the 12th Five Year Period* (Zhao and Shen, 2016). This introduces uncertainty regarding reliability of the basins' catch data as this involved an assumption that catches are spread evenly across the province, but in the absence of sub-provincial catch data this was deemed the best available approach.

Similarly, statistics for freshwater fisheries catch in India were obtained for each state. As for China, freshwater fish catch was assigned by the area of each basin in a particular state using Arc GIS and fisheries statistics from the Handbook on Fisheries Statistics by the Government of India (2014). However, these statistics contained a mixture of both inland aquaculture and capture fisheries harvest data. This was reconciled by associating the species composition of inland catch for 2012 in FAO statistics and official State statistics with potential origin. From the statistics it was established which freshwater and anadromous species from inland waters are most likely cultured (aquaculture in India mainly consists of Indian major carps, Pangasiid catfishes and snakeheads), and these were subtracted from catch estimates. The residual statistics (species that do not appear in aquaculture statistics) represent an estimate of the inland fish catch, which can then be applied to each of the states on a pro rata basis.

A similar approach was also adopted for the Russian Federation using data from 2018 as part of a joint project by FAO and VNIRO (Russian Federal Research Institute of Fisheries and Geography). National fisheries data were presented by administrative boundaries from FAO (unpublished) and included fisheries catch for the indigenous and recreational fisheries from the Far East and North East areas of Russia. Fisheries data for river basins and lakes in Russia used in this study, as indicated in Tables 2 and 3, were delineated from the regional statistics. Note, basin delineation was not exact as more than one basin may occur within a region and thus catch was apportioned to their basins.

2.2 Accounting for Uncertainty

Inland fisheries are prone to large inter-annual variation, which occurs due to environmental drivers such as the extent of flooding (e.g. Kolding and van Zwieten, 2014) and variation in annual temperature cycles or oscillations in ocean currents (e.g. Nunn et al. 2003). As such fishery catches exhibit boom and bust cycles of high and low fish catches, which creates uncertainty. To account for this uncertainty, theoretical upper and lower range catch estimates for river basins and waterbodies (*BR*) were obtained from Ainsworth et al, (2021) and the literature. Fishery estimates for basins (*B*) and hydrobasins (*H*), where only a single value of fishery catch could be obtained, or where the only other fishery data was considerably older (pre-2000), were also used. These values can be considered indicative of the catch, but may not be representative of either the maximum catch (as fish catches may have developed further in more recent years) or current levels of catch (in cases where the fishery may have declined).

The average year of reports of fish catch was calculated for each basin and lake and weighted based on volume of catch (Supplementary Material Table S2) (sum of year x sum of catch/sum of catch), to provide a weighted median year for the fish catch estimates along with the date ranges that fish catch data were available for each basin. The overall weighted average year for fish catches used in this study was 2010, and was used as the baseline for our study.

Fisheries information for countries that were not part of river basins in this analysis were considered 'missing fishery catch' (MC_1) and were included as data reported by FAO (FAO, 2022). Additionally, country fisheries catch that was not accounted for within river basin catch estimates were also considered as 'missing fishery catch'. To account for this, the basin fishery figures per country were subtracted from the FAO 2010 inland capture fishery estimates for each country and any excess fish catch not accounted for in river basins was presented as 'missing fishery catch' (MC_2) along with fish catch from countries not studied in this analysis. Where river basin catches were presented as upper and lower ranges the potential 'missing fishery catch' was also derived as upper and lower ranges of 'missing catch estimates' for the countries concerned (MC_r).

To account for uncertainty in FAO country estimates (components MC_1, MC_2 and MC_r), the relationship between aggregated basin catch data and FAO country data was established (Supplementary Material Table S1). The majority of basin catches were delineated at a country level, but where this was not the case (i.e. the Congo basin) Arc GIS was used to establish the proportion of basins in each country unless catch proportions were cited from the literature (Supplementary Material Table S2). A nonlinear relationship between aggregated basin data (*y*) and FAO 2010 data (*x*) was derived (Figure 3) and described by:

$$y= -3\mathrm{E}{-07}x^2 + 1.54x \quad (R^2=0.81;\ P= <0.05) \qquad \text{[equation 1].}$$

Where FAO data were used to estimate the global fish catch (components MC_1, MC_2 and MC_r), these values were adjusted according to equation 1. Estimated global inland fish (*GC*) catch was based on the summation of each component above as follows:

$$GC= BR+B+H+MC_1+MC_2+MC_r \quad \text{[equation 2]}$$

To account for uncertainty in the global catch estimates as a result of upper and lower ranges in *BR* and MC_r Monte Carlo simulations of the *BR* and MC_r components (1000 simulations) were calculated, and *GC* was taken as the mean of the simulations. Proportional standard error (PSE) for basins used in the Monte Carlo simulations was established (Figure 5), and the summation (PSE) was applied to the global total (*GC*) to provide a measure of uncertainty.

3. Results

3.1 Estimation of global inland fish catch

Fisheries catches from 72 major river basins, 35 large lakes, 31 hydrobasins and 109 countries were extracted from the information searches (Supplementary Material Table S2). The total global inland fishery catch for 2010 was estimated at 17.4 million tonnes (95% confidence interval ±105,676 tonnes, SE= 53,917 tonnes, PSE= ±3.93 million tonnes) compared with the 10.8 million tonnes recorded by FAO for 2010 (FAO, 2022). Major river basins contributed the majority of inland fisheries catch, accounting for 50-65%, and hydrobasins contributed the least (9.9 %) (Tables 1-3). However, it should be noted that no fisheries data were obtained for waterbodies in Central America, Caribbean, Eastern and Western Asia, Western and Southern Europe, North and East Africa, because there was little information regarding specific inland fisheries in these regions; fisheries catch data for these regions was either covered within the hydrobasins or were considered missing fisheries catch and were substituted with adjusted national data as in equation 1.

The majority of inland fisheries catch is concentrated in the tropical and subtropical latitudes of the world, with a few exceptions (e.g. Scandinavia, Russian Federation and South America) (Figure 4). The world's largest inland fisheries in terms of catch are the Mekong, Irrawaddy, Brahmaputra and Lake Victoria, with mean annual estimated catch of 2.1, 0.9, 1.0 and 0.9 million tonnes, respectfully, which accounted for 28% of estimated global fisheries catch (Tables 1 & 2). Lake Victoria accounted for 41-53% of the total estimated fisheries catch from lakes (Table 2). Other large lakes (Tonle Sap Lake, Lake Tanganyika and Lake Chad) contributed 26-28% of the total estimated fisheries catch from lakes. The resulting allocation of catch to basins leaves some countries and areas outside major basins and hydrobasins; these were considered 'Missing country catches' and were accounted for using adjusted national statistics from FAO 2010. This accounted for 13.4-14.7% of total estimated fisheries catch, the majority of which came from Asian countries (1,587,075-1,644,684 tonnes) (Table 4).

Uncertainty due to inter-annual variation in inland catch was accounted for using Monte Carlo simulations (*BR, MC*$_r$), following Fluet-Chouinard et al., (2018). Thirty-three river basins had either one or multiple components of the inland fisheries catch estimated using Monte Carlo simulations (Figure 5 and indicated with an * in Tables 1 & 2 and Supplementary Material Table S2). The basin elements that contributed the largest amount of uncertainty to the estimated global total (indicated in Figure 5) include the Yangtze River (mean= 591,599 tonnes, SD= 294,373; SE as a percentage of the mean =1.6%) and the Orinoco river basin in Colombia (mean= 4,361 tonnes; SD= 1,939; SE as a percentage of the mean =1.4%). The river basins that contributed the least amount of uncertainty to the global total are the Okavango Delta (mean= 703 tonnes, SD= 15.6, SE as a percentage of mean= 0.1 %) and the Brahmaputra floodplain fishery (mean= 820,053 tonnes; SD= 13,383; SE as a percentage of the mean= 0.05 %). The 'boom and bust' variation of some inland fisheries predisposes their basin fish catches to have varying levels of uncertainty, which has been considered.

Underreporting of inland fish catch (i.e. where the summation of river basin catch estimates were higher than unadjusted officially reported national data in 2010) are prevalent, and is not geographically restricted (Figure 6; Supplementary Material Table S1). The estimated underreporting or unaccounted national production totalled 4.1 million tonnes, with the largest underreporting in South and South East Asia (424,713 tonnes and 2.5 million tonnes, respectively), Brazil (407,828 tonnes) and Kenya (207,156 tonnes) (Figure 6; Supplementary Material Table S1).

4. Discussion

This study uses information collated from peer review and grey literature to account for global inland fish catch from different river basins and hydrobasins, and to establish an alternative estimate of global inland fish catch. A picture emerges of where the world's inland fisheries occur according to basin boundaries and sub-boundaries (Figure 4). The information suggests fish catches from river basins, lakes and hydrobasins, with the addition of adjusted missing country data, could be up to 17.4 million tonnes. This is 60% higher than the FAO 2010 reported global inland fisheries catch of 10.8 million tonnes based on national reports. This figure is also consistent with the estimated inland fisheries catch (16.6 million tonnes) of Fluet-Chouinard et al., (2018), which extrapolated a model based on household consumption survey data. This figure is, however, higher than the "Big Numbers Project" which estimated global inland fish catch in 2010 based on a limited number of case studies and extrapolations as 13 million tonnes (World Bank, 2012), but our study includes estimates of subsistence fishing from the literature, which was missing in the "Big Numbers Project".

The basin approach to global inland capture fisheries provides a meaningful level of analysis for the catch of inland fisheries from contiguous river and lake systems that transcend national boundaries. It also allows the identification of the key fisheries that lie within a productive basin (i.e. most productive; important commercially or that are biodiversity hotspots), and allows us to understand how different components of the fisheries provide relative contributions to food security, livelihoods or biodiversity. For example, fish catches were particularly high around areas of high rural population density, where the people are able to exploit these resources, where there is a strong culture of fish consumption, or where the local climate, economy or religion restrict the rearing of livestock.

The information collated in this study was reported from a wide range of years (1960-2018). Although the median year of the study was 2010, there was variation between individual basins (Supplementary Material Table S2). Consequently, this study requires us to accept data from a wider timeframe than would be typically considered when reporting fishery catches. Irrespective, when considering time stamped fish catch data the majority of inland fisheries statistics (95%) from reports and information from literature reviews are from after the year 2000, 50% post 2010 and 38% are from the last five years of this study period (2014-2018) (Supplementary Material). Only in some extreme cases did catch estimates (6% of time stamped data) span nearly four decades (1960-1999). Nevertheless, current country level aggregated inland fisheries catch statistics are sufficient to offer an overview of global inland fish catches as part of a global account for food production. They do not, however, provide sufficient resolution for detailed analysis that might infer trends in individual fisheries or even the state of fisheries overall within all but the smallest countries.

More than 14,953 fish species inhabit permanent or occasional freshwater systems (Tedesco et al., 2017), but only approximately 300 taxa, which form commercial fisheries or fisheries of sufficient volume to warrant reporting, are included in FAO fisheries statistics. This is considered a small proportion of the potential number of species being targeted (FAO, 2011). Of potential concern with regards reporting is the increasing proportion of unidentified fish catch recorded as freshwater fish, freshwater crustaceans and freshwater molluscs *not elsewhere identified* (‘nei’), which has averaged 59% (SD= 3.49%) of the total inland fisheries catch reported annually between 1950 and 2019. With over half of the total global inland fishery catch unidentified, this prevents deeper analysis of trends in the catch of many species that form commercially important fisheries.

The data compiled in this study were considered the best data available at the time of this study. Fisheries are highly variable, driven by a range of environmental variables (Welcomme et al., 2010; Lorenzen et al., 2016), and new studies and assessment methods may derive more reliable catch estimates. Thus, if this study was done again, it is likely the estimate of global fish catches would vary as the fisheries are all in varying states of exploitation and change brought about by changing environments, resource exploitation and economic development (Reid et al., 2019). Some of the world’s most productive fisheries are undergoing a decline in fish catches. The recent 10-year fishing ban introduced on the Yangtze River to protect China’s ‘mother river’ (Mei et al., 2020), for example, has resulted in a precipitous decline in China’s reported inland fisheries catch from 2.2 million tonnes in 2017 to 1.4 million tonnes in 2020 and is expected to decline even further (FAO, 2022). In India and Bangladesh, barrage construction and water quality issues have led to a decline in fisheries in the Ganges- Brahmaputra River (DoF, 2012). Predictions of lost catch arising from hydropower construction in the

Mekong River range from 238,000 tonnes to 880,000 tonnes (ICEM, 2010; DHI HDR, 2015). Indeed, many of the major river basins of the world have planned or ongoing dam construction projects driven the desire for 'green energy', which will inevitably obstruct fish migration and affect river flows and flooding and hence impact important inland fisheries (Winemiller et al., 2016). Given the declining or stagnating fish catch from basins and countries that contain the most productive fisheries, it is not unreasonable to state that the estimated catch of 17.8 million tonnes in 2010 may likely represent the historic maximum of global inland fish catch.

There are particular characteristics that predispose inland fisheries to underreporting in many countries and there is little doubt that inland capture fisheries are still under reported in many regions, particularly in South America, Africa and Asia (Figure 6) (Bartley et al*.,* 2015). The drivers of this underreporting include the fisheries being highly seasonal, small-scale, highly dispersed, multi-species, multi-gear, often for household consumption, and part of a diversified livelihoods strategy. As a consequence, accurate assessment is difficult, and the status of some fisheries resources is often poorly understood or unknown (Lynch et al., 2017).

Underreporting identified in this study was highest in Thailand at 0.97 million tonnes (Supplementary Material Table S1) because floodplain, swamp and river catches from the Mekong and Chao Praya basins are not effectively incorporated into national statistics and may be underestimated by at least a factor of five (Lymer et al., 2008). The modelled estimate of inland fisheries production from Thailand of 1.1 million tonnes per year documented in Lymer et al., (2008) is in line with river basin estimate from this study of 1.1-1.3 million tonnes.

Development policies and unrealistic or imposed production targets can also result in rapid and continued growth of fisheries statistics, rather than actual increases in fish catch. National statistics in Myanmar appear to have been adjusted to meet the targets of a 30-year fisheries plan (Funge-Smith, 2016; Baran et al., 2017). Although FAO downscaled the national reported data post 2009, fish catches have still increased with a consistent increment year on year. Therefore, the inland catch estimated by FAO for Myanmar which, is 0.2 million tonnes lower than that of the aggregated basin catches (Supplementary Material Table S1), is likely as a result of inherent issues with overestimated national reporting which has not been downscaled like the data recorded by FAO has.

Selective data recording from only the largest or most commercially important sites, such as markets or commercial operations, is prevalent in large rivers such as the Amazon and the Mekong. In Brazil, where underreporting was estimated at 0.4 million tonnes (Supplementary Material Table S1), attempts to collect fish data from isolated communities spread over a large area is challenging and subsistence catches are largely unrecorded in Amazonas State (Junk, 2007; Issacs and Almeida, 2011). In another case, analysis of commercial inland fish catches in the USA, revealed that the commercial inland fish catches of several interior states were not incorporated into routine national reports of inland fish catch. The revised commercial inland catch was nearly double that reported (Murray et al., 2020).

Many countries appear to lack the financial or human resources to collect appropriate fish catch data on inland waterbodies. In Tanzania, national fisheries estimates are below the catch estimates for Lake Victoria alone, which are reported by the Lake Victoria Fisheries Organisation (mean lake catch from Tanzania was 316,797 tonnes compared with the national figure for all fisheries in the country of 312,228 tonnes). Catch recording at landing sites is either non-existent or the data produced are unreliable; generally, the lack of financial resources and incentives instils little confidence in the catch statistics (Welcomme and Lymer, 2012).

Recreational fishing catches are also rarely accounted for in inland fisheries statistics (Cooke and Cowx, 2004; Cooke et al., 2018; Embke et al., 2022); even though FAO has requested countries to report retained recreational fish catch since 1995. The absence of recreational fisheries data in national statistics appears to contribute to underreporting in Finland, Sweden, Australia, New Zealand and South Africa (underreporting ranged from 2,426 tonnes to 12,078 tonnes), where fisheries harvest estimates were mainly based on recreational data.

Subsistence fisheries and catches that pass through informal markets are also largely unaccounted for as they are highly seasonal or geographically dispersed, but recent studies suggest these catches can represent a significant contribution to food security (Welcomme et al. 2010; Bower et al., 2019; Embke et al., 2019; Embke et al., 2022). There is also potential confusion of source of catch in a number of Asian countries, with fish catches from some stocked or enhanced water bodies reported as either aquaculture or wild capture fisheries. The wild component of a culture-based fishery may be reported as aquaculture catch, thus understating the contribution of inland wild capture fisheries. Enhanced fisheries are considered capture for statistical purposes, but true culture-based fisheries are statistically considered to be a form of aquaculture. Both maybe reported as capture fisheries (de Silva et al., 2003) or as aquaculture, depending on the country. Fish caught for household consumption or away from formal markets, probably accounts for a large quantity of unrecorded fish catch in many regions. River basin consumption surveys consulted in this study (Amazon and Mekong rivers) suggest river basin fish catch is considerably higher than nationally reported fish catches (Issacs and Almeida, 2011; So et al., 2015).

The lack of accurate information on catches and catch composition, as well as limited sub-national, downscaled trend information gives rise to a range of opinions and perspectives on the state of inland fisheries. These range between a view that a decline of inland fisheries is inevitable in the face of population increase and multiple threats to inland water systems (Friend et al*.,* 2009), to a more positive outlook that hidden inland fisheries are more productive and resilient than previously thought (Bartley et al., 2015). Not all inland fisheries are in decline, as suggested by the continuously increasing aggregate trend in global inland fisheries catch. However, it must be considered that some increases in catch could be attributed to improved reporting at a country level and might not represent actual long-term increases in fish catches (FAO, 2018). Overall increasing global catch could may still mask declines in one or more river basin fisheries. Conversely, enhancement or management measures may be increasing fish catches in reservoirs and man-made water bodies, contributing to real increases in national inland fish catches.

To provide a perspective of the status and trends in inland fisheries across the globe, it is recommended that a number of sentinel fisheries based on key river basins is established. There are few examples of the sentinel fishery survey approach being used in inland waters, although sentinel species have been used as indicators of regional stock status or as indicators of environmental disturbance in freshwater ecosystems (Gibbons and

Munkittrick, 1994; Christophe et al., 2015; ICES, 2018). A subset of river basins or elements of a fishery developed under a sentinel fisheries monitoring programme, such as those set up for “index” or “monitored” salmon rivers in the ICES region (ICES, 2021), could provide much needed continuous records of otherwise data-poor fisheries and indicate the overall state of a river basin’s fisheries. Sentinel fisheries act as indicators for other similar, but less well-monitored fisheries in the same region, and allow for cost-effective real-time management and condition assessment of fisheries (Fishing into the Future, 2017, Henry et al., 2020).

Proposals for a subset of river basins, lakes or fishery elements that would be suitable for a global sentinel inland fisheries catch monitoring programme can be identified from fisheries catch estimates from this study (Table 5). Those nominated constitute 29-43% of the inland fisheries catches estimated from this study and are representative of the range of inland fisheries on each continent. These sentinel fisheries make major contributions to food and nutritional security, exhibit high levels of employment or dependence provided by the fisheries, are based on multiple species fisheries and where specific fisheries are predicted to be impacted by major threats or pressures in the foreseeable future. It is critical that these sentinel sites are monitored using robust, standardised methodologies (Lorenzen et al., 2016), and data on specific indicators of the status of the fisheries (e.g. total catch by species, catch per unit effort of primary gears, change in species composition of catch and size of fish caught) are reported annually to FAO as part of the annual reporting activities. It may be necessary for international donor agencies, NGOs or CSOs to support these activities in countries where resources and human capacity are weak.

5. Conclusions

The contribution of inland fisheries to food security, livelihoods and provision of other ecosystem services such as recreational fisheries, is now becoming increasingly recognised (Cooke et al., 2016; Funge-Smith and Bennett, 2019). Understanding the status and trends of inland fisheries in individual water bodies, nationally and globally is important, but currently lacking in all but perhaps the largest and most important fisheries. Inland fisheries are neglected or sometimes invisible in government processes, in which fishers are weakly represented in decision-making or where other water users take precedent (Lynch et al., 2017; Elliott et al.

2022). This study identifies that inland fish catches likely peaked at around 17.4 million tonnes in 2010, and have subsequently declined owing to the fall in catches of some of the world's largest and most productive fisheries. This study also identifies key inland food fisheries and their relative contributions to inland fisheries at a basin and also global level.

This work only scratches the surface when it comes to identifying the issues regarding data reliability in inland fisheries. Indeed, inland fisheries statistics cannot improve without greater institutional support and investment for fisheries management. Lorenzen et al., (2016) identified three research needs for improved inland fisheries data: wider adoption of quantitative methods in inland fisheries; increased use of comparative studies as more fisheries data become available; and develop indicators of fisheries and environmental status to evaluate trade-offs of conflicting activities.

Solutions to the issues and weaknesses identified would be the next step forward. This could be in the reform and standardisation of the methods of data collection and improvement in species identification, which would inform effective monitoring and management, and would also ensure fisheries data are comparable and suitable for global assessment. Particularly the inclusion of data not usually collected as part of national statistics, such as recreational, subsistence and part-time fisher data, is essential as these sectors likely account for a large portion of unreported catch (5.4% in the case of recreational fisheries) (Ainsworth, 2020, Funge-Smith et al., 2018).

Interrogation of river basin fish catches in this study also indicates how a global monitoring system might be developed. The selection of relevant fisheries for which data are regularly collected to contribute to a global system of sentinel fisheries important for food or biodiversity, or where pressures on the fishery are significant (Table 5). This helps address the limitations of national aggregated statistics as indicators of the state of inland fisheries. Such a system could link to other complimentary systems, such as the USGS basins threat mapping system (FAO, 2021). Integration with the basins threat mapping system would provide a robust assessment framework for inland fisheries, and the associated ecosystems upon which they depend, and provides a visual and quantifiable indication of the relative threats to inland fisheries at the basin, sub-basin and fishery levels.

This system would allow countries to assess the status of their inland fisheries at low cost, which would enable them to plan for future needs in management, food security, livelihoods and recreational impact, and would provide a measure of progress towards the UN Sustainable Development Goals (FAO, 2021).

The FAO recognizes that "inland waters remain the most difficult subsector for which to obtain reliable capture production statistics" (FAO, 2014). Inland fisheries are still perceived as a sector that does not substantially contribute to global food production and are frequently treated as economically unimportant and a by-product of freshwater earmarked for other use. The analysis in this paper and Ainsworth et al. (2021) challenges this preconception and presents the large breadth of information about inland fisheries that is available and contributes to the growing effort to improve knowledge and valuation of inland fisheries globally.

6. Acknowledgments

The authors would like to thank Dr Andy Nunn for providing feedback on the abstract, and also the reviewers whose feedback has improved this paper. Also thank you to FAO who funded the FAO circular C942 on which this paper is based. The authors know of no conflicts of interest regarding this paper.

7. Data Availability Statement

The data that support the findings of this study are openly available data from open sources published from Ainsworth (2020) and Ainsworth et al., (2021) and are presented in the Tables (1-4) and supplementary material table (S1 & S2).

8. References

Ainsworth, R.F. (2020). Fish and Food Security: Global Valuation of Inland Fisheries to Food Security. PhD Thesis, University of Hull, UK.

Ainsworth. R.F., Cowx, I.G. & Funge-Smith, S.J. (2021). A review of major river basins and large lakes relevant to inland fisheries. *Fisheries and Aquaculture Circular*, No. C942 Rev 3, Rome, FAO, 325pp. doi.org/10.4060/cb2827en

Allan, J.D., Abell, R., Hogan, Z., Revenga, C., Taylor, B.W., Welcomme, R.L. & Winemiller, K. (2005). Overfishing of Inland Waters. *Bioscience*, 55, 1041- 1051.

Baran, E., Joffre, O., Gätke, P., Ko, W., Wah, Z.Z., & Soe, K.M. (2017). Summary report on fisheries in the Ayeyarwady Basin. *Ayeyarwady State of the Basin Assessment (SOBA) Report 4.1*. National Water Resources Committee, Myanmar.

Bartley, D.M., De Graaf, G.J., Valbo-Jørgensen, J. & Marmulla, G. (2015). Inland capture fisheries: status and data issues. *Fisheries Management and Ecology*, 22, 71-77. doi.org/10.1111/fme.12104

Bayley, P.B., Vasquez, P., Ghersi, F., Soini, P. & Pinedo, M. (1992). Environmental review of the Pacaya Samiria National Reserve in Peru and assessment of project 527-0341. *Arlington: The Nature Conservancy.*

Béné, C. (2007). Diagnostic study of the Volta Basin fisheries. Focal Basin Project -Volta. Report No. 1: Overview of the Volta Basin fisheries resources. WorldFish Centre, Penang, Malaysia.

Bower, S.D., Song, A.M., Onyango, P., Cooke, S.J. & Kolding, J. (2019). Using transdisciplinary research solutions to support governance in inland fisheries. In R. Chuenpagdee & S. Jentoft (Eds). *Transdisciplinarity for small-scale fisheries governance* (pp. 341-355). Springer, Cham. doi: 10.1007/978-3-319-94938-3_18

Christensen, M.S. (1993a). The artisanal fishery of the Mahakam River floodplain in East Kalimantan, Indonesia: I Composition and price of landings, catch rates of various gear types including trends in ownership. *Journal of Applied Ichthyology*, 9, 185–192. doi.org/10.1111/j.1439-0426.1993.tb00394.x

Christensen, M.S. (1993b). The artisanal fishery of the Mahakam River floodplain in East Kalimantan, Indonesia: III Actual and estimated yields, their relationship to water levels and management options. *Journal of Applied Ichthyology,* 9, 202–209. doi.org/10.1111/j.1439-0426.1993.tb00396.x

Christophe, M., Rachid, A. & Mario, L. (2015). Fish as reference species in different water masses. In: C. Amiard_Triquet, J-C, Amiard & C Mouneyrac (eds) *Aquatic Ecotoxicology, advancing tools for dealing with emerging risks* (pp. 309-331). Academic Press.

Coates D. (2002). Inland Capture Fishery Statistics of Southeast Asia: Current Status and Information Needs. Asia-Pacific Fishery Commission, Bangkok, Thailand. RAP Publication No. 2002/11, 114 p.

Coates, D. (1985). Fish yield estimates for the Sepik River, Papua New Guinea, a large floodplain system east of 'Wallace's Line'. *Journal of Fish Biology*, 27, 431–443. doi.org/10.1111/j.1095-8649.1985.tb03191.x

Cooke, S.J., Allison, E.H., Beard, T.D., Arlinghaus, R., Arthington, A.H., Bartley, D.M., Cowx, I.G., Fuentevilloa, C., Leonard, N.J., Lorenzen, K., Lynch, A.J., Nguyen, V.M., Youn, S-J., Taylor, W.W., & Welcomme, R.L. (2016). On the sustainability of inland fisheries: Finding a future for the forgotten. *Ambio*, 45, 753- 764. doi.org/10.1007/s13280-016-0787-4

Cooke, S.J., Twardek, W.M., Lennox, R.J., Zolderdo, A.J., Bower, S.B., Gutowsky, F.F.G., Danylchuk, A.J., Arlinghaus, R., & Beard, D. Jr. (2018). The nexus of fun and nutrition: recreational fishing is also about food. *Fish and Fisheries*, 19, 201-224. doi.org/10.1111/faf.12246

Cooke, S.J. & Cowx, I.G. (2004). The role of recreational fishing in global fish crises. *BioScience*, 54, 857–859. doi.org/10.1641/0006-3568(2004)054[0857:TRORFI]2.0.CO;2

Cowx, I.G., Van der Knaap, M., Muhoozi, L.I & Othina, A. (2003). Improving fishery catch statistics for Lake Victoria. *Journal of Ecosystem Health and Management,* 6, 299-310. doi.org/10.1080/14634980301490

Deines, A.M., Bunnell, D.B., Rogers, M.W., Bennion, D., Woelmer, W., Sayers, M.J., Grimm, A.G., Shuchman, R.A., Raymer, Z.B., Brooks, C.N., Mychek- Londer, J.G., Taylor, W. & Beard, D.Jr. (2017). The contribution of lakes to global inland fisheries harvest. *Frontiers in Ecology and the Environment*, 15, 293-298. doi.org/10.1002/fee.1503

De Silva, S.S., Moehl, J., Satia, B., Bartley, D. & Subasinghe, R. (2003). Inland fisheries and aquaculture: a synergy for sustainable food fish production. FAO Fisheries Circular, 886, Rev 2, Rome, FAO, 37-45.

Elliott, V.L., Lynch, A.J., Phang, S.C., Cooke, S.J., Cowx, I.G., Claussen, J.E., Dalton, J., Darwell, W., Harrison, I., Murchie, K.J., Steel, A,E. & Stokes, G.L. (2022). A future for the inland fish and fisheries hidden within the sustainable development goals. *Frontiers in Environmental Science*, 10, 756045. doi: 10.3389/fenvs.2022.756045

Embke, H. S., Rypel, A. L., Carpenter, S. R., Sass, G. G., Ogle, D., Cichosz, T., Hennessy, J., Essington, T. E., & Zanden, M. J. V. (2019). Production dynamics reveal hidden overharvest of inland recreational fisheries. *Proceedings of the National Academy of Sciences*, 116, 24676–24681. doi.org/10.1073/pnas.1913196116

Embke, H.S., Elizabeth A. Nyboer, Ashley M. Robertson, Robert Arlinghaus, Shehu L. Akintola, Tuncay Atessahin, Laamiri Mohamed Badr, Claudio Baigun, T. Douglas Beard, Jr., Gergely Boros, Shannon D. Bower’ Horacio Clare, Steven J. Cooke, Ian G. Cowx, Adolfo Franco, Linda Grapci-Kotori, Vladimir Puentes Granada, Robert John Hart, Carlos R. Heinsohn, Henry Henley, Vincent Jalabert, Andrzej Kapusta, Tibor Krajc, John D. Koehn, Gonçalo Lopes, Roman Lyach, Terence Magqina, Marco Milardi, Juliet Nattabi, Andrew Nightingale, Hilda Nyaboke, Sui Phang, Warren M. Potts, Rajeev Raghavan, Filipe Ribeiro, Norman Mercado-Silva, Naren Sreenivasan, Andy Thorpe, Tomislav Treer, Didzis Ustups, Pavel Vrána, Olaf L.F. Weyl, Louisa E. Wood, Mustafa Zengin, Abigail J. Lynch’ (2022) Global dataset of species specific inland recreational fisheries harvest for consumption. Scientific Data, 9,488. doi.org/10.1038/s41597-022-01604-y

FAO (2010). State of the World’s Fisheries and Aquaculture. Rome: Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2011). Review of the State of the World Fishery Resources: Inland Fisheries. FAO Fisheries and Aquaculture Circular No. 942, Rev. 2. Rome, FAO. 97 pp

FAO, (2014). State of World Fisheries and Aquaculture. Opportunities and Challenges. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (2017). FAO Global Capture Production database updated to 2015 - Summary information. Food and Agricultural Organisation of the United Nations, Rome, Italy.

FAO (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Food and Agricultural Organisation of the United Nations, Rome, Italy.

FAO (2020). Fisheries and Aquaculture Statistics Branch. Food and Agricultural Organisation of the United Nations, Rome, Italy.

FAO (2021). Report of the Second Advisory Roundtable on the Assessment of Inland Fisheries, Rome, 25–27 November 2019. FAO Fisheries and Aquaculture Report No. 1314. Rome. doi.org/10.4060/cb2196en

FAO (2022). FAO yearbook. Fishery and Aquaculture Statistics 2020. Food and Agricultural Organisation of the United Nations, Rome, Italy.

FAO & WorldFish Centre (2008). Small-scale capture fisheries: A global overview with emphasis on developing countries. Big Numbers Project. Preliminary Report. FAO Rome; WFC, Penang; World Bank, Washington D.C, 64.

Fishing into the Future (2017). Sentinel Surveys Briefing Paper. Fishing in the Future. Online: Accessed chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.fishingintothefuture.co.uk%2Fwp-content%2Fuploads%2F2017%2F07%2FWP3-FitF-Sentinel-Survey-Briefing-Paper-2.pdf&clen=407095&chunk=true

Fluet- Chouinard, E., Funge- Smith, S.J, & McIntyre, P.B. (2018). Global hidden harvest of freshwater fish revealed by household surveys. *Proceedings of the National Academy of Sciences*, 115, 7623-7628. doi.org/10.1073/pnas.1721097115

Friend, R., Arthur, R., & Keskinen, M. (2009). Songs of the doomed: The continued neglect of capture fisheries in hydropower development in the Mekong. In: Molle, F., Foran, T., Käkönen, M. (eds) *Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance*. Earthscan, London, 307-332 p. doi.org/10.4324/9781849770866

Froese, R., Zeller,D., Kleisner,K., & Pauly, D. (2012) What catch data can tell us about the status of global fisheries. *Marine Biology*, 159, 1283-1292. doi.org/10.1007/s00227-012-1909-6

Funge-Smith, S. J. (2016). How National Household Consumption and Expenditure Surveys Can Improve Understanding of Fish Consumption Patterns within a Country and the Role of Inland Fisheries in Food Security and Nutrition. In W. W. Taylor, D. M. Bartley, C. I. Goddard, N. J. Leonard & R. Welcomme (Eds.). *Freshwater, fish and the future: Proceedings of the global cross-sectoral conference* (pp. 121-130). Rome, Italy, East Lansing, MI and Bethesda, MD: Food and Agriculture Organization of the United Nations, Michigan State University and American Fisheries Society.

Funge-Smith, S.J, (2018). Summary of Global Inland Fisheries. In S.J. Funge-Smith (eds). *Review of the state of World Fishery resources: inland fisheries.* FAO Fisheries and Aquaculture Circular No. C942 Rev.3, Rome. 397 pp.

Funge-Smith, S.J., Beard, D., Cooke, S. & Cowx, I.G. (2018). Recreational fisheries in inland waters. In: S.J. Funge-Smith (eds). *Review of the state of World Fishery resources: inland fisheries.* FAO Fisheries and Aquaculture Circular No. C942 Rev.3, Rome. 397 pp.

Funge-Smith, S. & Bennett, A. (2019). A fresh look at inland fisheries and their role in food security and livelihoods. *Fish and Fisheries*, 20, 1176-1195. doi.org/10.1111/faf.12403

Gibbons, W.N. & Munkittriek, K.R. (1994). A sentinel monitoring framework for identifying fish population responses to industrial discharges. *Journal of aquatic ecosystem health*, 3, 227-237. doi.org/10.1007/BF00043244

Government of India (2014). Handbook on Fisheries Statistics 2014. Government of India Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi.

Harrod, C., Ramírez, A., Valbo-Jorgensen, J., Funge-Smith, S. (2018) Chapter 18: How climate change impacts inland fisheries. In Barange, M. Bahri, T. Beveridge, M. Cochrane, K.L. Funge-Smith, S. & Poulain, F., (eds) *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options.* FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628p.

Henry, A.M., Carlucci, J., Rodrigue, M., Linner, R., & Chen, Y. (2020). Developing a longline/ jig sentinel survey program for an area with limited monitoring and fishing efforts. *Aquaculture and Fisheries*, 5, 139-147. doi.org/10.1016/j.aaf.2019.12.006

ICES. (2018). Report of the Working Group on North Atlantic Salmon (WGNAS), 4–13 April 2018, Woods Hole, MA, USA. ICES CM 2018/ACOM: 21. 386 pp.

ICES. (2021). North Atlantic salmon stocks In Report of the ICES Advisory Committee, 2021. ICES Advice 2021.

INFOFISH (2022) Small scale fisheries come into focus. INFOFISH International. Online. Access via: https://www.fao.org/fileadmin/user_upload/ssf/documents/THE_ILLUMINATING_HIDDEN_HARVEST.pdf

Isaac, V.J. & Almeida, M.C. (2011). El consumo de pescado en la Amazonía Brasileña. COPESCAALC Documento Ocasional. No 13. Rome, FAO. 43 p.

Junk, W.J. (2007). Freshwater fishes of South America: Their biodiversity, fisheries, and habitats - a synthesis. *Aquatic Ecosystem Health and Management*, 10, 228-242. doi.org/10.1080/14634980701356733

Khan, M.N. (2015). Review of the decline of artisanal fisheries along the Arabian Sea Coast, Pakistan. In K.J. Murchie & P.P. Daneshgar, (eds). *Mangroves as fish habitat*. Bethesda, Maryland, American Fisheries Society, Symposium 83. doi.org/10.47886/9781934874424.ch5

Kolding, J. & van Zwieten, P.A.M. (2014). Sustainable fishing of inland waters. *Journal of Limnology*, 73,128-144. doi.org/10.4081/jlimnol.2014.818

Lorenzen, K., Cowx, I.G., Lester, N.P., Koehn, J.D., Randall, R.G., So, N., Bonar, S.A., Bunnell, D.B. Venturelli, P., Bower, S.D. & Cooke, S. J. (2016). Stock assessment in inland fisheries: a foundation for sustainable use and conservation. *Reviews in Fish Biology and Fisheries*, 26, 405-440. doi.org/10.1007/s11160-016-9435-0

Laë, R., Williams, S., Malam Massou, A., Morand, P., Mikolasek, O. (2004). Review of the present state of the environment, fish stocks and fisheries of the River Niger (West Africa). In Welcomme, R & Petr, T (eds) *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining livelihoods and biodiversity in the new millennium*. *Vol. I.* Rome , FAO, pp. 199-277.

Lesack, L.F.W. (1986). Estimates of catch and potential yield for the riverine artisanal fishery in The Gambia, West Africa. *Journal of Fisheries Biology*, 28: 679–700. doi.org/10.1111/j.1095-8649.1986.tb05203.x

Lymer, D., Martin, F., Marmulla, G. & Bartley, D.M. (2016). A global estimate of theoretical annual inland capture fisheries harvest. In Taylor, W.W., Bartley, D.M., Goddard, C. I., Leonard, N.J. & Welcomme, R.L. (eds) *Freshwater, Fish and the future. Proceedings of the global cross-sectoral conference.* Food and Agriculture Organization of the United Nations, Rome; Michigan State University, East Lansing; and American Fisheries Society, Bethesda, Maryland, pp. 63-75.

Lymer, D., Funge-smith, S., Khemakorn, P., Naruepon, S. & Ubolratana, S. (2008). A review and synthesis of capture fisheries data in Thailand – Large versus small-scale fisheries. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2008/17, 51 pp.

Lynch, A.J., Cooke, S.J., Deines, A.M., Bower, S.D., Bunnell, D.B., Cowx, I.G., Nguyen, V.M., Nohner, J., Phouthavong, K., Riley, B. & Rogers, M.W. (2016). The social, economic, and environmental importance of inland fish and fisheries. *Environmental Reviews*, 24, 115-121. doi.org/10.1139/er-2015-0064

Lynch, A.J., Cowx, I.G., Fluet-Chouinard, E., Glaser, S.M., Phang, S.C., Beard, D. Jr., Bower, S.D., Brooks, J.L., Bunnell, D.B., Claussen, J,E., Cooke, S.J., Kao, Y-C., Lorenzen, K., Myers, B.J.E., Reid, A.J., Taylor, J.J., & Youn, S-J. (2017). Inland fisheries - Invisible but integral to the UN Sustainable Development Agenda for ending poverty by 2030. *Global Environmental Change*, 47, 167-173. doi.org/10.1016/j.gloenvcha.2017.10.005

Murray, D.N., Bunnel, D.B., Rogers, M.W., Lynch, A.J., Beard Jr, D., (2020). Trends in inland commercial fisheries in the United States. *Fisheries Magazine*, 45, 585-596. doi.org/10.1002/fsh.10483

Mei, Z., Peilin, C., Wang, K., Wei, Q., Barlow, J. & Wang, D. (2020). A first step for the Yangtze. *Science,* 367,1314p. doi: 10.1126/science.abb5537

Mora, C., Myers, R.A., Coll, M., Libralato, S., Pitcher, T.J., Sumaila, R.U., Zeller, D., Watson, R., Gaston, K.J & Worm, B. (2009) Management effectiveness of the World’s marine fisheries, *PLOS Biology*, 7. doi.org/10.1371/journal.pbio.1000131

Novoa, D. (2002). Los recursos pesqueros del eje fluvial Orinoco-Apure: Presente y futuro (The fishery resources of the Orinoco-Apure fluvial axis: present and future. Caracas, Venezuela, INAPESCA. (In Spanish)

Nunn, A.D., Cowx, I.G., Frear, P.A. & Harvey, J.P. (2003). Is water temperature an adequate predictor of recruitment success in cyprinid fish populations in lowland rivers?. *Freshwater Biology*, 48, 579-588. doi.org/10.1046/j.1365-2427.2003.01033.x

Ogutu-Ohwayo, R. (2004). Management of the Nile perch, *Lates niloticus* fishery in Lake Victoria in light of the changes in its life history characteristics. *African Journal of Ecology*, 42: 306–314. doi.org/10.1111/j.1365-2028.2004.00527.x

Pauly, D.P. & Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communication*, 7, 10244. doi.org/10.1038/ncomms10244

Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J. & Smol, J.P. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, 94, 849-873. doi.org/10.1111/brv.12480

SEPEC (2017). (Colombian Fisheries Statistical Service) (2017) Graphic Reports and Landed Catches. Bogota, Government of Colombia [online] http://sepec.aunap.gov.co/InformesAvanzados/Index2 Accessed 03/05/2017.

Schubert, A., Nyingi, W., Tuda, P., Aura, C.M., Obiero, K., Manyala, J., Cowx, I.G., Vianna, G.M., Ansell, M., Meeuwig, J.J. & Zeller, D. (2022). Reconstructing Kenya's total freshwater fisheries catches: 1950-2017. *Marine and Freshwater Research*, 73, 57–70. doi.org/10.1071/MF21189

So N., Phommakon, S., Vuthy, L., Samphawamana, T., Hai Son, N., Khumsri, M., Peng Bun, N., Sovanara, K., Degen, P., & Starr, P. (2015). Lower Mekong fisheries estimated to be worth around $17 billion a year. *Catch and Culture*, 21. Mekong River Commission.

Sorensen, P.W. & Palomares, M.L.D. (2021). Global inland capture and culture finfishes follow different trends when evaluated by the human development index. *Sustainability*,13, 8420. doi.org/10.3390/su13158420

Swales, S. (2002). Fish and Fisheries of the Fly River, Papua New Guinea: Population changes associated with natural and anthropogenic factors and lessons to be learned. In: B. Harvey (eds). *Biodiversity and Fisheries: A*

Primer for Planners. Proceedings of Blue Millennium Managing Global Fisheries for Biodiversity, World Fisheries Trust, Species Diversity programme; A United Nations Environment Programme online publication. 27 p.

Tedesco, P.A., Beauchard, O., Bigorne, R., Blanchet, S., Buisson, L., Conti, L., Cornu, J-F., Dias, M. S., Grenouillet, G., Hugueny, B., Jézéquel, C., Leprieur, F., Brosse, S., Oberdorff, T. (2017). A global database on freshwater species occurrence in drainage basins. *Scientific Data*, 4, 170141. doi.org/10.1038/sdata.2017.141

Thilsted, S.H., Thorne-Lyman, A., Webb, P., Bogard, J.R., Subasinghe, R., Phillips, M.J. & Allison, E.H. (2016). Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. *Food Policy*, 61, 126-131. doi.org/10.1016/j.foodpol.2016.02.005

Thorpe, A., Zepeda, C., & Funge‐Smith, S. J. (2018) Chapter 5: The economic value of Inland fisheries. In S. J. Funge-Smith (Eds), *Review of the state of world fishery resources: Inland fisheries*. FAO Fisheries and Aquaculture Circular No. C942 Rev. 3. (pp. 216–255). Rome, Italy: Food and Agriculture Organization of the United Nations.

Tufts, B.L., Holden, J. & DeMille, M. (2015). Benefits arising from sustainable use of North America's fishery resources: economic and conservation impacts of recreational angling*. International Journal of Environmental Studies*, 72, 850-868. doi.org/10.1080/00207233.2015.1022987

Welcomme, R.L., Cowx, I.G., Coates, D., Béné, C., Funge-Smith, S., Halls, A. & Lorenzen, K. (2010). Inland capture fisheries. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365: 2881–2896. doi.org/10.1098/rstb.2010.0168

Welcomme R.L. (2011). An overview of global catch statistics for inland fish. *ICES Journal of Marine Science*, 68, 1751–1756. doi.org/10.1093/icesjms/fsr035

Welcomme, R.L. & Lymer, D. (2012). An audit of inland capture fishery statistics – Africa. FAO Fisheries and Aquaculture Circular No. 1051. Rome, FAO. 61 pp.

Winemiller, K.O., McIntyre, P B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N.K., Harrison. I., Stiassny, M.L.J., Silvano, R.A.M., Fitzgerald, J.B., Pelicice, F.M., Agnostinho, A.A., Gomes, L.C., Arantes, C. C., Sousa, L.M., Koning, A.A., Hoeinghaus, D.J., Sabaj, M., Lundberg, J.G., Armbruster,J., Thieme, M.L., Petry, P., Zuanon, J., Torrente Vilara, G., Snoeks, J., Ou, C., Rainboth, W., Pavanelli, C.S., Akama, A., van Soesbergen, A., & Saenz, L., (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science*, 351, 128-129. doi: 10.1126/science.aac70

World Bank (2012). Hidden harvest: The global contribution of capture fisheries. World Bank, FAO and WorldFish Washington.

WorldFish (2015). Annual Report 2014/ 2015. WorldFish, Penang, Malaysia.

Zhao, W. & Shen, H. (2016). A statistical analysis of China's fisheries in the 12th five-year period. *Aquaculture and Fisheries*, 1, 41-49. doi.org/10.1016/j.aaf.2016.11.001

9. Tables

Table 1: Estimated inland Fishery catches attributed to major river basins: 8,720,538-11,392,241 tonnes (50-65% of estimated global inland catch). (*) Indicates where one or more components of fishery catch was estimated using Monte Carlo simulations.

Basin	Catch (t)	Basin	Catch (t)
Mekong River*	1,900,000- 2,331,808	**Senegal River**	30,540
Irrawaddy River*	589,452- 1,207,888	**Don Jiang**	27,210
Yangtze River*	100,000- 1,112,964	**Danube River***	24,188-25,588
Brahmaputra River*	935,089- 981,397	**Ob-Irtysh**	22,834
Amazon River*	653,678-698,678	**Liao He**	22,386
Ganges River	429,540	**Han Jiang**	20,998
Nile River*	419,778-439,546	**Laguna de Bay**	20,400
Chao Phraya	364,216	**Luan He**	20,105
Red (Hong) River*	323,278- 351,674	**Tocantins-Araguaia**	16,360
Niger*	167,000- 326,000	**Casamance River**	15,000
Penner	278,776	**Ural River**	13,631
Yasai	251,376	**Daling He**	12,932
Pearl (Xun-Jiang)	169,836	**Dnieper River**	12,600
Salween River*	110,018- 198,294	**Mahakam River***	12,350-31,000
Indus River*	166,801-242,801	**Brahmani**	12,153
Congo River*	151,51-162,622	**Tapti**	10,235
Domodar	116,443	**Narmada**	9,619
Ziya He	109,149	**Mississippi River***	8,988-11,041
Krishna	106,894	**Magdalena River***	5,808-9,094
Orinoco River*	91,024-127,742	**Rufiji River***	5,500-7,500
Godavari	90,400	**Cross River***	3,500-8,800
Amur River	88,787	**Sepik River***	3,000-5,000
Mahanadi	82,741	**Murray-Darling**	3,433
Zambezi*	73,169-104,543	**Mahi**	3,322
Volta River*	57,091-82,091	**Ogooue River**	2,507
Yonding He	72,110	**Gambia River***	2,350-2,700
Volga River	68,200	**Fly River**	2,350
La Plata	63,849	**Amu Darya River***	1,000-3,000
Lena River	55,434	**Okavango River ***	676-730
Fuchan Jiang	49,137	**Yukon River**	514
Cauvery	47,913	**Dniester River**	500
Min Jiang	42,723	**Balkhash**	459
Yellow (Huang he)	40,476	**Kaladan**	428
Yenesi River	39,014	**Nipigon**	152
Finland (country)*	36,500-40,952	**Kura River**	96
Limpopo River	31,010		

Table 2: Estimated inland fishery catch from large lakes (>400 km^2): 1,697,424-2,188,911 tonnes (9.7-12.6% of estimated total inland fisheries). Note: for total figure some lakes were included in their corresponding river basin fish catch to avoid double counting (Table 1). (*) Indicates where one or more components of fishery catch was estimated using Monte Carlo simulations.

Lake name	Catch (t)	Lake name	Catch (t)
Lake Victoria*	752,024- 1,061,107	**Lake Winnipeg**	6,428
Tonle Sap Lake*	179,500- 246,000	**Lake Edward (Nile)**	6,000
Lake Tanganyika*	164,310-188,380	**Kainji Reservoir**	6,000
Lake Chad*	155,000-184,377	**Philippine Lakes**	5,828
Caspian Sea*	112,950-131,453	**Lake Lagoda**	4,794
Lake Albert (Nile basin)	110,000	**Lagos Lagoon**	4,000
Lake Malawi*	33,000- 44,000	**German Lakes**	3,256
Lake Kyoga (Nile basin) *	15,000-34,700	**Lake Turkana***	3,076-4,413
Great Lakes Basin	19,083	**Lake Tumba**	1,500
Lake Kariba*	7593-19,420	**Lake Onega**	1,430
Egyptian Lakes	12,798	**Lake Toba**	1,150
Lake Van	12,744	**Lake Sevan**	1,000
Lake Taal	11,800	**Great Slave Lake**	1,000
Lake Buluan	11,200	**Lake Langano**	1,000
Lake Titicaca	10,160	**Lake Baikal**	789
Lake Lanao	10,000	**Lake Khövsgöl**	325
Songkhla Lake	9,634	**Shebeli- Juba**	100
Jebel- Aulia Reservoir	8,000	**Mingachevir reservoir**	94
Kossu Reservoir	8,000	**Lake Issyk-Kul**	10
Lake Peipus	6,848		

Table 3: Estimated Inland fishery catch from hydrobasins: 1,730,126 tonnes (9.9% of estimated total inland fisheries production)

Hydrobasin	Catch (t)	Hydrobasin	Catch (t)
China coast	421,159	Madagascar	25,940
Sumatra	152,253	Kalimantan	15,125
Java-Timor	152,253	India North East Coast	14,807
Sulawesi	152,253	North and South Korea	14,333
Mexico-Northwest coast	151,416	Sweden	10,250
India east coast	103,985	Germany	9,000
Gulf of Guinea	76,000	South Africa	7,157
Sabarmati	70,191	Malaysian Peninsula	5,924
Sri Lanka	66,910	Naujan	5,000
India South Coast	62,913	NE South America	1,350
Angola, Coast	38,154	New Zealand	832
India West Coast	35,519	England and Wales	747
Bay of Bengal, Northwest Coast	35,169	Pacific and Arctic coast	509
Japan	32,868	Iceland	201
West Africa coastal	30,700	Ireland	78

Table 4: Unadjusted missing country fisheries data and data from countries lying outside of river basins: 2,347,819- 2,567,232 tonnes (13.4-14.7% of total estimated inland fisheries catch).

Continent	Catch (t)
Africa	613,443- 768,018
Americas	62,461- 64,514
Asia	1,587,075- 1,644,684
Europe	59,938- 60,536
Oceania	7,234
Russian Federation	17,668- 22,246

Table 5: Basins or fishery elements identified as suitable candidates for sentinel fisheries according to region and a reason.

Fishery	Economic	Biodiversity of fishery	More research needed	Food Security	Future or current threats to fishery	Employment provided	Large relative fish catch
Lake Fisheries							
Tonlé Sap Lake	✓			✓	✓	✓	
Philippine Lakes							✓
Africa Rift Lakes (Victoria, Malawi Tanganyika, Turkana, Albert)	✓	✓		✓	✓	✓	✓
Lake Volta				✓	✓		✓
Lake Titicaca			✓				
America Great Lakes	✓			✓	✓		
Caspian Sea		✓			✓		✓
River and floodplain fisheries							
Brahmaputra floodplain fishery			✓	✓			✓
Sudd Swamps			✓				
Niger Central Delta			✓				✓
Delta Fisheries							
Irrawaddy River Delta			✓	✓		✓	✓
Amazon River Delta		✓	✓				
River Fisheries							
Salween River		✓		✓	✓		✓
Yangtze River			✓		✓		✓
Ganges River			✓				✓
Egyptian Nile		✓					✓
Zambezi River				✓	✓		✓
Congo River			✓				
Paraná River					✓		
Orinoco River					✓		
Danube River			✓		✓		
Volga River		✓			✓		
Amur Salmon Fishery	✓						✓

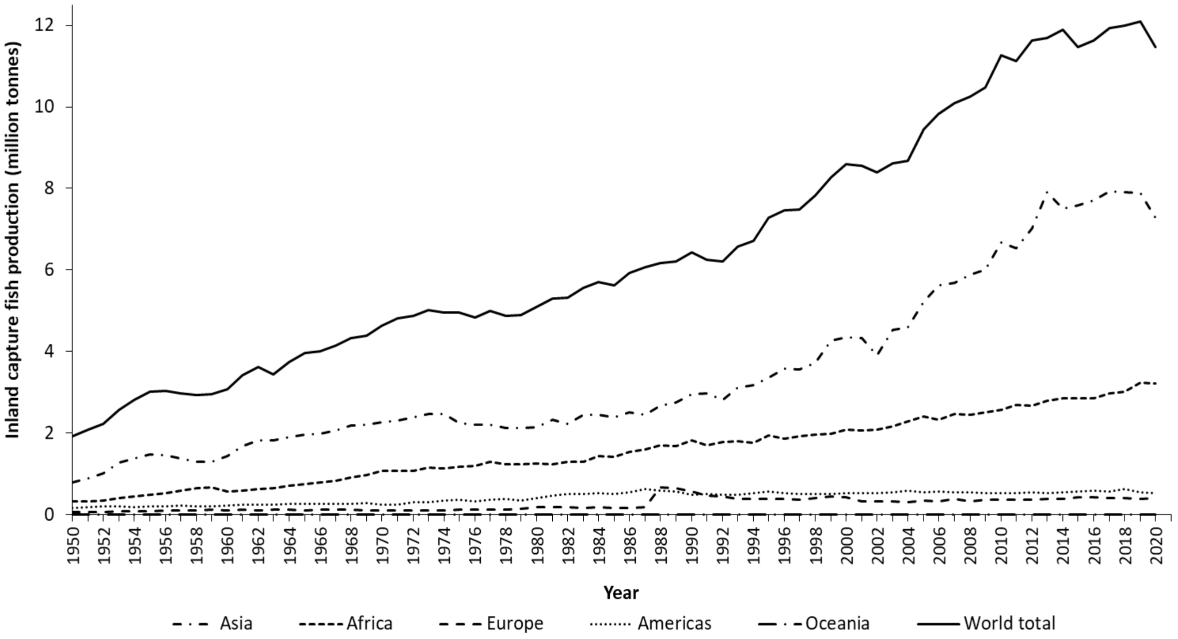

Figure 1: Inland capture fisheries (million tonnes) from 1950 to 2020 by continent and world total (FAO, 2022)

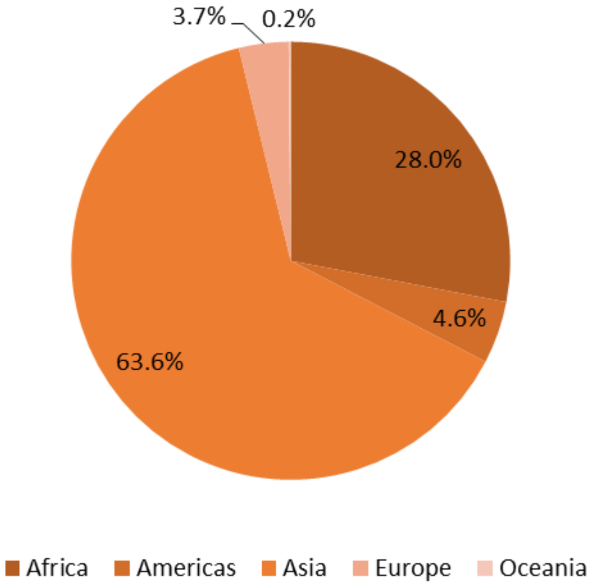

Figure 2: Inland capture fisheries catch by continent in 2020 by percentage total catch (FAO, 2022).

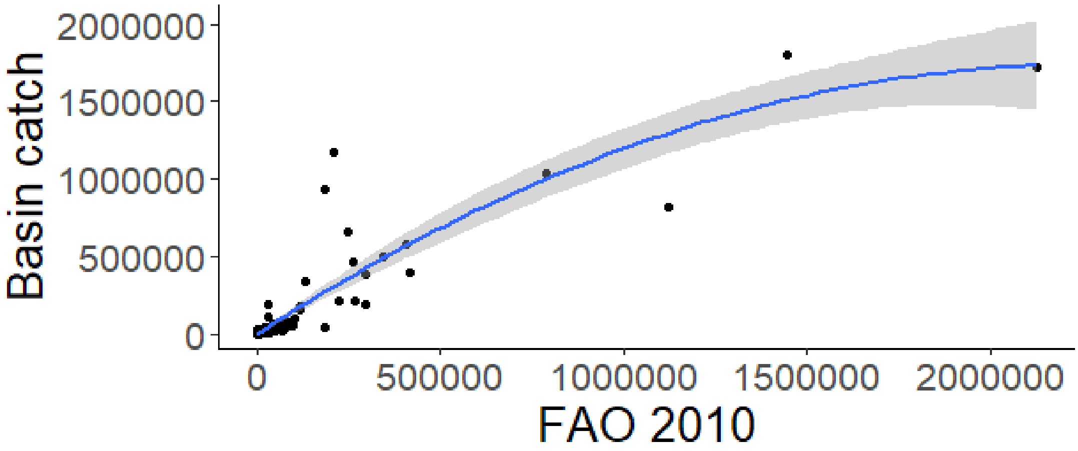

Figure 3: Plot of the non-linear relationship between basin catches aggregated to country level and FAO 2010 data (FAO, 2022), which produces equation 1, $y= -3E\text{-}07x^2 + 1.54x$ (R2=0.81; P= <0.05) used to adjust the missing country data (MC_1, MC_2 and MC_r) in the Monte Carlo simulations. Countries indicated contained some of the most productive inland fisheries. Data used to create this figure are outlined in Supplementary Material Table S1.

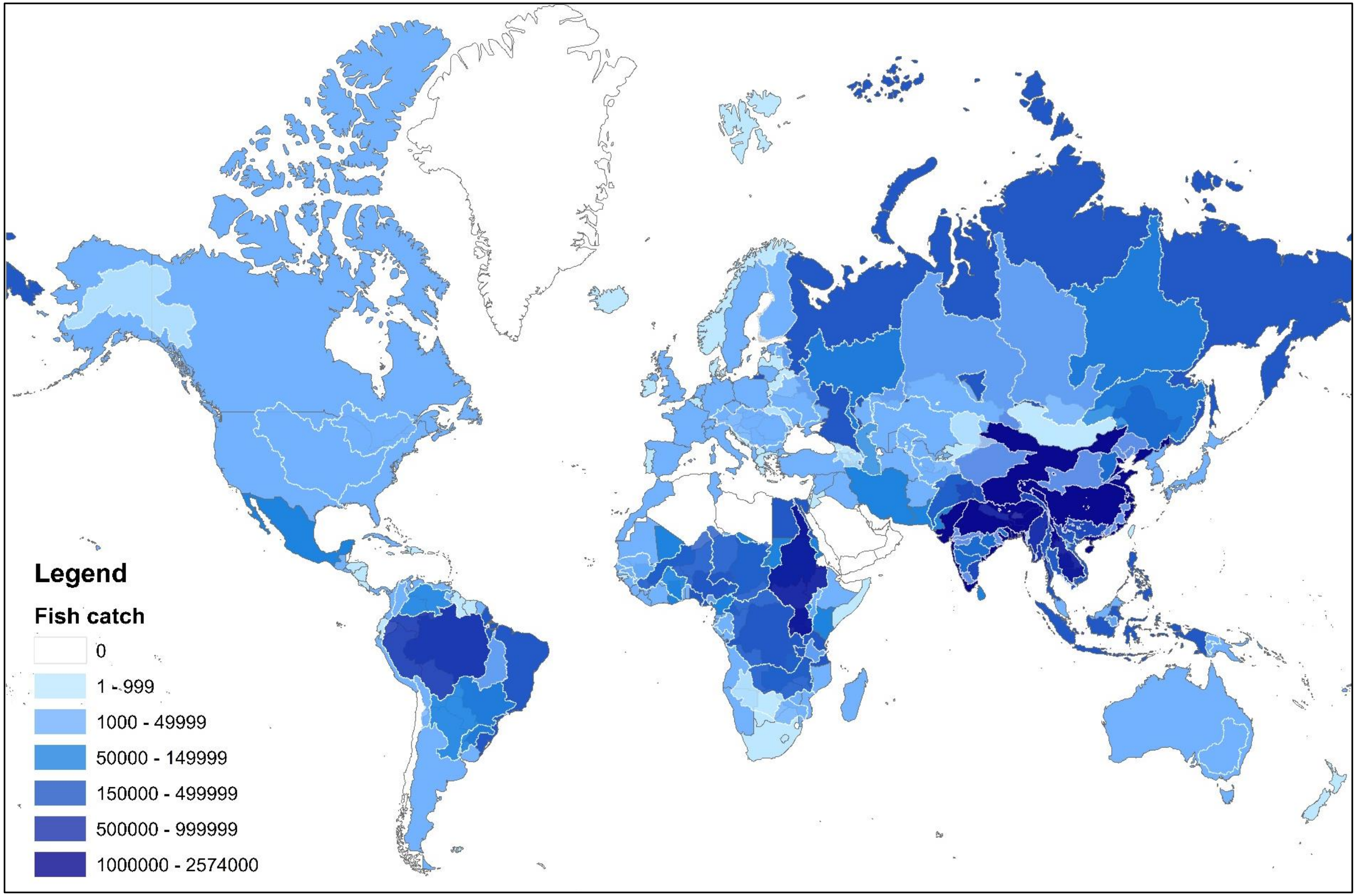

Figure 4: Estimated river basin inland fish catch (tonnes) (blue-scale and white outline) and FAO 2010 inland fish catch by country (blue scale basemap). Note: major lakes are incorporated into its corresponding river basin. Also, for basins with catch ranges the mean catch is presented.

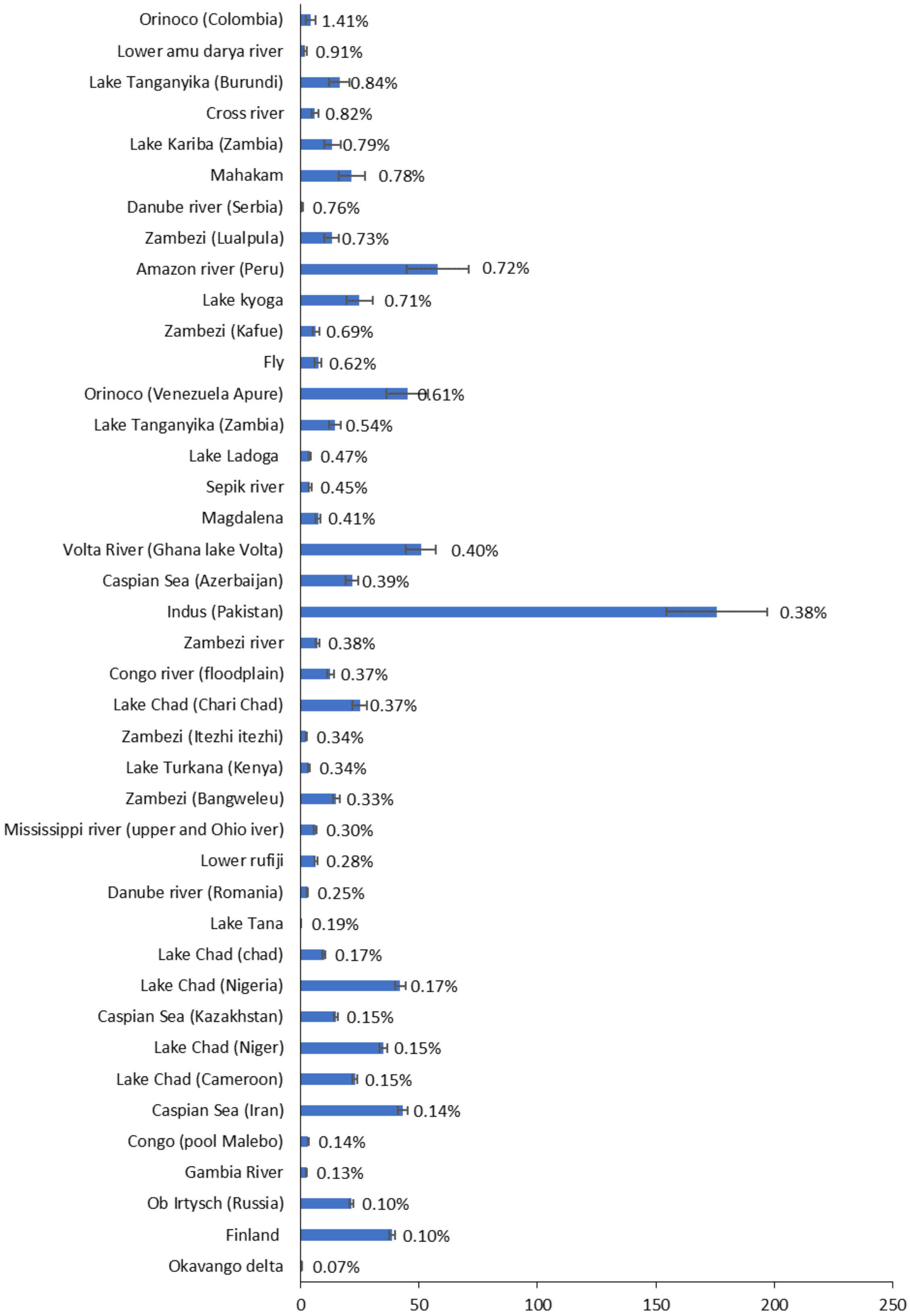

Figure 5: Mean catch (thousand tonnes) of 1000 Monte Carlo simulations of river basin elements (bars) and error bars depicting standard deviation around the mean. Bars ordered bottom to top in descending order of proportional standard error (indicated on figure). Indexed box indicates results of basins with large catches.

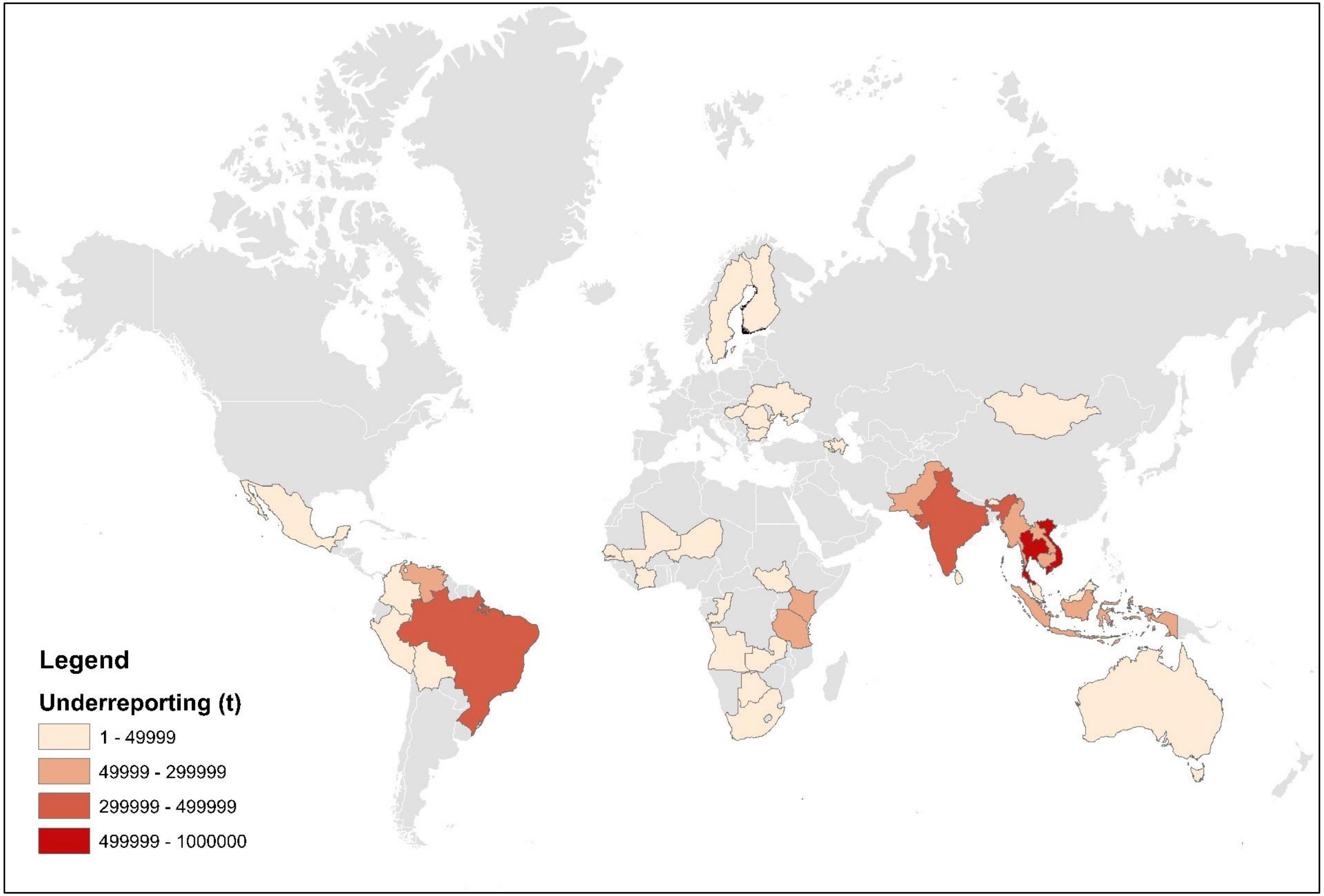

Figure 6: Underreporting of inland fisheries catch by country (i.e. where aggregated river basin catch estimates were higher than FAO 2010 national data) (as set out in Supplementary Material Table S1) (red- scale).

Supplementary material

Estimation of average date of reporting fisheries catch data

The average year of reports of fish catch was calculated for each basin and lake and weighted based on volume of catch (Table S1), to provide a weighted median year for the fish catch estimates along with the date ranges that fish catch data were available for each basin. The overall weighted average year for fish catches used in this study was 2010, which is a reflection of the large fish catches from the Mekong in 2000 and Irrawaddy and Yangtze Rivers in 2014 and 2015, respectively. At a regional level the weighted average fish catch from South America was the lowest with a year of 2007 (range 1980-2013), followed by Africa (weighted average 2009: date range 1960-2015), Asia including China and India (weighted average 2010: date range 1980-2018), North America (weighted average 2014: date range 2005-2018) and Russia (weighted average and date range 2018). Fish data spanned a nearly six decades from 1960 to 2018 and the most common year for which fish data were available was 2014. This partly reflects the delays in reporting and publishing catch data. Fishery data that was not time stamped (no indication of year could be found in the literature) totalled 3.1-3.4 million tonnes, which mainly consisted of historical data and catch estimates from hydrobasins.

Table S1: FAO 2010 and aggregated basin catches that formed Figure 3 and underreporting (where aggregated basin catches were higher than FAO catches) used to create Figure 6.

Country	FAO 2010 catch	Aggregated basin catches	Under reporting (t)
Angola	10,000	29,021	19,021
Armenia	617	1,000	383
Australia	1,376	3,433	2,057
Azerbaijan*	1,131	21,803	20,672
Bangladesh*	1,119,094	822,454.5	
Benin	30,350	5,700	
Bhutan	6	7	1
Bolivia	6,946	11,000	4,054
Botswana*	60	31713	31,653
Brazil	248,122	655,950	407,828
Bulgaria	1,085	14,284	13,199
Burkina Faso	14250	5521	
Burundi	17,305	16,500	
Cambodia*	405,000	583,000	178,000
Cameroon*	68,000	22,900	
Canada	27,385	20,799	
Central African Republic	35,000	5,631	
Chad	91,000	69,937	
China	2,124,668	1,720,540	
Colombia	21,049	45,834	24785
Congo	30,500	37,520	7,020
Congo, Dem, Rep	220,000	208,003	
Côte d'Ivoire	6,763	8,000	1,027
Croatia	456	9	
Egypt	263,847	214,688	
Ethiopia*	18,058	1,501	
Finland*	28,874	38,726	9,852
Gabon	10,400	2,507	
Gambia*	4,654	2,525	
Germany	15,010	12,256	
Ghana*	96,105	55,000	
Guinea*	16,000	4,670	
Hungary	6,216	6,472	256
Iceland	260	201	
India	1,444,153	1,795,714	351,561
Indonesia*	344,902	493,559	148,957
Iran	75,145	43,041	
Ireland	116	78	
Japan	39,844	32,868	
Kazakhstan*	46,827	14,891	
Kenya*	131,943	339,099	267,096
Kyrgyzstan	27	10	
Lao PDR*	30,900	189,500	158,600

Madagascar	35,500	25,940	
Malawi*	98,298	48,250	
Malaysia	4,545	5,924	1,379
Mali*	100,000	100,735	735
Mexico	116,410	151,416	35,006
Mongolia	100	325	225
Mozambique	44,836	20,607	
Myanmar*	785,550	1,040,447	254,897
Namibia	2,800	2,700	
New Zealand	892	832	
Niger*	40,000	47,905	7,905
Nigeria*	293,382	187,002	
Pakistan	115,348	174,000	58,652
Papua New Guinea*	13,500	11,500	
Peru*	44,638	65,660	21,022
Philippines	185,406	43,828	
Romania	2,457	2,908	451
Russia	262,938	466,258	203,320
Senegal	34,164	45,540	11,376
Serbia	4,807	727	
South Africa	900	7,157	6,257
South Sudan	0	30,000	30,000
Sri Lanka	52,410	66,910	14,500
Sudan (former)	66,000	39,000	
Sweden	1,368	10,250	8,882
Tanzania United, Rep*	293,043	378,797	85,754
Thailand*	209,300	1,176,216	966,916
Turkey	40,259	12,744	
Turkmenistan	15,000	8,486	
Uganda*	413,805	394,688	
Ukraine	4,640	13,588	8948
United Kingdom	2,473	747	
USA*	21,151	12,642	
Uzbekistan*	4,078	2,000	
Venezuela, Bolivia Rep*	27,464	105,000	77,536
Vietnam*	182,655	930,596	747,941
Zambia*	76,396	80,475	4,079
Zimbabwe	11,200	5,000	

Table S2: Breakdown of basin fish catch estimates from Ainsworth, (2020), Ainsworth et al., (2021) (Tables 1-3) and weighted average date (year) of fish catch data used in this study. Fisheries catch data with no year information was not considered in weighted average calculations. (*) denotes where Monte Carlo simulations were carried out on a particular element of a basin fishery, with the upper and lower catch estimates indicated. References are stated in their respective document.

Basin	**Total**	**Country**	**Waterbody**	**Catch estimates (tonnes)**	**Year**	**Reference**	**Notes**	**Weighted average year**
Niger	**167,000-326,000**	Guinea	Niger River*	3,340- 6,000	n/a	Laë *et al.* (2004), Laë (1992).		
		Niger		8,350- 16,000				
		Mali		6,8470- 133,000				
		Nigeria		86,840-171,000				
Volta	**57,091-82,091**	Burkina Faso	Volta River	4,546	n/a	Van den Bossche and Bernacsek (1990)	Volta River estimates include the White and Black Volta	1997
			Bagré Reservoir	975	n/a	Béné (2007)		
		Ghana	Lake Volta*	40,000-65,000	1989-2000	MOFA (2006)		
			Volta River	4,000	n/a	Van den Bossche and Bernacsek (1990)		
		Benin	Oueme	5,700	1976	Welcomme (1979)		
		Benin, Togo, Burkina Faso	Oti River	1,870	1976	Van den Bossche and Bernacsek (1990)		
Lake Chad	**155,000-184,377**	Cameroon	Lake Chad*	21,000-24,800	2003-2012	LCBC (2017b)		1997
		Chad		9,000-10,873				
		Niger		32,000-37,840				
		Nigeria		38,000-45,864				
			Chari River*	20,000-30,000	1960s	Blanche and Milton (1962)		
			Logone River	35,000				
Senegal	**30,540**	Senegal	Senegal River	30,540	2005	Cheikh Oumar et al., (2006)		2005
Gambia	**2,350-2,700**	Gambia	Gambia River*	2,350-2,700	1980-2002	Lesack (1986); Laë *et al.* (2004)		2001
Nile	**419,778-439,546**	Egypt	Lake Nasser	26,290	2012	GAFRD (2012	Lake Victoria excluded from Nile figure	2008
			Lake Burullus	52,076				
			Lake Manzala	62,272				
			Lake Mariout	7,427				

			Lakes Edku, Bardawil, Quarun	12,798			
			Nile main channel	66,623			
		Sudan	Lake Nubia	1,000	2003	Witte et al., (2009)	
			Gebel Aulia reservoir	13,000			
			Senner reservoir	1,000			
			Roseires reservoir	1,500			
			White Nile reservoir	13,000	n/a	Hamza (2014)	
			Blue Nile reservoir	1,500	n/a		
		South Sudan	Sudd swamps	30,000	2003	Witte et al., (2009)	
		Uganda	Lake Albert	110,000	2008	NaFIRRI (2012)	
			Lake Kyoga*	15,000-34,700	1989-2006	Ogutu-Ohwayo (2004); Mbabazi et al., (2004)	
			Lake Edward/George	6,000	1991	Conen (1991)	
		Ethiopia	Lake Tana*	292-360	2006	De Graaf et al., (2006)	
Lake Turkana	**3076-4,413**	Kenya	Lake Turkana*	3001-4,338	2012-2013	SDOF (2013)	2013
		Ethiopia		75	n/a	Janko (2014)	
Lake Victoria	**752,024-1,061,107**		Whole lake system*	752,024-1,061,107	2010-2016	LVFO (2017), LVFO (2016)	2014
Lake Tanganyika	**164,310-188,380**	DRC	Lake Tanganyika*	90,000	1995	Conen et al., (1998)	1997
		Tanzania		55,000			
		Burundi		9,000-24,000	1992-1999	Magnet et al., (2000)	
		Zambia		10,310-19,380	2009-2013	Department of Fisheries, Zambia (2016)	
Lake Malawi	**33,000- 44,000**	Malawi	Lake Malawi*	33,000- 44,000	n/a	Weyl et al., (2010)	
Congo		Congo DRC	Lualaba	72,500	n/a	Nieland and Béné (2008)	1994

	151,512-162,622		Luapula	8,800	1983			
		DRC, Congo, CAR	Ubanji	7,520	1984			
		Cameroon, DRC, Congo, CAR	Tributaries and floodplains*	10,000-15,000	n/a			
		Congo	Likouala	15,000	n/a	Welcomme (1985)		
			Sangha	15,000		Nieland and Béné (2008)		
		DRC	Malebo Pool*	3,000-3,500	1984	Van den Bossche and Bernacsek (1990)		
		DRC, Zambia	Lake Mweru	5,953	1983	Konare (1984)		
		DRC	Lake Tumba	1,500	1982	Corsi (1984)		
		Zambia	Bangweulu River*	12,298-17,849	2013-2015			
Zambezi	**73,169-104,543**	Zambia	Upper Zambezi*	5,424-8,012	2008-2012	Department of Fisheries, Zambia (2016)		2009
			Lower Zambezi*	528-920	1995-2015			
			Lake Kariba*	7593-19,420	1997-2013			
			Itezhi-tezhi river*	1,874-2,752	1995-2015			
			Kafue floodplain*	3,945-8,907	2013-2015			
			Luapula River*	7,815-18,542	1995-2015			
		Malawi, Zambia	Luangwa River	786	1980	Coopconsult-Propesca (1982)		
		Mozambique	Zambezi Delta	16,264	n/a	Turpie et al., (1999)		
		Namibia, Botswana	Lake Liambezi	2,700	2011-2012	R. Peel (pers comms)		
		Mozambique	Cahora Bassa reservoir	4,343	1982	Van den Bossche and Bernacsek (1990)		
		Namibia, Zambia	Chobe-Caprivi floodplain	1,273	1994-1995	Turpie et al., (1999)		
		Malawi	Shire river/ floodplain	9,750	n/a			

		Zambia	Barotse floodplain	5,874	1995			
		Zimbabwe	Lake Kariba	5,000	1995	Mhlanga and Mhlanga (2013)		
Limpopo	**31,010**	Botswana	Gaborone Dam	4,632.8	2004-2005	FAO (2007b)		2004
			Bokaa Dam	8,545.4				
			Sashe Dam	13,331.3				
			Lestobogo Dam	4,500.8				
Okavango	**676-730**	Botswana	Okavango*	676-730	1996-2005	Kgathi et al., (2005)		2001
Lake Langano	**1,000**	Ethiopia	Langano	1,000	1980s	Van den Bossche and Bernacsek (1991)		1980
Casamance	**15,000**	Senegal	Casamance River	15,000	n/a	Welcomme (1985)		
Rufiji	**5,500-7,500**	Tanzania	Rufiji River*	5,500-7,500	n/a	Turpie (2000)		
South Africa	**7,157**	South Africa	Inland reservoirs	7,157	n/a	McCafferty et al (2012)	Recreation only	
Kainji Lake	**6,000**	Nigeria	Niger River	6,000	n/a	Neiland and Béné (2008)		
Cross	**3,500-8,800**	Nigeria	Cross River*	3,500-8,800	n/a	Van den Bossche and Bernacsek (1990)		
Lagos Lagoon	**4,000**	Nigeria	Ogun River	4,000	n/a	Van den Bossche and Bernacsek (1990)		
Kossou reservoir	**8,000**	Ivory Coast	Bandama River	8,000	n/a	Van den Bossche and Bernacsek (1990)		
West African rivers	**30,700**	West Africa		30,700	n/a	Béné and Heck (2005)		
Red River	**351,674**	China	Red River*	8,213	2015	Zhao and Shen (2016)		2012
		Vietnam		315,065-343,461	2010-2014	General Statistics Office Vietnam (2017)		
Mekong	**1,900,000-2,311,808**	Cambodia	Mekong River*	627,000-767,000	2000	Hortle and Bamrungrach (2015); Hortle (2007).		2000
		Lao PDR		209,000-246,000				
		Thailand		760,000-921,000				

		Vietnam		304,000-369,000				
		China		8,808	2015	Zhao and Shen (2016)		
Mekong	**246,000**	Cambodia	Tonlé Sap Lake	179,500-246,000	2001	Lieng and Van Zalinge (2001)		2001
Irrawaddy	**589,452-1,207,888**	Myanmar	Irrawaddy River*	580,481-1,198,917	2010-2014	Department of Fisheries Myanmar (2017,2022)		2013
		India		7,045	2014	Government of Inida (2014)		
		China		1,926	2015	Zhao and Shen (2016)		
Salween	**110,018-198,294**	China	Salween River*	3,408	2015	Zhao and Shen (2016)		2013
		Myanmar		106,610-194,886	2010-2014	Department of Fisheries Myanmar (2017, 2022)		
Mahakam	**12,350-31,000**	Indonesia	Mahakam River*	12,350-31,000	1985-1990	Christensen (1993a, b)		1990
Pearl	**169,836**	China	Pearl River	169,836	2015	Zhao and Shen (2016)		2015
Yangtze	**100,000-1,112,964**		Yangtze River*	100,000-1,112,964				2015
Yellow	**40,476**		Yellow River	40,476				2015
Tarim	**7,658**		Tarim River	7,658				2015
Balkhash	**459**		Balkhash River	459				2015
Dong Jiang	**27,210**		Dong Jiang	27,210				2015
Han Jiang	**20,998**		Han Jiang	20,998				2015
Min Jiang	**42,723**		Min Jiang	42,723				2015
Fuchan Jiang	**49,137**		Fuchan Jiang	49,137				2015
Yongding He	**72,110**		Yongding He	72,110				2015
Luan He	**20,105**		Luan He	20,105				2015
Liao He	**22,386**		Liao He	22,386				2015
Daling He	**12,932**		Daling He	12,932				2015
Yasai	**251,376**		Yasai	251,376				2015
Amur	**80,387**	China	Amur River	74,097	2015	Zhao and Shen (2016)		2015
		Russia		6,300	2018	FAO (forthcoming)		
Brahmaputra	**981,397**	India	Brahmaputra river	135,526	2014	Government of India (2014)		2013

		Bangladesh river fishery		2,280	1989-1990	Neiland and Béné (2008)		
		Bangladesh floodplain fishery*		797,024-843,325	2010-2015	FRSS (2012, 2017)		
		Bhutan		7	2015	FAO (2017)		
		China		259	2013	China Agriculture Yearbook (2014)		
Ganges	**429,540**	India	Ganges River	429,540	2014	Government of India (2014)		2014
Mahi	**3,322**		Mahi River	3,322				2014
Narmada	**9,619**		Narmada River	9,619				2014
Krishna	**106,894**		Krishna River	106,894				2014
Cauvery	**47,913**		Cauvery River	47,913				2014
Penner	**278,776**		Penner River	278,776				2014
Brahmani	**12,153**		Brahmani River	12,153				2014
Domodar	**116,443**		Domodar River	116,443				2014
Kaladan	**428**		Kaladan River	428				2014
Godavari	**90,400**		Godavari River	90,400				2014
Tapti	**10,235**		Tapti River	10,235				2014
Indus	**166,801-242,801**	Pakistan	Indus River*	136,000-212,000	2005-2014	Pakistan Statistical Yearbook (2014); Khan (2015)		2011
		China		37	2015	Zhao and Shen (2016)		
		India		30,764	2014	Government of India (2014)		
Caspian Sea	**112,950-131,453**	Azerbaijan	Caspian Sea*	17,205-26,400	2005-2010	Salmonov et al., (2013)		2009
		Turkmenistan		8,486	1997	FAO (1998)		
		Iran (Islamic Rep)		39,647-46,435	2006-2014	FAO (2015)		
		Kazakhstan		13,631-16,151	2005-2006	Timirkhanov et al., (2010)	Fishery catch also includes the Ural River	
		Russia		33,981	2018	FAO (forthcoming)		
Ob-Irtysh	**23,556**	Russia	Ob-Irtysh River	22,834	2018	FAO (forthcoming)		2018

		China		722	2015	Zhao and Shen (2016)		
Ural	**13,631**	Kazakhstan	Ural River	13,631	2006	Timirkhanov et al., (2010)	Fishery catch also includes the Caspian Sea	2006
Volga	**68,200**	Russia	Volga River and reservoirs	68,200	2018	FAO (forthcoming)		2018
Lena	**55,434**		Lena River	55,434				2018
Yenisey	**39,014**		Yenisey	39,014				2018
Lake Ladoga	**4,974**		Neva River	4,974				2018
Lake Peipus/Pepsi	**6,848**		Narva River	6,848				2018
Lake Baikal	**789**		Yenisey River	789				2018
Lake Onega	**1,430**		Volga River	1,430				2018
Lake Tumba	**1,500**			1,500				2018
Danube	**24,188-25,588**	Romania	Danube River*	2,507-3,309	2007-2008	European Comission (2009)		2012
		Bulgaria		14,284	2014	European Maritime and Fisheries Fund (2016)		
		Serbia		428-1,026	2003-2010	Statistical Office of the Republic of Serbia		
		Croatia		8.64	n/a	Čaldarović (2006)		
		Ukraine		488.2	2005	Schmutz (2006)		
		Hungary		6,472	2013	Fisheries Operational Programme of Hungary (2015)		
Finland	**36,500-40,952**	Finland	All waterbodies*	36,500-40,952	2000-2017	OSF (2019)	Majority recreational	2008
Amu Darya	**1,000-3,000**	Uzbekistan	LowerAmu Darya*	1,000-3,000	1990s	Pavlovskaya (1995)		1990
Kura	**96**	Azerbaijan	Kura River	96	n/a	Salmonov et al., (2013)		
Mingachevir Reservoir	**94**	Azerbaijan	Kura River	94	2010	Salmonov et al., (2013)		2010
Dnieper	**12,600**	Ukraine	Dnieper River	12,600	n/a	Movchan (2015)		

Dniester	**500**	Ukraine	Dniester River	500	n/a	Movchan (2015)		
German waterbodies	**3,256**	Germany	Recreational lake fishery	3,256	n/a	Centenera (2014)	Lakes Brandenburg, Macklenburgm Constance and Elbe	
	9,000		German inland waters	9,000	n/a	Ernst and Young (2011)		
Magdalena	**5,808-9,094**	Colombia	Magdalena River*	5,808-9,094	2004-2013	FAO, (2015); SEPEC (2017)		2008
Orinoco	**91,024-127,742**	Venezuela	Orinoco	60,000	1995	Novoa (2002)		1998
			Apure*	30,000-60,000	2000-2008	Novoa, (2002); Machado-Allison and Bottini (2009)		
		Colombia	Orinoco*	1,024-7,742	1995-2009	Ramírez-Gill and Ajaco-Martínez (2011)		
Amazon	**653,678-698,678**	Brazil	Amazon*	575,678	2009	Issac and Almedia (2011)		2008
		Peru		35,000-80,000	n/a	Bayley et al., (1992); Amazon Waters (2016)		
		Bolivia		9,000	n/a	FAO (2005)		
		Colombia		34,000	1991	Bayley (1998)		
Tocantins-Araguaia	**16,360**	Brazil	Tocantins River	3,424	2011	MPA (2012)		2007
			Araguaia River	5,606	2006	Zacarkim et al., (2015)		
			Tucuruí Dam	7,330	2005	MPA (2012)		
Lake Titicaca	**10,160**	Bolivia	Lake Titicaca	2,000	n/a	FAO (2005)		1980
		Peru		8,160	1980	Orlove (1986); Levieil (1987)		
La Plata	**63,849**	Brazil	Itaipu Dam	1,192	1998	Agostinho et al.,(1999)		1998
		Brazil, Paraguay	Middla Paraná	60,000	n/a	Quirós et al.,(2004)		
		Brazil	Pananal Wetlands	1,450	1995	Catella et al., (1997)	Recreational	
			Cuiba River	1,207	2000-2001	Mateus et al., (2004)		
Great Lakes Basin	**19,083**	United States	Lake Superior	1,233	2017	NOAA (2019)		2017
		Canada		295		OCFA (2019)		
		Indigenous		316	2014	Mattes, (2016)		

		United States	Lake Michigan	1,544	2017	NOAA (2019)		
		United States	Lake Huron	872	2017	NOAA (2019)		
		Canada		1,148		OCFA (2019)		
		United States	Lake Erie	2,190		NOAA (2019)		
		Canada		11,232		OCFA (2019)	Includes catches from Lake St Clair	
		United States	Lake Ontario	31		NOAA (2019)		
		Canada		222		OCFA (2019)		
Mississippi	**8,988-11,041**	United States	Upper Mississippi*	4,559-6,612	1989-2005	GLMRIS (2012)	Catches from Illinois, Kaskaskia and Rock Rivers	1996
			Lower Mississippi	3,751	n/a	IEC (2004)	Louisiana only	
			Ohio River	678	2005	GLMRIS (2012)	Ohio, Wabash, Cumberland and Kentucky Rivers	
Yukon	**514**	United States	Yukon commercial salmon fishery	509	2018	JTC (2019)	Substantial recreational fishery 309,394 (n) fish caught between 2015-2018	2018
		Canada		5	2008	Environment Yukon (2010)		
Murray-Darling	**3,433**	Australia	Murray-Darling recreational fishery	3,433	2001	Henry and Lyle (2003)		2001
Sepik	**3,000-5,000**	Papua New Guinea	Sepik River*	3,000-5,000	n/a	Coates (1985)		
Fly	**5,000-10,000**		Fly River*	5,000-10,000	n/a	Swales (2002)		