ICES Journal of Marine Science (2011), 68(8), 1751–1756. doi:10.1093/icesjms/fsr035

An overview of global catch statistics for inland fish

Robin L. Welcomme

Imperial College, Department of Life Sciences, Silwood Park, Buckhurst Road, Ascot SL5 7PY, UK; tel: +44 1787 278017; e-mail: welcomme@btinternet.com.

Welcomme, R. L. 2011. An overview of global catch statistics for inland fish. – ICES Journal of Marine Science, 68: 1751–1756.

Received 5 October 2010; accepted 18 February 2011; advance access publication 16 April 2011.

The reported global inland fish catch passed 10 million tonnes in 2008, after almost linear growth from the early 1950s. The rise coincides with an increasing number of reports of falling catches resulting from environmental degradation. It is thought that catches from inland waters were underreported in the past because of constraints on collecting the relevant data. National approaches to data collection are not generally comparable and their accuracy not usually assessed. National data processing and reporting should be audited, and training undertaken to harmonize these activities. The apparently bigger catches probably result from better reporting of actual catches rather than any increase in the amount of fish landed. Current data are sufficient only for a general overview of global inland catches of fish, rather than for the detailed analysis needed for management, policy formulation, and the valuation of inland fisheries. There is a need for improved approaches to data collection and for historical catches to be corrected to account for changes in methodologies and reporting procedures.

Keywords: data collection, global catch trends, inland fisheries, statistics.

Introduction

The annual catch of finfish, crustaceans, and molluscs from the world's inland waters, as reported to the Food and Agriculture Organization (FAO), passed 10 million tonnes for the first time in 2008 (FAO, 2009), after a period of almost linear growth from the early 1950s. The increase is difficult to explain because views on trends in inland fisheries are contradictory. Despite the recorded increases in catches, some believe inland fisheries are doomed (Friend *et al.*, 2009), largely because the many threats to aquatic ecosystems attributable to anthropogenic activities will inevitably lead to their decline. Such activities include water abstraction, habitat degradation, land drainage, dam construction, pollution and eutrophication, alien invasive species, climatic variability, and bad or non-existent fishery management. This opinion is supported by studies and reports from around the world that allege that catches are falling and species are disappearing, with many symptoms of chronic overfishing seen at the level of individual species or whole communities: see Thorpe and Van Anrooy (2010) for central Asia, and Aps *et al.* (2004) for central and eastern Europe.

Accurate information is needed to gauge the impacts of such activities on a fishery, to evaluate the effectiveness of any management measures, and to value the fishery in the context of national food security and Gross Domestic Product. Here, I examine the relevance of existing inland fishery data, as reported to FAO, in resolving these issues. The analysis and discussion applies to both capture fisheries supplying food as well as recreational fisheries. Not all countries report their recreational catch, but it may be economically important and, in some areas, can also contribute significantly to the total catch (Cooke and Cowx, 2006; Cowx *et al.*, 2010).

The nature of inland fishery statistical data

Information on inland fisheries is reported to the FAO where it is maintained in the FAO global-capture-production database (http://www.fao.org/fishery/statistics/software/fishstat/en). Reporting is supposed to be annual, but many countries fail to make timely reports, and in such cases, the FAO estimates the catch data based on past reports and information available from other sources. In 2008, for example, the FAO had to estimate inland catches for 38% of countries, for which the combined catch was nearly 16% of the global total (Table 1). Such estimates were mostly for countries with minor fisheries, although a few had a substantial inland fishery sector, e.g. Zambia, Cambodia, and Paraguay. For a decade or more, there have been no reports at all from smaller countries such as Afghanistan, Bhutan, Jamaica, Somalia, or Bosnia.

Many countries report and correct their data retrospectively, resulting in changes in trends depending on the dataset used. For example, Zambia had not reported its catch for the 6 years from 2001 to 2007 in the reports submitted in 2007, but reported a complete dataset in 2010, including the missing data. Other countries, such as Cambodia, reported large catch increases, noting that they had changed their data-collection systems so that the time-series was not backwardly compatible.

Trends in catch statistics

The FAO nominal catch statistics for fish list a total catch of finfish, crustaceans, and molluscs for worldwide inland waters of 10.2 million tonnes in 2008. Catches have risen steadily at ~3% per year since FAO statistical records began in 1950 (Figure 1).

In addition to total catch by weight, countries may report the catch composition by various taxonomic groupings. Of the 220 countries reporting fish catches in 2007, 72 (mostly arid countries or small-island states) did not report any inland catch. There were fairly complete species lists for 52 countries (of which FAO made estimates for 8), restricted lists, including identification of important fish groups, for 26 (of which FAO estimated 6), 36 countries distinguished fish "not elsewhere identified" (inland

Table 1. Number of countries for which the FAO had to estimate inland catches in 2008.

Continent	Countries with inland fish catches	Countries for which catch was estimated	Tonnage reported	Tonnage estimated	Countries for which catch was estimated (%)	Total tonnage estimated (%)
Africa	43	22	2 502 570	1 134 880	51.16	45.35
Asia	31	9	6 740 366	58 014	29.03	0.86
Europe, incl. Russia	40	8	403 355	11 670	20.00	2.89
North America	2	0	55 644	0	0.00	0.00
Oceania	7	4	17 786	15 706	57.14	88.31
South and central America	22	12	500 908	405 486	54.55	80.95
Total	145	55	10 220 629	1 625 756	37.93	15.91

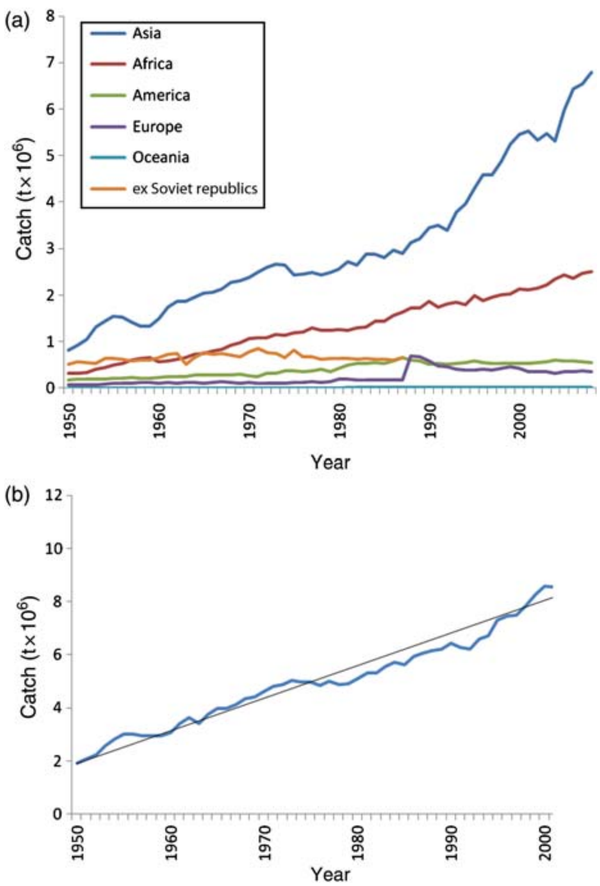

Figure 1. (a) Trends in inland fish catches by continent, 1950–2008. Note that the FAO dataset is discontinuous for catches in the former Soviet republics that were reported in the group "Other" until 1987. Thereafter, the former Soviet republics provided individual reports. Here, the catches from the former USSR (including Russia, Ukraine, Moldova, and Belarus) were combined with those of Europe, causing the rise in European catches at that time. Remaining countries in "Other" were added to the Asian total. (b) Global trends in inland fish catches, 1950–2008, including fish, crustaceans, and molluscs, but excluding reptiles and mammals. The linear regression is $y = 121\,273\,x + 2 \times 10^6$; $r^2 = 0.9616$ (Source: FAO Fishstat database).

fish *nei*) from reptiles, molluscs, and crustaceans (of which the FAO estimated 11), and there was no breakdown at all for 34 countries (of which the FAO estimated 21).

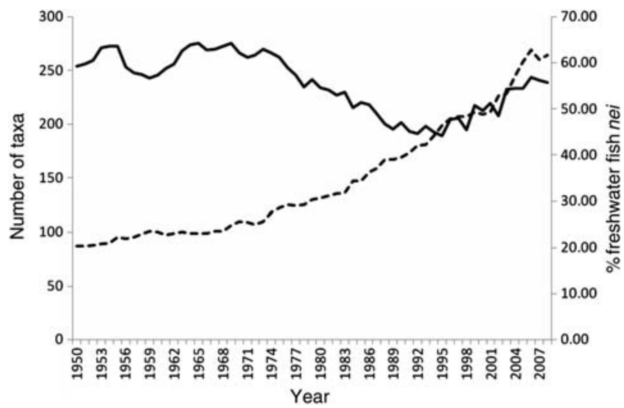

Figure 2. Global trends in the number of taxa (solid line) and the percentage of freshwater species *nei* (i.e. not elsewhere indicated; dashed line) reported by year for 1950–2008.

Those countries reporting by species listed increasing numbers of taxa since 1950, although the use of the general "Freshwater fishes *nei*" category has remained roughly the same, at around 56% of recorded catches. This could indicate a real increase in the number of species entering fisheries over time, or simply better identification of the catch (Figure 2).

Catches of crustaceans and molluscs are probably underreported, because they are mainly taken by unrecorded subsistence activities. For example, Hortle (2007) found that actual catches of crustaceans and molluscs from the Mekong basin were considerably more than reported. Most consumption and catch surveys ask about finfish only and do not offer the option to record other aquatic animals. This underestimation can be rectified only by recognizing that the other taxa are indeed being collected or caught.

Characteristics of inland water fisheries

Difficulties in obtaining fishery data from inland waters arise from the nature of the fisheries, their geography, the characteristics of the gear used, and the diversity of the fish populations.

Types of fishery

Inland fisheries tend to be small scale and labour-intensive. Usually, the whole human riparian population is involved in some capacity, at least part-time. Inland fisheries represent one aspect of complex lifestyles that are dictated by the seasonality of the fished rivers and lakes and by the crop seasons when farmers are also fishers. Inland fisheries are highly significant for food security and incomes in such communities. In general, people participate in the food fishery at three levels: subsistence, artisanal, and commercial. Of these, only commercial fishers undertake fishing full-time. The time allocated to fishing by the other categories may vary from season to season, or year to year, according to economic and social conditions, because people usually engage in other economic activities, such as farming or construction, during periods when fish catches are low or unprofitable. Even the smallest lakes, streams, and rice paddies are subsistence-fished by someone, generally children and women (Brummett *et al.*, 2010), but such fisheries are rarely investigated. In addition to fisheries for food, recreational fisheries are important in some countries; again, these catches are rarely sampled or reported.

Characteristics of inland waters

Inland waters are generally fragmented geographically, except a few major lakes and reservoirs. A country may have many lakes and small dams that are individually difficult to sample and control. Rivers are linear systems that range from many tiny watercourses (low-order streams—*sensu* Leopold *et al.*, 1964) to a few major rivers (Table 2). In both cases, fish are often landed at isolated locations and do not pass through formal markets, so catch recording is problematic.

An approximate yield estimate for lakes and rivers can be extrapolated from the empirical relationships between areas of lakes, or river lengths, and the fishery yield. Although derived for tropical fisheries, this approach more generally indicates potential contributions to fish supply. Estimates for rivers (Welcomme, 1976; Table 2) probably err on the low side. The potential yield for rivers with normal floodplain development in Africa alone was estimated at 0.5 million tonnes in 1976. In addition, extensive floodplains, such as internal deltas, had estimated yields of ~40–60 kg ha^{-1} for Africa and 120 kg ha^{-1} for Asia. The recorded catches from many river-floodplain systems rose after these estimates were made, although little synthesis has been carried out since.

Downing *et al.* (2006) calculated that there are ~304 million natural lakes in the world, with an area of 4.2 million km^2, dominated by millions of waterbodies <1 km^2. In addition, impounded waters contribute a further 0.26 million km^2. An empirical relationship between lake area and fish catches, calculated from a dataset available at the FAO, indicates that lakes worldwide could yield some 90 million tonnes, were they all to have yields similar to those of the tropics (Table 3). This estimate is extremely crude, and undoubtedly excessive because yields from higher-altitude or cold lakes are lower, and a large proportion of the total lake area is probably at non-tropical latitudes. Most importantly, Tables 2 and 3 both demonstrate the relatively large contribution made by smaller lakes and rivers.

Table 2. Theoretical calculation of the number and average length of rivers in Africa with normal floodplain development[a], according to their stream order (*sensu* Leopold *et al.*, 1964), and estimates of their annual yield (Y) for the total river length (L) derived from the equation $Y = 0.0033\ L^{1.9539}$ (from Welcomme, 1976).

Stream order	Number	Average length (km)	Average yield (t)	Total yield (t)	Percentage of total	Cumulative percentage
1	4 166 969	2	0.01	33 336	5.97	5.97
2	870 615	4	0.04	37 436	6.71	12.68
3	181 900	9	0.22	39 290	7.04	19.72
4	38 005	20	1.09	41 577	7.45	27.16
5	7 940	45	5.56	44 131	7.91	35.07
6	1 659	203	28.44	47 175	8.45	43.52
7	347	238	144.89	50 277	9.01	52.53
8	72	547	738.62	53 181	9.53	62.05
9	15	1 259	3 764.62	56 469	10.12	72.17
10	3	2 898	19 188.87	57 567	10.31	82.48
11	1	6 669	97 801.65	97 802	17.52	100.00
Total				558 241		

[a]This relationship excludes extensive floodplains and riparian wetlands such as internal or coastal deltas.

Table 3. Global numbers of lakes of different areas (A) estimated by Downing *et al.* (2006), with theoretical yields (Y) calculated from data on 502 lakes in the FAO database of rivers and lakes, using the derived regression $Y = 160\ A^{0.24}$.

Average lake area (km^2)	Number of lakes	Total area of lakes (km^2)	Percentage of total area	Approximate yield (kg ha^{-1})	Estimated total yield (t)
0.003	277 400 000	693 500	16.35	673.93	46 737 046
0.025	24 120 000	603 000	14.21	387.81	23 384 943
0.25	2 097 000	524 250	12.36	223.16	11 699 163
2.5	182 300	455 750	10.74	128.41	5 852 286
24.7	15 905	392 854	9.26	74.11	2 911 441
248	1 330	329 840	7.77	42.60	1 405 118
2 456.00	105	257 880	6.08	24.57	633 611
37 978.00	16	607 648	14.32	12.74	774 144
378 119.00	1	378 119	8.91	7.34	277 539
Total	303 816 657	4 242 841	100		93 675 291

The tables also illustrate the fact that, although a large proportion of inland waters is small lakes or low-order streams with individually insignificant catch levels, their combined contribution could be massive. Unfortunately, their spatial dispersion and large number makes traditional sampling virtually impossible. As a result, models based on limited sampling elsewhere have to be used to estimate the total catch from the whole. Most of the models currently applied are based on old research, and often do not reflect modern knowledge. Moreover, because of the large numbers of waterbodies and watercourses involved, small changes in the model parameters can greatly influence the magnitude of the estimates. There is, therefore, a need for much basic research on both the numbers of waterbodies and watercourses in various parts of the world, and on their yield patterns.

Characteristics of the gear

In rivers, fishers exploit the diversity of habitats, the many species, and the seasonality conditions, using a range of gears adapted to the capture of the various exploited species and life stages. For example, 114 gears are described for the lower Mekong (Deap *et al.*, 2003). In lakes, gears tend to be less complex and are mainly gillnets, longlines, liftnets, and to a lesser extent trawls, although smaller gears such as traps, castnets, and handlines are used by subsistence fishers. For example, P. C. Goudswaard (pers. comm., FAO/UNDP IDAF unpublished) listed 23 different gears in use in Lake Volta, Africa.

Illegal gears are common in both lakes and rivers, may supply a considerable proportion of the catch through informal markets, and are generally not reported.

The complexity of fishing gear, its fragmentary nature (e.g. trap-fishers may set several dozen traps each night), and its wide spatial distribution over a range of habitats makes it extremely difficult to establish and enumerate basic units of effort.

Characteristics of fish populations

Freshwater fish assemblages are generally very diverse. In rivers, the number of species ranges from tens in small basins to >3000 in large systems such as the Amazon or Mekong; the total is strongly correlated with the basin area (Oberdorff *et al.*, 1995). Many species are usually available to the fisheries, particularly in the lower reaches of most rivers where the resident fauna often exceed 100 species. In lakes, the number of species is also broadly correlated with the basin area (Amarasinghe and Welcomme, 2002), but there is a notable thermal effect, with cold, high-latitude, and high-altitude lakes containing many fewer species than lowland, low-latitude lakes of equivalent size. The African Great Lakes, for example, can contain upwards of 600 species. In reservoirs, fish assemblages are associated with those of the host river, although some species are often lost because of the inability of river fish to adapt to more lake-like conditions. Frequently, alien species capable of self-recruiting in impoundments have been introduced to compensate for this loss. The number of species contributes to the lack of reporting to species level.

Needs for data

In addition to the need for an overall view of the fishery as a provider of food and income in national economies, information is needed for management purposes. There are three main approaches to the management of inland fisheries, described below.

Management of the fish

This mainly involves direct manipulation of fish populations in small dams, natural lakes, and floodplain waterbodies by stocking, introducing new species, and eliminating unwanted species. Relevant data are needed in such fisheries to evaluate the effectiveness (costs vs. biological production) of various types of manipulation regime and to formulate future strategies for stocking activities.

Management of the fishery

Management by traditional technical, input-and-output methods (similar to those used in marine fisheries) is applicable only to very few large lakes and reservoirs with relatively stable stocks and environments. In those cases, information is needed to regulate the fisheries on individual species and to assess the effectiveness of various management approaches.

Management of the environment

Inland fisheries in rivers, lakes, and river-regulated reservoirs depend mainly on factors external to the fishery, the human and natural processes in the basin. Here, information is needed to evaluate the impacts of the various environmental disturbances in the basin to mitigate their effects and support ecosystem-based management.

Main approaches to collecting fishery information

The dispersed nature of the resource and the diversity of gear and fish communities make the sampling of inland waters difficult and costly. A number of approaches have been adopted to overcome these problems in different countries.

Direct survey approaches

Landing surveys

Estimates of catch are made at landing sites, usually the most important ones where observers may record the catch daily. Direct observations may be supplemented by interviews, logbooks kept by selected fishers, and creel surveys. In large fisheries, estimates are more commonly based on periodic catch-assessment surveys, which subsample the landing sites in space and time to generate an estimated total catch from the known total number of landing sites. Landing surveys can provide insights on the usage of various types of gear, and the fishing effort, and they allow fish to be identified to species level. Typical of this approach are the large-boat fisheries of the Amazon described by Almeida *et al.* (2004).

In some cases, fish catches taken by particular gears may be monitored where these are large and represent a specific type of landing (often in a relatively restricted area). Typical of these is the "Dai" (set bagnet) fishery of the Tonle Sap (Mekong system; Halls *et al.*, in press). In that case, I think overfocusing on this fishery essentially led to the rest of Cambodia's fisheries being ignored and unreported, so the estimates had to be revised upwards massively after the inclusion of the floodplain fishery.

Market surveys

Catch estimates are based on counts of fish passing through major markets or checkpoints on main trade routes. This method has been used widely for many African fisheries, and it gives a general indication of the quantity of fish passing through the marketing system. However, being one step removed from the fishery, there are no data on the gear used, the numbers of fishers involved, or the total effort. By this stage, moreover, the fish will often have been treated by cutting into pieces and smoking, although the quantity of the processed or semi-processed product can be used as a proxy for actual fish yield.

Consumption surveys

Household consumption surveys have been used to avoid the complexities of directly monitoring the fishery. However, being two steps removed from the fishery, they may integrate catches over a large area and from a range of gears, e.g. in the Lower Mekong case described by Hortle (2007). Such studies are important, however, because they avoid the problems of fish passing through formal market chains or recording checkpoints, but they do lose information on the origin of the fish consumed.

Research-based approaches

Stock assessment

Stock assessment as applied to marine fisheries (e.g. the methods listed by Sparre and Venema, 1998) is relatively rare in inland waters and is generally restricted to very large lakes, e.g. Lake Victoria (Mkumbo *et al*., 2007), or to individual commercially important species in rivers, e.g. the Amazonian *Colossoma* fishery (Petrere, 1983). It is difficult to apply such methods in multigear, multispecies fisheries because the assessment results are of uncertain value. Moreover, the unstable nature of river and reservoir fisheries means that there is no environmental equilibrium. Nevertheless, such activities do give some indication of the likely fishery production from defined waterbodies and can be used to validate assessments made by other methods. In addition, if such assessments are carried out over a number of years and combined with catch data, predictive models of future catches can be developed.

Regression models

The simple models described in the legends for Tables 2 and 3 are typical, but a wider series of models for lake, reservoir, and riverine fisheries has been described by various authors (Henderson and Welcomme, 1974; Ryder, 1982; Laë *et al*., 1999; Welcomme, 2001). Ideally, models should be updated periodically based on new information, but the data needed for updating are often not available, or no scientists are funded to do the work. As a result, many of the models currently in use are old and in need of updating with more recent data. An example of the effects of such updating is the recent incorporation of rice-field fishery catches into national statistics by Bangladesh and the Lower Mekong nations, where estimates of the mean yield per unit area were multiplied by the total areas of the relevant rice fields. This works well in homogeneous rural systems, particularly where a large human population depends on the fishery.

Estimates based on best scientific opinion

Often a lack of resources may oblige a country to assess its resources based on comparisons with similar systems elsewhere, usually with the assistance of external experts. A typical case is that of Myanmar (Burma; http://www.fao.org/docrep/004/ad497e/ad497e04.htm), where there is an almost complete lack of fishery infrastructure, but similarities in terms of fishing intensity, diet, and environment with the Lower Mekong system make it relatively easy to form an educated guess of the likely total yield.

The main problems with fishery information

Several weaknesses are apparent in the existing inland water statistics. Some of these are listed below.

Inadequate data-collection systems

Many countries do not have the financial or manpower resources to establish adequate sampling systems. Moreover, many fishery landing sites are so dispersed that they defy conventional catch-recording methods, so require altogether different approaches or proxy indicators. As a consequence, the data are absent, fragmented, underreported, or misreported.

Selective data collection

Data are only collected from commercially important sites such as major landing places or markets or from commercial fishing operations. This is often linked to some sort of revenue collection, however, so may be subject to misreporting. Focusing on these sites means that whole sectors, such as subsistence, artisanal, and recreational fisheries, are frequently excluded from national estimates. Usually, though, such small-scale operations produce more fish than larger, more visible enterprises (Tables 2 and 3). In addition, most reporting is limited to finfish, whereas other incidental or targeted species such as crustaceans, molluscs, amphibians, and aquatic insects and plants go unrecorded. Typical of this problem is the Amazon, where the systematic collection of statistics from the large-boat fishery on the main-stem Amazon has been well organized for a number of years (Almeida *et al*., 2004), but the myriad smaller systems with artisanal and subsistence fisheries remain unstudied.

Double counting of landings

This may arise when the same fish are presented at a number of landing sites or markets and is a special problem in international lakes and rivers such as Lake Victoria, Lake Chad, or the interface between the Brazilian and Colombian Amazon, where the same fish may be recorded in more than one country. There is also a problem with preserved fish which, if not sold, are reprocessed and returned to the next market.

Confusion with aquaculture

The distinction between capture fisheries in the wild, culture-based fisheries, and aquaculture is not clear, but it hinges largely on the ownership of the waters fished. This is a problem, especially with regard to stocked, enhanced, or culture-based fisheries in waterbodies without clear ownership. The FAO instructs that, for culture-based fisheries, the fish used for stocking must be reported as aquaculture production, whereas the wild harvests are in capture fisheries. Nevertheless, some countries apparently report such production as aquaculture, hence introducing negative biases in their estimates of inland fisheries catches.

Political pressure

There are often political pressures to inflate catch estimates, either to meet centrally dictated quotas or to raise the profile of the sector. Further, deliberate underreporting to conceal the true value of a fishery to evade taxes and levies is also a widespread phenomenon. This is particularly the case in concessionary or leased fisheries.

Piracy and unrecorded catches

In addition to the probably enormous quantity of unrecorded fish caught for home consumption or local markets by the artisanal and subsistence sectors, fish may be caught and sold illegally in unregulated markets. For example, Egyptian authorities estimate that about half the catch from Lake Nasser is illegal and unrecorded (van Zwieten *et al.*, in press), and Cowx (2005) estimated that some 30% of the catch of Nile perch in Lake Victoria was unreported and passed through informal markets.

Other problems

These arise because some national statistics do not distinguish between the different lake and river basins, or between "inland" and "coastal marine" catches, despite the latter often being from inland estuaries or freshwater coastal lagoons. Furthermore, catches are not usually reported by species or species-group in a comprehensive manner.

Most countries do not specify their sampling and reporting procedures, and some use different methods to estimate catches for different waterbodies, making it difficult to compare results between countries. Also, the various methods have not generally been calibrated against each other, so many of the nominal catch statistics must be considered as unreliable, unless they are reconciled with other sources of information. However, if the errors and biases are considered to be constant, the relevant statistics may be used to indicate trends.

Acknowledgements

I thank Devin Bartley, Gertjen de Graaf, Simon Funge-Smith, Gerd Marmulla, and Ian Cowx for their constructive comments that helped to improve and add detail to this paper.

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