

# TOWARD A COMPREHENSIVE ESTIMATE OF GLOBAL MARINE FISHERIES CATCHES<sup>1</sup>

Daniel Pauly and Dirk Zeller

*Sea Around Us*, University of British Columbia, Vancouver, BC, Canada

Marine fisheries are the chief contributors of wholesome seafood (finfish and marine invertebrates; here “fish”). In much of the global south, fish is the only or primary animal protein that rural people can afford (Mohan Dey et al. 2005); fish also are an important source of micronutrients essential to people with otherwise deficient nutrition (Kawarazuka and Béné 2011). However, the growing popularity of fish in countries with developed or rapidly developing economies created a demand that cannot be met by fish stocks in their own waters (e.g., the EU, the United States, China, and Japan).

These markets are increasingly supplied by fish imported from developing countries or caught in the waters of developing countries by various distant-water fleets (Swartz et al. 2010a, 2010b) with these consequences:

- Foreign or export-oriented domestic industrial fleets are increasingly fishing in the waters of developing countries (Le Manach et al. 2013; Belhabib et al. 2015a).
- Industrially caught fish has become a globalized commodity that is mostly traded between continents rather than consumed in the countries where it was caught (Alder and Sumaila 2004).
- The small-scale fisheries that traditionally supplied seafood to coastal rural communities and the interior of developing countries (notably in Africa; Belhabib

et al. 2015b) are forced to compete with heavily subsidized foreign industrial fleets (Sumaila et al. 2008, 2010) without much support from their own governments (Jacquet and Pauly 2008).

The lack of attention that small-scale fisheries suffer in most parts of the world (Pauly 2006a) manifests itself also in the statistics that are submitted annually by many member countries to the Food and Agriculture Organization of the United Nations (FAO), which often omit or substantially underreport small-scale fisheries data (Zeller et al. 2015). FAO harmonizes the data submitted by its members, which then becomes the only global dataset of fisheries statistics in the world, widely used by policy makers and scholars (Garibaldi 2012).

However, this dataset not only underestimates artisanal (small-scale commercial) and subsistence fisheries but generally also omits the catch of recreational fisheries, discarded bycatch<sup>2</sup> (Zeller and Pauly 2005), and illegal and otherwise unreported catch, even when estimates are available (Zeller et al. 2011). Thus, except for a few obvious cases of overreporting (e.g., China; see Watson and Pauly 2001), the landings data updated and disseminated annually by the FAO grossly underestimate actual fisheries catch. Although the fact of this underestimation is widely known by FAO staff and among fisheries scientists working with FAO catch data, its global magnitude had not been explicitly documented until the publication of Pauly and Zeller (2016).

Here, we summarize the results of the catch reconstructions presented on pp. 185–457, in the hope that this may eventually lead to FAO member countries submitting to FAO fisheries statistics that are more realistic, which would facilitate the implementation of ecosystem-based fisheries management (Pikitch et al. 2004), a vital component of the *FAO Code of Conduct for Responsible Fisheries* (FAO 1995).

The catch reconstruction rests on two basic principles (Pauly 1998; chapter 1):

- When “no data are available” on the catch of a given fishery, it is not appropriate to enter “N.A.” or “no data” into one’s database. Such entries will later be turned into a zero, which is a bad estimate of the catch of a fishery known to exist (see also Covey 2000).
- Rather, an estimate should be inserted in all such cases, based on the fact that fishing is a social activity that is bound to throw a “shadow” on the society in which it is embedded and from which a rough (but better than zero) estimate of catch can be derived (e.g., from the seafood or the fuel consumed locally or the number of vessels engaged in fisheries and the average catch rate of vessels of this type).

Chapter 2 outlines the approach through which these principles were operationalized in the *Sea Around Us* (Zeller et al. 2007, 2015). Notably, when doing reconstructions, it quickly turned out that the perception of “no data” being available was not correct; the “social shadow” yielded hundreds of articles in the peer-reviewed and report literature with catch data, or data from which catch rates could be inferred, even for remote islands (Zeller et al. 2015). Also, it became obvious that many countries sent to FAO a stripped-down version of the catch data their fisheries research institutes actually possess and even publish on their websites.

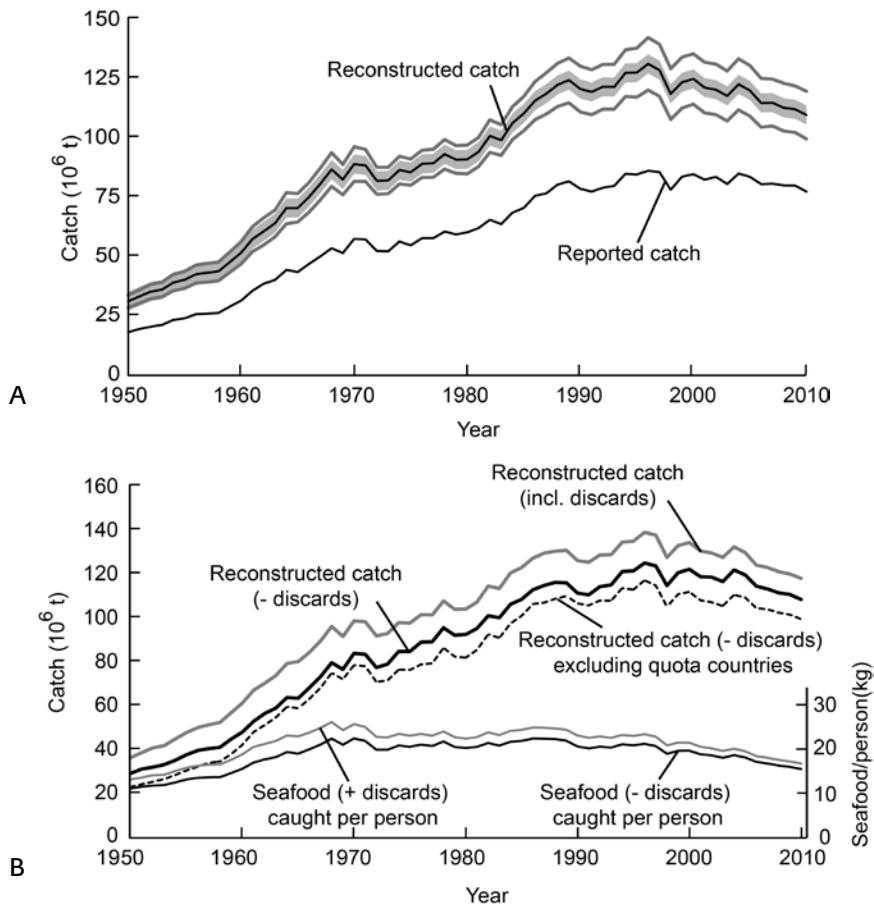
Thus, it was straightforward, though tedious, to reconstruct time series of fisheries catch for all countries of the world from 1950,

the first year FAO published its much-appreciated “Yearbook” of global fisheries statistics, to 2010. This was done by “sectors,” defined as follows:

- *Industrial*: Large-scale vessels (trawlers, purse-seines, longliners), which may move fishing gear across the seafloor or through the water column (e.g., demersal and pelagic trawlers), irrespective of vessel size; this corresponds to the “commercial” sectors of countries such as the United States.
- *Artisanal*: Small-scale fisheries whose catch is predominantly sold (hence they are also “commercial fisheries”).
- *Subsistence*: Small-scale operations whose catch is predominantly consumed by the people fishing it and their families.
- *Recreational*: Small-scale operations whose major purpose is enjoyment.

We used national or regional definitions of these sectors in each reconstruction, as a global definition is neither achievable nor useful. In addition to the reconstructions by sector, we also assigned catches to either “landings” (i.e., retained catch) or “discards” (i.e., discarded catch), labeled as either “reported” or “unreported” with regard to national and FAO data. Thus, reconstructions present “catch” as the sum of “landings” plus “discards.” We note that FAO explicitly requests that countries not include discards in their FAO data submission. Thus, the FAO data represent a “landings” dataset.

The sum of the reconstructed catches of all sectors in all EEZs of the world (see pp. 185–457), plus the industrial catch of tuna and other large pelagic fishes in the high seas (see chapter 3), leads to two major observations. First, the trajectory of reconstructed catches differs distinctly from those reported by FAO on behalf of its member countries. The latter statistics suggest that, starting in 1950, the world catch increased steadily to around 86 million tonnes (mt) in 1996, stagnated, and then slowly declined to around 77 mt by 2010 (figure 14.1A).



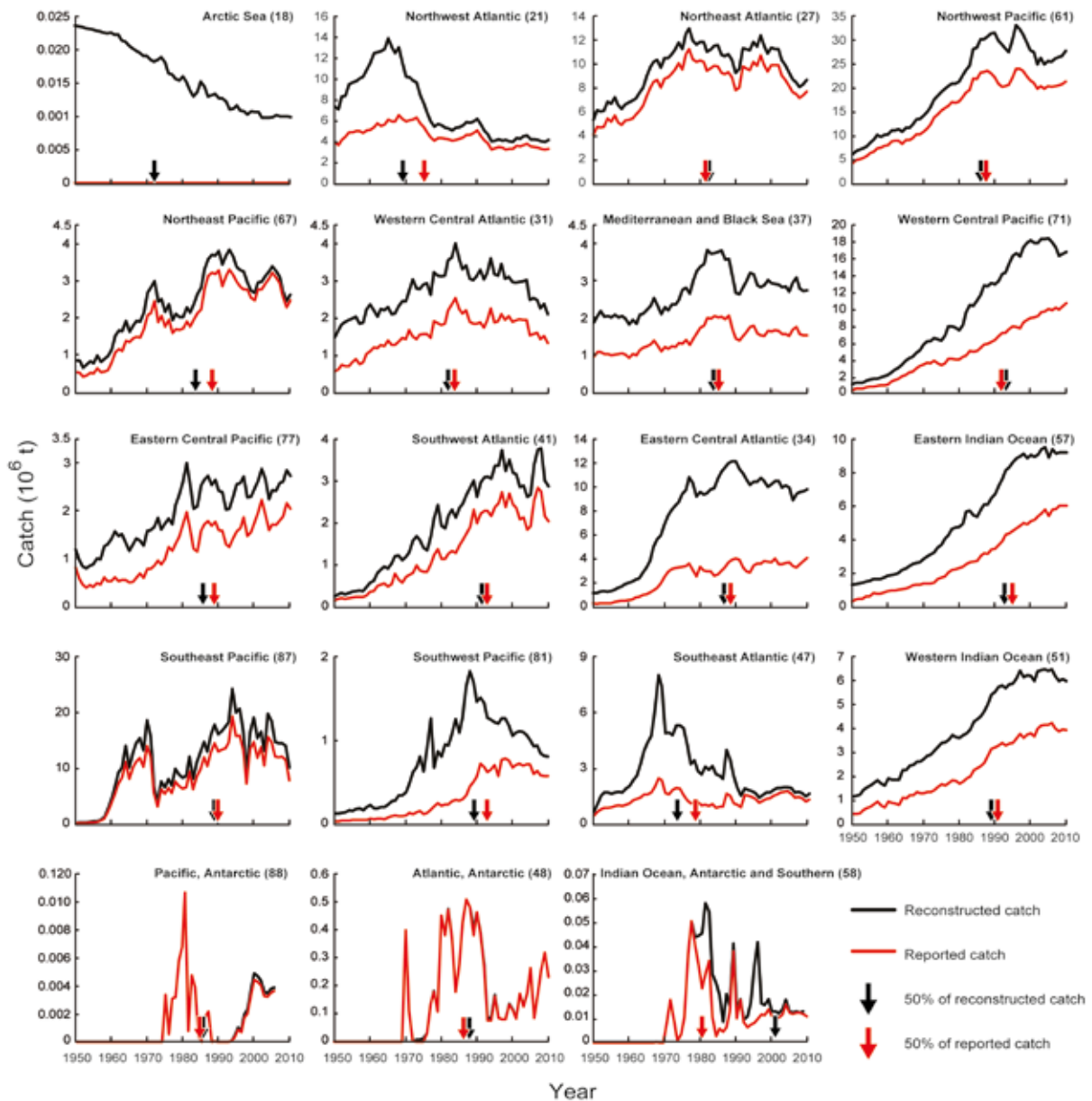
**Figure 14.1.** Trajectories of reported and reconstructed marine fisheries catches 1950–2010. (A) Note the difference between the world’s marine fisheries catches, assembled by FAO from voluntary submissions of its member countries (“reported”), and the catch “reconstructed” to include all fisheries known to exist, in all countries and in the high seas (“reconstructed” = “reported” + estimates of “unreported”). See chapter 2 for details on catch reconstruction techniques and the Monte Carlo approach used to estimate the uncertainty associated with the reconstructed catches (gray area: uncertainty ranges as per table 2.1; gray lines: uncertainty ranges doubled). (B) Effect of removing the discards on estimates of global catch and of seafood caught per capita and of removing the catches of the major countries using quota management (i.e., United States, New Zealand, Australia, and northwestern Europe) on reconstructed total catches; the remaining catch still strongly declines. (Adapted from Pauly and Zeller 2016.)

In contrast, the reconstructed catch peaked at around 130 mt ( $\pm 11$  mt) in 1996 and strongly declined thereafter.<sup>3</sup> Overall, the reconstructed catches are 50% higher than the reported data. Second, since 1996 the reconstructed catch declined significantly, at a mean rate of 1.22 mt/year ( $\pm 0.17$  mt;  $p < .01$ ), whereas FAO, at least until 2010, described the reported catch as characterized by “stability” (FAO 2011; Pauly and Froese 2012), although it exhibited a significant decline since 1996 (0.38 mt/year  $\pm 0.13$  mt;  $p < .05$ ).

Note that the recent strong decline in catches is not caused by enlightened countries reducing catch quotas so that stocks can

rebuild. Thus, a similar decline (1.01 mt/year  $\pm 0.17$ ;  $p < .01$ ) is obtained when the catch from the United States, northwestern Europe, Australia, and New Zealand (i.e., countries where quota management predominates) is excluded (figure 14.1B). Note also that low quotas are not imposed when a stock is abundant; low quotas in fully developed fisheries are generally a management reaction to past or ongoing overfishing, just like declining catches in unmanaged, strongly exploited fisheries (Froese et al. 2012, 2013; Kleisner et al. 2013).

Closer examination of the reconstructed and reported catches in each of the 19 maritime

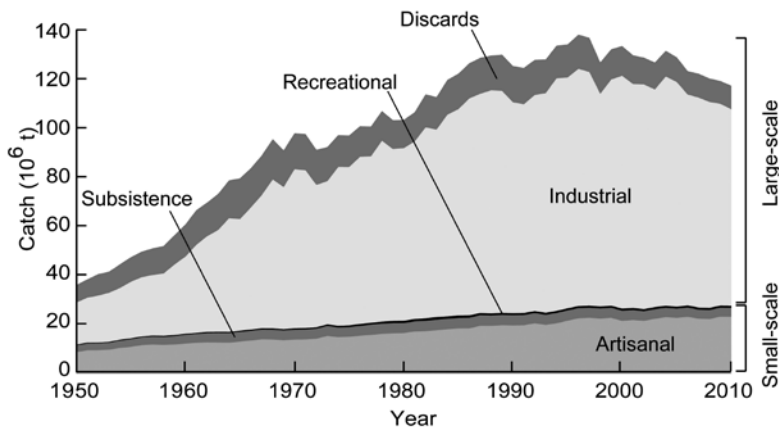


**Figure 14.2.** Reconstructed and reported catches in the 19 maritime “Statistical Areas” which FAO uses to roughly spatialize the world catch. Note that for Area 18 (Arctic), the reported catch by the United States and Canada was zero, and only Russia (former USSR) reported a minuscule catch in the late 1960s, even though the coastal fishes of the high Arctic are exploited by Inuit and others (Zeller et al. 2011). (Adapted from Pauly and Zeller 2016.)

FAO statistical areas suggests that the North Atlantic and North Pacific, where industrial fishing originated, were the first regions of the world to experience declining catches (figure 14.2). In contrast, lower-latitude areas experienced declines later, or still appear to have increasing catches. The increasing trend is most pronounced in the eastern Indian and western central Pacific oceans, where the reconstructed catches are very uncertain, be-

cause the statistics of various countries could only partially correct a regional tendency to exaggerate catches. FAO’s eastern Indian and western central Pacific Ocean areas are also the only areas with an increasing reported catch, which, when added to that of other FAO areas, makes the world reported catch appear stable.

Catch reconstructions emphasize the assignment of all marine catches to fishing sectors (figure 14.3). Global marine catches



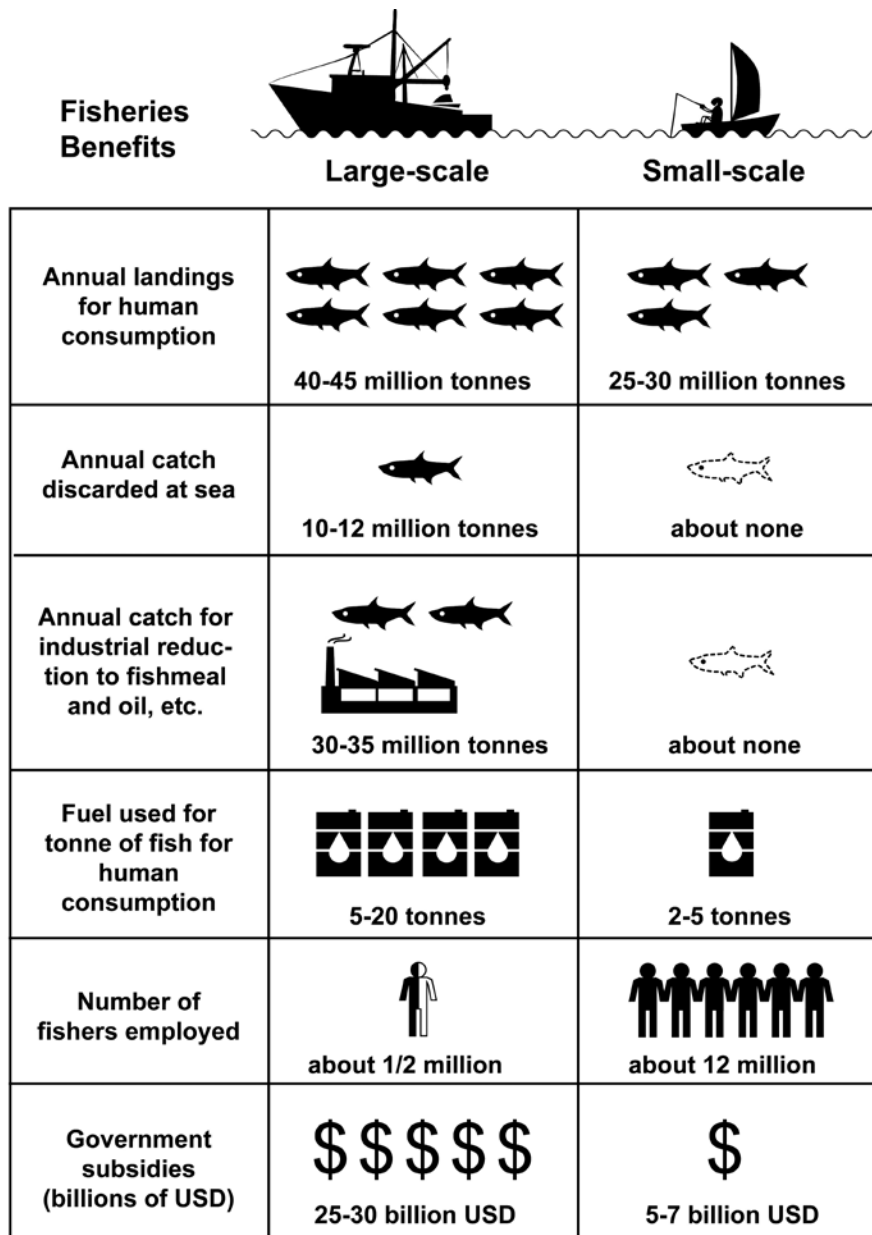
**Figure 14.3.** Reconstructed global catch by fisheries sectors. Based on domestic and foreign reconstructed catches in the EEZ of all countries and island territories of the world, plus high seas catches, by sectors, that is, large-scale (industrial) and small-scale (artisanal, subsistence, recreational), with discards (overwhelmingly from industrial fisheries) presented separately. (Adapted from Pauly and Zeller 2016.)

are dominated by industrial fisheries, which contributed 73 mt of landings in 2010, down from 87 mt in 2000. Thus, it is a declining industrial catch that is driving down global catches (assisted somewhat by declining discards; figure 14.3), in contrast to the artisanal sector, which generated a catch increasing from about 8 mt/year in the early 1950s to 22 mt/year in 2010 (figure 14.3). Although subsets of artisanal catches are sometimes included in official catch statistics provided to FAO, subsistence fisheries rarely are, even where they are crucial (Zeller et al. 2015). Worldwide, subsistence fisheries caught an estimated 3.8 mt/year between 2000 and 2010 (figure 14.3), a substantial fraction of it through gleaning by women in coastal ecosystems such as coral reef flats and estuaries (Harper et al. 2013). The importance of subsistence fishing for the food security of developing countries, particularly in the tropical Indo-Pacific, cannot be overemphasized (Chapman 1987; Palomares et al. 2014; Zeller et al. 2015).

Recreational fishing, whose current global estimate of just under 1 mt/year is rather imprecise, is declining in developed countries but increasing in developing countries. This activity, which generates an estimated US\$40 billion/year of benefits, involves between 55 and 60 million people and generates about one million jobs worldwide (Cisneros-Montemayor and Sumaila 2010).

Discarded bycatch, generated mainly by industrial fishing, notably shrimp trawling (Andrew and Pepperell 1992), was estimated at 27 mt/year ( $\pm 10$  mt) and 7 mt/year ( $\pm 0.7$  mt) in global studies conducted for FAO in the early 1990s and 2000s, respectively (Alverson et al. 1994; Kelleher 2005). However, these point estimates were not incorporated into FAO’s “catch” database, which thus consists only of landings.<sup>3</sup> Here, these studies were used, along with numerous other sources, to generate time series of discards (figure 14.3). They show that in 2000–2010, 10.3 mt/year of fish were discarded, a practice that was banned in Norway beginning in the late 1980s, and for the suppression of which the EU parliament passed legislation in 2014. Thus, discarded catches (until they are phased out) ought to be included in catch databases, if only to allow correct inferences on the state of the fisheries involved in this problematic practice.

Another way to present some of the major aspects of the catch reconstructions (and ancillary data) is in the form of an updated Thompson graph (Thompson 1988). This contrasts small-scale (artisanal and subsistence) and large-scale (industrial) fisheries (figure 14.4) such that the many social and ecological benefits of small-scale, particularly artisanal fisheries (see also Dioury 1985) become obvious.



**Figure 14.4.** Comparing large- and small-scale fisheries during the period 2000–2010 through an updated Thompson graph (Thompson 1988; Pauly 2006b), which contrasts the performance of large-scale (industrial) and small-scale (artisanal and subsistence) fisheries on key criteria. The definitions of large-scale (“industrial,” often mislabeled “commercial”) and small-scale (often mislabeled “traditional”) are those prevailing in each maritime country, yet they do not differ much (Chuenpagdee and Pauly 2008). The tonnage of fish reduced to fishmeal (Alder et al. 2008), and the fuel consumption figures (Tyedmers et al. 2005) were scaled up from nominal reported catches; while the numbers of fishers employed (Teh and Sumaila 2013) and the subsidies (chapter 6) were split into large- and small-scale (Jacquet and Pauly 2008).

### SOME POLICY IMPLICATIONS

The reconstructed catch data presented here for all countries in the world allow us to formulate better policies for governing the world’s marine fisheries, especially when combined with a similar reconstruction of the fishing effort to obtain this catch (e.g., by computing

the engine power of the vessels involved therein; see Watson et al. 2013; Greer 2014). Also, the taxonomic composition of this catch, not presented here (but available by country and territory on pp. 185 to 457 and through the *Sea Around Us* website; see [www.seaaroundus.org](http://www.seaaroundus.org)), will allow derivation of much more accurate

catch-based indicators of fisheries status than has hitherto been possible.

A policy change that would be straightforward for FAO to implement is to request countries to submit their annual catch statistics separately for large-scale and small-scale fisheries, which would be an excellent contribution toward the implementation of the recently adopted *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication* (Pauly and Charles 2015). Given that FAO harmonizes all submitted data sources and even derives its own estimates for countries that do not submit data (Garibaldi 2012), FAO could readily derive sector assignments for countries that do not have such assignments.

The very high catches that were achieved in the 1990s were probably not sustainable. However, they do suggest that stock rebuilding, as successfully achieved in many U.S. fisheries, is a policy that needs wide implementation and would generate even higher sustained benefits than previously estimated from reported catches (Sumaila et al. 2012). On the other hand, the catch decline documented here is extremely worrisome in its implications for food security, as evidenced by the decline in per capita seafood availability (figure 14.1B). There is, moreover, little chance that aquaculture—at least the version of it that people in the West have in mind—can compensate for this decline, should it continue.

Most of what people in the West perceive as aquaculture is the farming of carnivorous fish such as salmon; however, such farming consumes more fish (anchovies, sardines, etc., in the form of fishmeal and oil) than it produces (Naylor et al. 2000; see also chapter 12). Hence, the more carnivorous fish we farm, the less fish we have for other purposes, including direct human consumption (figure 14.4; Pauly 2006b).

Furthermore, China, with 62% of the world's aquaculture production (FAO 2014), is now the world's largest importer of fishmeal (Cao et al. 2015), and its aquaculture industry has become increasingly dependent on wild

capture fisheries. Thus, rather than a supplement or replacement to capture fisheries, aquaculture may become another driver for overfishing (Cao et al. 2015).

The last policy-relevant point to be made here transcends fisheries; it deals with the accuracy of the numbers used by the international community for decision making and for generating the factual knowledge needed for such decision making. After World War II, the newly created United Nations and its technical organizations, including the FAO, began a major project of “quantifying the world” (Ward 2004) to provide national and international agencies with the data on which to base their policies. As a result, large databases on agricultural crops and forest cover, for example, were created, and their accuracy is becoming increasingly important, given our propensity to push the exploitation of our natural ecosystems toward and beyond their limits (Rockström et al. 2009).

Therefore, we ought to check and validate these databases from time to time, lest they begin to produce “poor numbers” (Jerven 2013). For example, reports of member countries to FAO about their forest cover, when aggregated at the global level, suggested that the annual rate of forest loss between 1990/2000 and 2001/2005 was nearly halved, but the actual loss rate doubled when assessed by remote sensing and rigorous sampling (Lindquist et al. 2012). Here we show, similarly, that the main trend of the world marine fisheries catches is not one of “stability,” as suggested by FAO (2011), but one of decline. Moreover, this decline, which began in the mid-1990s, started from a higher peak catch than suggested by the aggregate statistics supplied by FAO members, implying that we have more to lose if we let this decline continue. On the upside, this also means that there may be more to gain by rebuilding stocks.

A solution could therefore be for the global community to provide the FAO the funds to better and more intensively assist member countries in submitting better fishery statistics, especially statistics that cover all fisheries

components, and to report data by sector (Pauly and Charles 2015). Such improved statistics can then lead to informed policy changes for rebuilding stocks and maintaining (sea) food security. Alternatively, FAO could team up with other groups (as was done for forestry statistics) to improve the fisheries statistics of member countries that often have fisheries departments with very limited human and financial resources.

Ultimately, the only database of international fisheries statistics that the world has (through FAO) should and can be improved. The rapid decline of fisheries catches clearly documented here is a good reason for this.

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#### NOTE

1. Cite as Pauly, D., and D. Zeller. 2016. Toward a comprehensive estimate of global marine fisheries catches. Pp. 171–181 in D. Pauly and D. Zeller (eds.), *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*. Island Press, Washington, DC.
2. However, FAO explicitly request that countries not include discards in their data submissions to FAO.
3. Note that in both cases, 1996 was not chosen visually (and arbitrarily) but was the output of the segmented regression analysis to which both the FAO and the reconstructed time series were subjected (see also Pauly and Zeller 2016).