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FAO's statistic data and sustainability of fisheries and aquaculture: Comments on Pauly and Zeller (2017)

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ABSTRACT

In a recent commentary, Pauly and Zeller disagreed with the Food and Agriculture Organization's interpretation of its global capture fishery production records, arguing that trends were distorted by unreliable statistics in some countries. They criticized FAO for not having used their "catch reconstructions" in the 2016 *State of the World Fisheries and Aquaculture* (SOFIA) report and questioned the interpretation and significance of FAO's aquaculture production statistics. In this paper, we refute their claims and demonstrate that their critique is based on fundamental misunderstandings caused by mixing up statistical metrics and using simple normative explanations to interpret highly complex datasets. We explain how FAO maintains, curates and updates the only validated source of global fisheries landings, describe our capacity building projects and activities underpinning the annual updates for the over 231 different sources of fisheries data, and clarify such updates include dialogues with member countries to improve and revise present and historical records. FAO will continue to work closely with member states, IGOs, NGOs, academia and civil society, to further improve fishery and aquaculture databases, while calling on states to make renewed efforts to improve data quality. It also welcomes research efforts that contribute to the improvement of statistical data which are critical to the sustainable management of fisheries and aquaculture.

1. Introduction

Pauly and Zeller [1] published a critical commentary on the latest FAO's *State of World Fisheries and Aquaculture* (SOFIA) report [2]. This biennial publication, which has been downloaded over 150,000 times since its launch in July 2016, analyzes major trends in fisheries and aquaculture, including production, consumption, trade, management, conservation, sustainability and many other topics affecting the sector. In their commentary, Pauly and Zeller [1] argue that FAO's interpretation of global capture fishery production is incorrect, as it contrasts with that derived from their recently published "catch reconstruction" exercise [3]. They also criticize FAO for not having used their catch reconstruction in the SOFIA report and question the proposition that aquaculture will overtake wild capture fisheries in terms of food production. Here we clarify that their critique is based on fundamental misinterpretation. For clarity and conciseness, we will not reply to all of their specific points, but instead clarify the fundamental facts that are distorted in Pauly and Zeller [1], while providing a brief reply to their four main criticisms.

2. Clarifications on global fisheries statistics

2.1. FAO's data collection process

FAO's function of collecting, analyzing and disseminating fisheries data and information is embedded in Article 11 of the FAO's Constitution, and has been performed since its establishment in 1945. The FAO global capture production database[1] is the only available source of such information. Its careful and consistent collation, curation and analysis has been instrumental, in recent decades, in understanding the state of global fisheries, crucial to the development of normative guidelines for securing sustainable fisheries, and essential to FAO's efforts to provide specific management advice to countries. The database is primarily based on the official statistics submitted by member countries, but these are complemented or replaced with data from other sources (e.g. "best scientific data" on tuna landings from Regional Fisheries Management Organizations [RFMOs], landings by distant water fleets in countries' EEZs, etc.), which partially cover

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[1] The FAO Global Capture Production database is a collection of nominal catches that are the net weight of the quantities landed as recorded at the time of landing converted to their live weight equivalents [4]. In the context of this response, and for ease of reading, we will refer to the data in this database as "landings".

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catches unreported. The concepts, techniques, classifications and standards for the collection, processing and dissemination of FAO fishery statistics are set by the FAO Coordinating Working Party on Fishery Statistics (CWP) [5], a body created in 1960 to establish and harmonize standards across the world.

The nature of statistical reporting involves continued curation and updating of the data itself. FAO has established a series of mechanisms to ensure that the best available information is submitted, revised, and directly or indirectly (e.g. using consumption surveys) validated. These mechanisms help FAO work with individual countries to understand and update their information. For example, FAO worked with China to revise downwards its fisheries capture statistics by about 10% for the period 1997–2005 [6]. As anticipated in SOFIA [2], the release of the capture database with 2015 data will include a revision for Myanmar, as FAO has questioned why the damages caused by cyclone *Nargis* in 2008, the worst natural disaster in the recorded history of Myanmar, did not result in decreases in their reported catches. Following a study [7] which examined discrepancies between tuna landings in the FAO and RFMOs databases, the new release of the FAO datasets will also include a significant revision of tuna landings for the Philippines, as country data were found to include also landings by foreign vessels landed in the country. These exercises are ongoing, and demonstrate that the FAO datasets are the best they can possibly be. Despite the revisions listed above, preliminary calculations confirm the stable trend in global landings that has been reflected in the SOFIA report [2] but questioned by Pauly and Zeller [1].

FAO is convinced that the continued improvement in the overall quality of this unique and extremely valuable database can only be obtained by enhancing and supporting national data collection systems. Since the 1970s, FAO has been helping national institutions improve their collection systems through field projects, training activities, publications and software. Currently, FAO has about 30 capacity building projects in operation, in collaboration with international organizations and funding institutions, Regional Fisheries Bodies (RFBs), and individual countries. These include activities in East and West Africa, the Caribbean, the Mediterranean and South Asia. As a result of these efforts, data from more than half of the 231 countries and territories included in the database are revised every year. We realise that FAO needs to communicate more efficiently so that the thoroughness and care behind its data collection and curation efforts is understood, valued and appropriately recognized.

2.2. Estimation or reconstruction of IUU and discards

The users of fisheries catch statistics know that not all fish caught in the wild is retained, landed and reported to fishery authorities. A portion of the catch, which varies significantly in time, space and by sub-sector, may be discarded for diverse economic or management reasons [8]. In addition, there are also illegal, unregulated and unreported (IUU) fisheries, the catches of which are, by their very nature, largely unknown. In the FAO's database, capture fisheries production covers only landed catches converted to their live weight equivalents [4]. Pauly and Zeller [1] "catch reconstruction", by contrast, includes estimates of discards and IUU catches.

FAO has always been aware that its global capture database does not include all fish removals, as it is not its objective, but it has commissioned three evaluations of global discards, one in 1983 [9] (estimated as 6.7 Mt), the second in 1994 [10] (estimated to be between 17.9 and 39.5 million tonnes) and a third in 2005 [11] (estimated to be 7.3 million tonnes). The very significant difference in the total volume of discards between these three publications was explained by Kelleher [11] as reflecting the methodological difficulties associated with their estimation, even as an average of time and space. Agnew et al. [12] provide a global estimate of IUU fishing in 2009, to account for between 11 and 26 million tonnes. In 2015, FAO convened a workshop to provide technical guidelines leading to an update of the estimates from

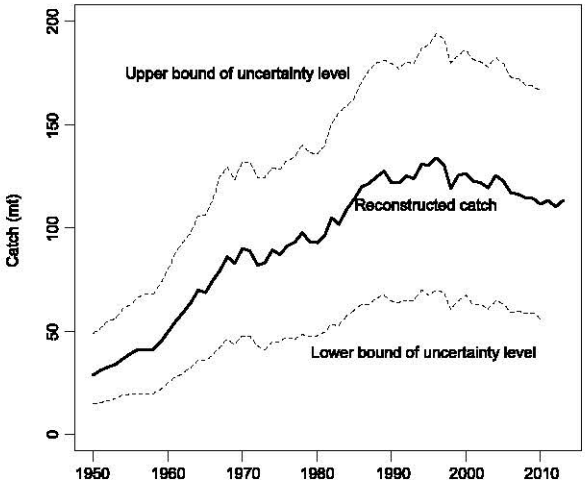

Fig. 1. Reconstructed marine fisheries catches 1950–2013 from the Sea around Us website and the upper and lower bounds of uncertainty level redrawn from Pauly and Zeller [3].

Agnew et al. [12]. The workshop noted the absence of robust and consistent methodologies, as well as significant confusion in the literature, as to what precisely constitutes IUU fishing. While FAO intends to estimate current levels of IUU fishing, all expert evidence points towards such estimates as being highly uncertain, given the temporally and spatially sparse nature of any information on these activities, many of which are illegal.

In this context, it is remarkable that Pauly and Zeller [3] have been able to estimate IUU and discard volumes for every country in the world, and for every year from 1950 to 2010, based on a six-step approach. Combining their estimates with FAO's capture database as the main baseline, they quantified total fish removals from all ecosystems. A huge uncertainty is involved in such reconstruction, as recognized by the authors. For example, their total removal estimate for 2010 is somewhere between 50 and 160 million tonnes (Fig. 1, see more discussion in Section 3.1). It is not FAO's role to validate academic publications that partially use FAO's data, but it is worth noting that the methodology used in catch reconstructions has already attracted criticisms in the scientific literature [13,14].

We must clarify that FAO recognizes the potential value of catch reconstructions. Such exercises may provide information on fisheries' contributions to food security and nutrition, help identify fisheries' sub-sectors that are not well covered in national data collection systems (e.g. recreational catches), and help countries revise their submissions. They may also prove useful in assessing overall fishing pressure on particular ecosystems. However, the uncertainty involved must be recognized when interpreting contrasting trends that may derive from such reconstructions compared to primary sources. It would be beneficial to keep original and secondary statistics separated, to avoid confusion in their interpretation by the user community, and to recognise their methodological differences and complexities.

3. Comments on Pauly and Zeller's statements

3.1. Is the catch of world marine fisheries really stable?

Pauly and Zeller [1] compare total fish removals with FAO landings data. Having explained the difference between landings and total removals, it should be easy to see that figures for the two are not comparable and, given the uncertainty in the latter, that it would not be sensible to argue about differences in their trends. Based on FAO's data, global marine landings have been oscillating in the last 30 years between 71.5 million tonnes in 1985 and 78.4 million tonnes in 2014, when catches of the highly variable Peruvian anchoveta (*En-*

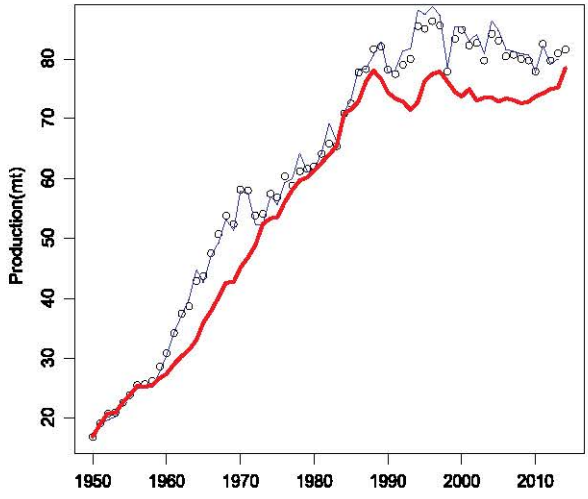

Fig. 2. Comparison between total marine landings (circles) in the FAO database (1950–2013) and "reported catches (1950–2010)" in Pauly and Zeller's [3] (thin line), plus FAO's marine landings excluding anchoveta (thick line).

graulis ringens) are excluded [2] (Fig. 2). This stability in total landings does not reflect stability in landings for all regions or species though. Disaggregated landings are indeed quite variable over time.

As reported catches in Pauly and Zeller [3] are almost the same as FAO's records (Fig. 2), the declining trend of reconstructed catches is mainly caused by the trends in discards and IUU estimates ("unreported" catch). Given the huge uncertainty involved such estimates it would seem imprudent to read too much into the trend of the signal. Moreover, even if such declines were real, a reduction in discards and IUU catches should be a reflection of improvements in fisheries management, which may also be responsible for the relative stability in landings in recent decades.

We also note that the relationship between "unreported" and "reported" catch in Pauly and Zeller is linear (Fig. 3). The only significant differences in their trends are a linear decrease in "unreported" catches over time, already mentioned in [3], and a stepwise change in the relationship between both variables after 1996 (Fig. 3). Such a stepwise shift is hard to explain and may reveals the need of further examining the assumptions behind the catch reconstruction method.

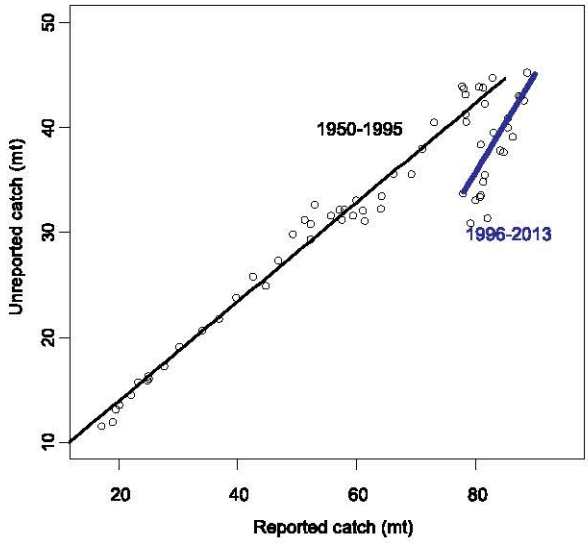

Fig. 3. Relationship between "reported" and "unreported" catch in Pauly and Zeller [3]. Linear regressions provided for the 1950–1995 and 1996–2013 periods.

3.2. What will future catches be?

Pauly and Zeller [1] imply that the increase in the percentage of overfished stocks in recent years, as reflected in SOFIA 2016, supports the decreasing trend seen in their reconstructed catches. They suggest that this is in contradiction with the stability in capture fisheries production reported in SOFIA. In support of their interpretation, they cite Worm et al. [15], who predicted that if present trends of overexploitation continue, all fish stocks would collapse by mid-century. This is unfortunate as this paper has been the focus of many rebuttals in the literature, (e.g., [16–18]). Indeed, the lead author published a follow-up paper [19] showing that while the majority of assessed stocks were below target levels, trends in fishing pressure had been reversed and exploitation rates in most ecosystems were at or below the level predicted to achieve maximum sustainable yields of fish.

But is there a contradiction between SOFIA's statements on global stability in landings and the increasing rate of overfished stocks? No, there is not. First, it is well known that landings do not necessarily reflect abundance and thus stock status [20]. Interpreting catch trends without considering management regulations and effort changes requires caution. Second, percentages of overfished stocks calculated by FAO and presented in the SOFIA report are based on the *number* of stocks, i.e. large and small stocks bearing the same weight in the calculation. Therefore, for example, when smaller stocks are overfished and large stocks recover or move from under-fished to fully fished, total landings increase, generating opposite trends. Finally, overfishing top predators could reduce natural predation, increase fishable biomass of prey species at lower trophic levels, and consequently total landings. This has indeed been recently demonstrated by Szuwalski et al. [21], consistent with the fishing down the food web theory [22]. Based on FAO's analysis of assessed commercial stocks, the share of fish stocks within biologically sustainable levels decreased from 90% in 1974 to 68.6% in 2013.

Pauly and Zeller [1] stated that the method they used to assess stock status was a simplification of the method FAO developed [23]. The FAO method was actually established to assess development stages of fisheries (undeveloped, developing, mature and senescent) and not the status of their resources, despite the intuitive connection between the two. FAO chose not to confuse the two, as discussed for example in the Pauly and Hilborn debate [20].

3.3. Why keep pretending that catch reconstructions do not exist?

FAO's mandate and its data collection process were explained earlier. FAO's data reflect landings as recognized by countries and fisheries bodies, and the figures are used for a wide range of purposes including catch reconstructions. Just as important as the difference between landings and total removals, it is important to differentiate original data (FAO data) from secondary data (reconstructed catches) consisting of estimates based on the original. Blending them does not necessarily add value to the original dataset, and may cause confusion and raise the risk of significant misinterpretation.

FAO does not "pretend that catch reconstructions do not exist", as Pauly and Zeller [1] claim. The recent FAO Committee on Fisheries (COFI) in July 2016, a meeting attended by delegates from 126 countries and 212 observing organizations, and which coincided with the release of the 2016 SOFIA report, included a side event on catch statistics, with participation of Pauly and Zeller's team. Various catch reconstruction methods were presented, and member countries and NGOs discussed the opportunities and challenges they face in their data collection. No country has to date revised its statistics as a result of the catch reconstruction exercise.

Pauly and Zeller [1] argued that FAO should estimate total removals, and they claim that the same method of interpolation FAO uses to estimate catches for a given single year when data is missing can easily be applied to estimate IUU catches and discards. This argument is

not statistically sound. Interpolation produces estimates between known observations, but extrapolation estimates the value of a variable beyond the original observation range, and it is thus subject to greater uncertainty and a higher risk of producing meaningless results. Considering the scarcity and methodologically diverse estimates of IUU fishing and discards, especially in many developing countries, such estimates may be obtainable not by interpolation, nor extrapolation, but rather by means of some magical method able to produce a large amount of estimates out of a very small original database. Even if one were prepared to take that risk, the value of the result would be questionable.

Finally, it is worth mentioning that SOFIA is FAO's official report, with a focus on dissemination of officially reported data and policy or practical issues around the world. The production of SOFIA follows editorial policies and medium term milestones, which do not make it an opportunistic and on-the-fly review of all existing information in the very rich and diverse field of fisheries and aquaculture science, which seems to be the type of report Pauly and Zeller [1] are asking for.

3.4. What is up with aquaculture?

Pauly and Zeller [1] warn FAO of the dangers of '*... serious double counting ... unless clear data adjustments are done*'. They further state that '*It would be appropriate for FAO, when summing up the fish produced globally and available for human consumption, to exclude the fish used as food for other (farmed) fish, and explicitly emphasize this.*' In fact, SOFIA 2016 did explicitly carry out such statistical adjustments. Table 1 in SOFIA 2016 clearly separates the utilization of fisheries and aquaculture production from what is used for human consumption and non-food uses. Moreover, Figure 29 presents *per capita* fish consumption, excluding fish used to produce fishmeal and fish oil or used as direct feeding for aquaculture, livestock, as well as other production destined to non-food purposes. Therefore, FAO stresses that there is no double counting. However, FAO realises there is possibly a need to improve the presentation of *per capita* fish food supply data in order to minimize such confusions.

Pauly and Zeller [1] also raise the danger of increased malnutrition in many maritime developing countries where the lower nutrition value of the more affordable aquaculture products make aquaculture a less ideal substitute for domestic wild-capture fisheries. FAO considers food security and nutrition to be one of its most important strategic objectives and fully recognizes the role of fisheries and aquaculture in securing food for all [24]. For example, the FAO SmartFish project [25] pointed out that some African countries' food security and nutrition policies overlooked fish despite its importance in people's diets as evidenced through dedicated surveys, and similar work is proceeding in Central America. Aquaculture has been the fastest growing food production industry in the world for the last few decades, outpacing human population growth. Despite some unsustainable practices it has a lower ecological footprint than other land-based animal protein production systems [26]. Fishmeal and fish oil inclusion rates are decreasing [27,28] (e.g. as a share of Atlantic salmon diets they fell from 65% to 24% and from 19% to 11%, respectively, between 1990 and 2013, [27]), while food conversion ratios (the ratio of biomass of food fed to fish produced) over the past 25 years have fallen from around 3:1 to around 1.3:1 [29]. With these technical advances, aquaculture's reliance on wild fish for feed should continue to decline, helping aquaculture continue to be a major source of food and nutrition, rather than a substitute for wild fisheries.

As is made clear in SOFIA 2016, FAO shares the concerns of the authors and others about the projected growing gap between fish supply and demand, especially in those parts of the world where fish are most needed [30–34]. FAO is working with member countries through the Blue Growth and other initiatives to maximize the potential of aquaculture to meet environmental, economic and social goals, especially those associated with food security and nutrition, and in pursuit of the United Nations Sustainable Development Goals [35]. Considering the need to increase food production by over 50% by 2050 [33], FAO considers aquaculture as having a significant contribution to make towards meeting this challenge.

4. Way forward

The continued use of FAO's datasets for research and management purposes is welcome, as this adds an additional richness to the efforts to collate information from all countries and territories on fish landings. Catch reconstructions, if properly validated by countries, can provide useful information on the success of management measures, as declines in discards and IUU fishing appear to indicate.

FAO, however, believes that the only way to improve fishery data is through enhancing national data collection systems, particularly in countries where they are weak, not operating regularly, or have technical or resource difficulties. FAO will continue its effort to work closely with member states and other organizations including IGOs, NGOs, academia and civil society, to help further improve fishery and aquaculture databases, information and knowledge. At the same time, FAO also calls on member states to make renewed efforts to improve data quality, and welcomes research efforts that, through improved fisheries information and thorough analyses, contribute to raising awareness on data issues critical to the sustainable management of fisheries and aquaculture.

FAO would also like to encourage the authors of catch reconstructions to separate discards from catches that are landed and contribute to food, trade and livelihoods in the fisheries sector. Discards are returned to the sea, and while they increase mortality, the biomass is recycled in the ecosystem, not removed. It would also be appropriate to clearly separate landings from estimates of IUU catches, as they are subject to very different assumptions, uncertainties and data collection systems. The impression that the latter complements the former to generate a perhaps more reliable dataset is questionable.

Finally, we would like to reflect on the fact that catch reconstructions themselves rely principally on the painstaking work of FAO in collating, curating and analyzing the only source of global, regional and national data on marine and inland capture fisheries. FAO has spearheaded and continues to lead in the global efforts to secure fisheries sustainability, efforts that rely partly on the quality and credibility of our statistics and their interpretation.

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