

## Comments on FAOs *State of World Fisheries and Aquaculture* (SOFIA 2016)



Daniel Pauly, Dirk Zeller\*

*Sea Around Us, Institute for the Oceans and Fisheries, University of British Columbia, 2202 Main Mall, Vancouver, Canada V6T 1Z4*

### ARTICLE INFO

#### Keywords:

Aquaculture  
Catch reconstruction  
Catch trends  
Global fisheries  
Marine capture fisheries  
Stock status

### ABSTRACT

Comments are provided on several points in the 2016 *State of the World Fisheries and Aquaculture* produced by the Food and Agriculture Organization of the United Nations (FAO). It is shown that data assembled by FAO from submissions by countries suggest a “stable” trend mainly because the declining catches of a number of countries with reliable statistics is compensated for by unreliable statistics from countries where reporting increasing catches may be politically expedient, e.g., China, Myanmar. Also, concerns are raised as to why FAO chose to ignore the well-documented data ‘reconstruction’ process, which fills the gaps that exist in data reported by countries to FAO. It is being ignored despite its importance for governance and resource conservation being well known. This process and its findings could be used by FAO to encourage countries to improve their data reporting, including retroactive corrections. This is important in view of successive analyses of the status of fisheries resources undertaken by FAO (published in current and past SOFIAs) and also in modified form by the *Sea Around Us*. This suggests a degradation of marine fisheries, and, if trends continue, a crisis by mid-century. Finally, comments are presented on the proposition that aquaculture will overtake wild capture fisheries in terms of food production, notably because current aquaculture requires huge quantities of wild-caught fish as feed. Indeed, this emphasis on aquaculture-as-substitute for fisheries raises issues of food security and malnutrition in developing countries, from which much of the fish used as feed originates.

### 1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) published in the late 1940s its first *FAO Yearbook of Fishery Statistics* [1], which became an annual publication in the mid-1950s. Since then, these much appreciated yearbooks (now digital data sets), to which aquaculture statistics were later added have been providing the basis for understanding the evolution of fisheries and quantifying the availability of seafood globally.

Since the mid-1990s [2], the FAO also publishes biannual analyses of major trends that are implicit in the data submitted by their member countries, and harmonized in their statistics database, i.e., the *State of World Fisheries and Aquaculture* (SOFIA). These extremely useful compendia are generally published in time for the biannual Committee on Fisheries (COFI) meeting, in which all its member countries are represented and which, in a sense, is the ‘parliament’ of global fisheries. It constitutes the only inter-governmental body where international issues on fisheries and aquaculture can be presented and examined.

Following on Pauly and Froese [3], the present contribution is a comment on some issues in the latest version of SOFIA [4]. Four points

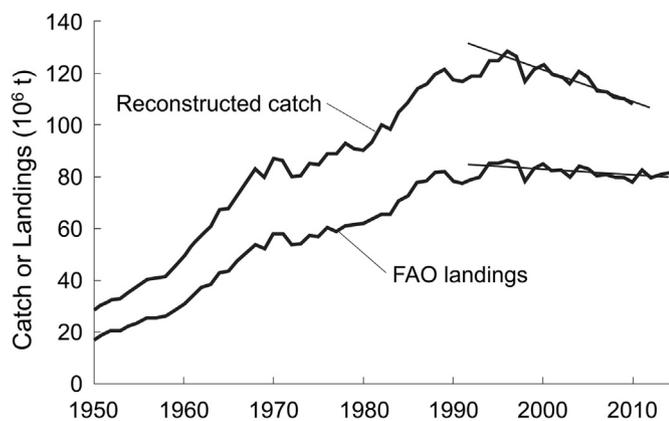
are identified here that might be of interest to the general fisheries, aquaculture and marine policy audience, and on which we feel competent to comment.

#### 1.1. Is the catch of world marine fisheries really “stable”?

There are in SOFIA 2016 [4] various quotes in which the FAO staff that authored SOFIA state that the world marine fisheries catch, or ‘capture production’ in FAO terminology (See Fig. 1A) is ‘stable’. For example, on page 2 (Part 1, World Review), it is stated that “... *capture fishery production* [is] *relatively static since the late 1980s*, ...”, or on page 10 (Part 1, World Marine Capture Production), where it is stated that after 1988 and excluding the highly variable Peruvian anchoveta (*Engraulis ringens*) “... *catches levelled off*...”, and on page 170 (Part 4, Outlook), where it is stated “... *the stabilization of total capture fisheries production at 90–95 million tonnes since mid-1990s*...”. Interestingly, SOFIA 2016 internally contradicts itself on this point of ‘stability’, as shown on page 38 (Part 1, The Status of Fishery Resources) where it is stated that “*The world’s marine fisheries expanded continuously to a production peak of 86.4 million tonnes*”

\* Corresponding author.

E-mail address: [d.zeller@oceans.ubc.ca](mailto:d.zeller@oceans.ubc.ca) (D. Zeller).



**Fig. 1.** Time series of global reconstructed marine fisheries catches (i.e., including discards) for 1950–2010 (modified from Pauly and Zeller [5,6]) and FAO FishStat landings statistics for 1950–2014. The regression trend lines presented cover the time period starting in 1996 (year identified as a breakpoint by the segmented regression analysis in Pauly and Zeller [6]) to the end of each respective time series. Both times series show a declining trend, with reconstructed catches declining at a rate of 1.2 million t yr<sup>-1</sup>, while FAO data decline at a rate of 0.2 million t yr<sup>-1</sup>.

in 1996 but have since exhibited a general declining trend.”

We do not believe that this perceived ‘stability’ in marine fisheries catches is the case. One reason is that the catch reconstructions that have been conducted through the *Sea Around Us* over the last decade for all countries of the world [5] and which will be discussed further below, indicate that since 1996, total world catches are declining at a rate of 1.2 million tonnes per year (Fig. 1). Even the global ‘capture production’ data of FAO show a clear declining trend of 0.2 million tonnes per year using the FAO data ending in 2014 (Fig. 1). Thus, the declining trend has not been reversed by the few years of reported data (2011–2014) that FAO has added compared to our analysis which covered 1950–2010 (the *Sea Around Us* is in the process of updating all data to more recent years). We emphasize here, given many ill-informed statements to the contrary, that 1996 was not a year that was selected for trend analysis because this is when catches peaked, but a year that an objective analytical method (i.e., segmented regression) selected as a trend breakpoint and as the start of a declining trend lasting until 2010, which was the last year for which reconstructed catch data existed at the time of publication of Pauly and Zeller [6].<sup>1</sup>

Contrary to the data reported by FAO on behalf of countries, reconstructed catch time series from Albania to Yemen [see country accounts in 5] are assessed in terms of their catch data reliability (a form of uncertainty assessment), using the scoring system summarized in Table 1. The ‘reliability’ scores therein (i.e., high score=very high ‘reliability’) were based on those developed by the Intergovernmental Panel on Climate Change to help quantify the uncertainty of its assessments by evaluating the quality of, and the agreement between their underlying data and information sources [7]. The catch-weighted averages of these catch data reliability scores are used here (Table 2). A second set of data quality indicators, called ‘taxonomic reliability’ and based on the taxonomic resolution of reported catches is presented also in Table 2, based on Pauly and Watson [8] and Alder, Cullis-Suzuki [9].

As can be seen, the overall trends for fisheries over the last few decades is one of decline in global catch contributions in countries with reasonably accurate and reliable fisheries statistics (Table 2). In fact, these countries would clearly dominate the overall global catch trend if it was not for a group of countries, especially in FAO Areas 57 and 71

<sup>1</sup> The *Sea Around Us* is in the process of updating all data to 2014, with a first release to 2013 expected early in 2017, and data to 2014 to be available by March 2017. Regular annual updates are expected to occur thereafter following the most recent releases of FAO data.

**Table 1**  
‘Catch data reliability’ scores for evaluating the quality of catch data time series of reconstructed catches in Pauly and Zeller [5,6] as adapted from IPCC criteria (Fig. 1 of Mastrandrea, Field [7]).

| Reliability score | Corresponding IPCC criteria <sup>a</sup> |  |
|-------------------|--|--|
| 4                 | Very high                                | High agreement & robust evidence   |
| 3                 | High                                     | High agreement & medium evidence or medium agreement & robust evidence                                     |
| 2                 | Low                                      | High agreement & limited evidence or medium agreement & medium evidence or low agreement & robust evidence |
| 1                 | Very low                                 | Low agreement & low evidence   |

<sup>a</sup> Mastrandrea, Field [7] note that “confidence increases” (and hence confidence intervals are reduced) “when there are multiple, consistent independent lines of high-quality evidence”.

**Table 2**  
Number of global fishing countries that show either a decrease, no change<sup>a</sup> or increase in the mean annual catches (excluding the highly variable Peruvian anchoveta, *Engraulis ringens*) for two time periods representing different global fisheries development phases (1970–1989; 1990–2010), the percent of total global catch these countries account for in each period, and two independent ‘reliability’ scores describing the reliability or trustworthiness of the catch time series and the taxonomic resolution of catch data of each country, respectively (see text).

| Catch category        | No. of countries | Percent global catch |           | Reliability             |           | Taxonomic resolution <sup>f</sup> (countries) |
|-----------------------|------------------|----------------------|-----------|-------------------------|-----------|---|
|                       |                  | 1970–1989            | 1990–2010 | Catch data <sup>e</sup> | 1970–1989 |   |
| Decrease <sup>b</sup> | 58               | 47.7                 | 27.3      | 3.05                    | 3.30      | 40 (18)                                       |
| Same <sup>c</sup>     | 19               | 10.7                 | 9.0       | 2.99                    | 3.39      | 41 (6)  |
| Increase <sup>d</sup> | 123              | 41.6                 | 63.8      | 2.70                    | 2.85      | 27 (18)                                       |

<sup>a</sup> ‘Same’ is +/- 10% of average catch; <sup>b</sup> Top five countries: Japan, South Africa, Russian Federation (incl. ex-USSR), Spain, Italy; <sup>c</sup> Top five countries: South Korea, Norway, New Zealand, Mozambique, Costa Rica; <sup>d</sup> Top five countries: China, Thailand, Vietnam, Indonesia, India; <sup>e</sup> Catch weighted average ‘reliability’ score based on Pauly and Zeller [5, 6] and summarized in Table 1; <sup>f</sup> ‘Taxonomic resolution’ score (possible range 1–100) based on Pauly and Watson [8] and Alder, Cullis-Suzuki [9]; These studies covered the 53 most important fishing countries

(the Eastern Indian Ocean and the Western Central Pacific, respectively) that have largely manufactured, or highly questionable, ever-increasing catch statistics. Also, lower catch quotas due to management action do not explain the catch decline identified, as was illustrated in Pauly and Zeller [6], who showed that global catches also declined when countries with quota management were excluded from the analysis.

That the statistics of several countries are manufactured or at least highly suspect was noted in the preceding SOFIA [pp. 10,11 in 10] which stated that “... marine catches submitted to FAO by Myanmar, Vietnam, Indonesia and China show continuous growth, i.e., in some cases resulting in an *astounding* [emphasis added] decadal increase (e.g., Myanmar up 121%, and Vietnam up 47%)”. Similar indications are also presented in the current SOFIA, which states that “[d]ata quality remains a concern for some major producers. Marine catches reported by Indonesia and Myanmar have increased markedly and continuously in the last 20 years. However, the fact that reported capture production did not decline significantly or continued to increase when natural disasters occurred (e.g. the tsunami of December 2004 and Cyclone Nargis in May 2008) made FAO concerned about the reliability of their official statistics. For Indonesia, new estimates, such as those produced by the Indian Ocean Tuna Commission, showed that catches might have been underestimated in the past and, consequently, the increasing trend could also have resulted from a better coverage of the enormous number of scattered landing sites. For Myanmar, recent findings by

FAO have shown that official statistics were based on target levels rather than on real data collection.” This last example of over-reporting for Myanmar [demonstrated as a problem several years earlier; 11] is thus a clear indication as to a likely main (political) reason for the disconnect between reported data and catch reality on the ground for some of the countries of interest here. A disconnect between actual catches and official reporting of data has also been shown for China [12–15].

We thus conclude this point by suggesting that rather than stressing an elusive ‘stability’ of the world marine fisheries catch, FAO should emphasize the rather tentative nature of the trend it reports and that its apparent stability is probably a misrepresentation of true global trends due to two factors: (1) reliable catch time series (Table 2) that are trending downwards being compensated for by unreliable catch time series (Table 2) that are trending up; and (2) by the generally improving quality of data collection systems in more recent years accounting for an increasing share of actual catches without making corrections and adjustments to the under-reporting of such catches in previous years (i.e., a time-series bias), leading to inconsistent historic baselines [6,16]. These points have substantial ramifications for any interpretation of global marine capture trends and patterns.

### 1.2. What will future catches and landings be?

In 1996, two senior FAO staff published an ingenious method for summarizing the status and trends of fisheries resources [17, see Fig. 2A]. Froese and Kesner-Reyes [18] proposed an efficient and elegant simplification of that approach which was adopted by the *Sea Around Us* and labelled ‘Stock-Status Plots’, as described by Kleisner, Zeller [19]. Fig. 2A and B show that the two methods provide similar results.

This consistency is important because the Stock-Status Plots were criticized by various authors [e.g., 20], who, however, never criticized the original publication of Grainger and Garcia [17], nor the appearance of various versions of Stock-Status Plots in successive editions of SOFIA [21,22 for formal rebuttals]. Here it is shown, in Fig. 2C that Figure 13 in SOFIA 2016 (p. 39) is also consistent with a Stock-Status Plot (Fig. 2B) that was generated to characterize global fisheries (see also [www.seaaroundus.org/data/#/global/stock-status](http://www.seaaroundus.org/data/#/global/stock-status)).

Such plots, it must be stressed, should not be read vertically as is unfortunately done regularly, i.e., to infer the percentage of stocks that are in various categories (*underfished*, *fully exploited*, etc.). This is because the fraction of these categories in the overall number of stocks depends very strongly on the precise, and ultimately arbitrary definition of *underfished*, *fully exploited*, etc., which moreover, vary over time (compare Fig. 2A with 2C, both issued by FAO).

Rather, with Stock-Status Plots, the key information about the status of marine resources is conveyed by the *trend* of the lines that separate the categories from each other. In the case of SOFIA 2016, (i.e., Fig. 2C) for example, the line separating *unexploited* from *fully exploited* stocks clearly trends downward and so does the line separating *fully exploited* from *overexploited* stocks, in spite of the period covered (1974–2013) being shorter than it should have been.

Quite simply, this means that FAO’s analysis based on data reported to FAO predicts that in the future more stocks are likely to be overexploited and that underexploited stocks will likely vanish in about 2 decades, assuming nothing changes in the general trend over time. As far back as 2009, Froese, Stern-Pirlot [23] suggested that there might not be any more ‘*underfished*’ stocks by around 2020, a trend that appears to be confirmed by Fig. 2C. Note that, in line with Garibaldi [24], one might wish to generally ignore the last year or two of available data (i.e., 2012 and 2013 in Fig. 2C), as these data are often highly uncertain, and subject to revision and change in subsequent years.

These trends are similar to those in Worm, Barbier [25], a contribution to which we were not part, but which we feel that we have to defend because its prediction that all stocks would ‘collapse’ by

2048 if current trends continue, and which was widely derided as absurd, is actually quite likely given *continuation of present trends*. Obviously, overexploited and even collapsed stocks can and do continue to provide (sub-optimal) catches, as illustrated in the *Sea Around Us* dual-pattern Stock-Status Plots (see top graph at [www.seaaroundus.org/data/#/global/stock-status](http://www.seaaroundus.org/data/#/global/stock-status)).

Here it is suggested that FAO should devote space and considerable emphasis, in subsequent SOFIAs, on how exactly these downward trends can be reversed, an issue that some authors have begun to examine [e.g., 26,27].

### 1.3. Why keep pretending that catch reconstructions don’t exist?

That the data reported by FAO on behalf of countries are incomplete is widely recognized [24] and privately conceded by many FAO staff. However, almost all of the problems with the data reported by FAO originate from the member countries that send data sets heavily focusing on industrial fisheries and under-representing or even omitting artisanal, subsistence and recreational fisheries.

Other problems are due to a tradition that sees fish<sup>2</sup> only as taxable commodities, hence only landed fish are reported, while discards are not. Thus, FAO instructs its member countries not to report discarded fish. In today’s age of endorsing the Ecosystem Approach to Fisheries (as also supported and emphasized by FAO), it is anachronistic to not include discarded catches as a clearly identified category in global fisheries statistics [see 6]. The reasoning that not all countries have data on their fisheries’ discards does not justify their omission, as FAO regularly derives substitution estimates of landings for countries that, for various reasons, do not report in a given year, as clearly stated on page 10 in SOFIA [4] and in Garibaldi [24]. The same could easily be done for discards. Again, retroactive estimation will be required to avoid biased baselines and associated time-series bias, see point (2) in last paragraph of item (1.1) above.

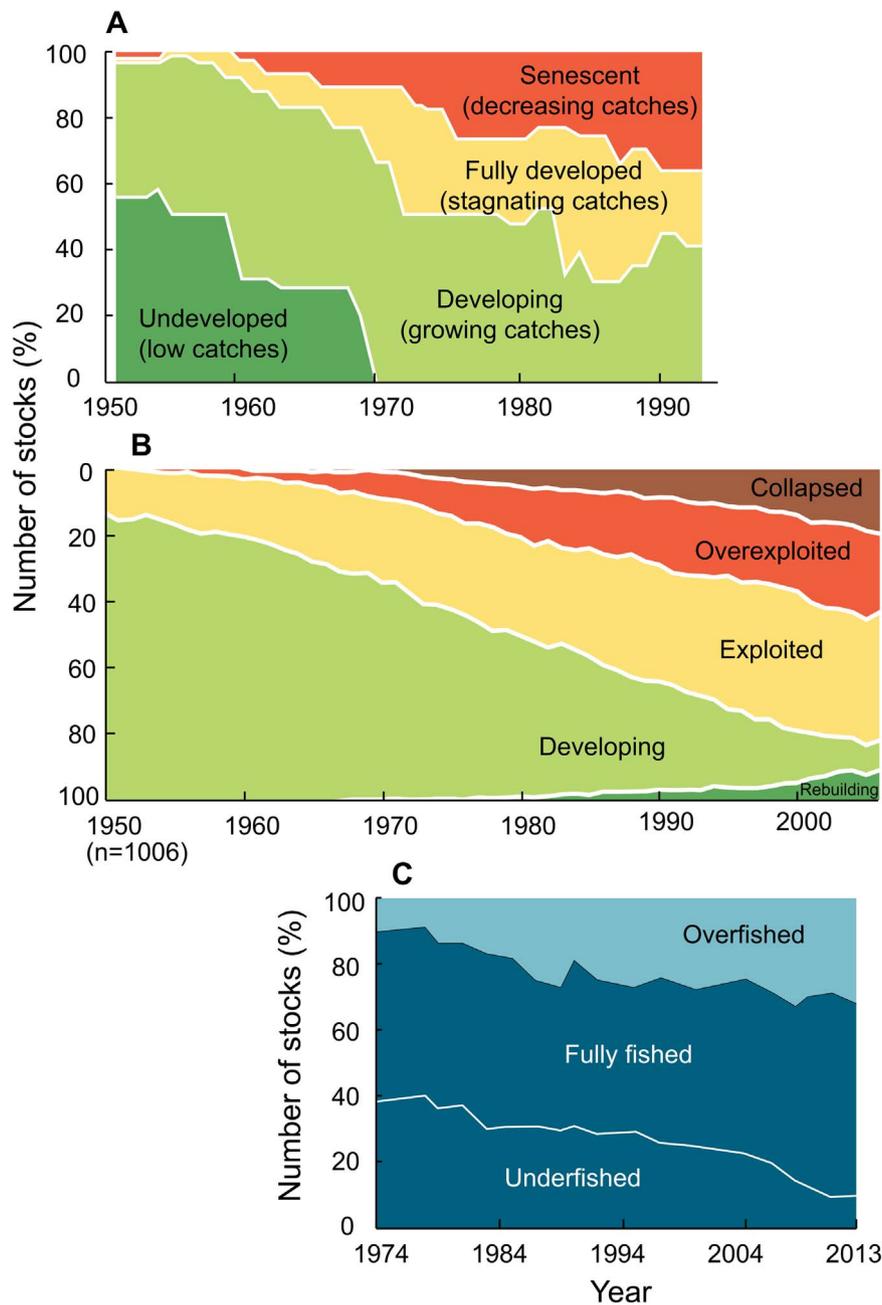
Another source of incompleteness in data reported by FAO is that, as an intergovernmental organization, FAO cannot quantify illegal catches. We note, however, that illegal and other unreported catches are often quantified in Working Groups of the International Council for the Exploration of the Sea (ICES), covering the North East Atlantic [28]. A clear statement by FAO as to the fate of illegal catch data in FAO statistics if such data were provided by host countries would be beneficial.

These omissions in the FAO database, largely inherited from national data submissions, translate into zero estimates for all these catch categories.<sup>3</sup> In a major effort to correct for these omissions, the *Sea Around Us* has undertaken a decade-long ‘catch reconstruction’ effort covering all countries of the world and involving hundreds of experts from these countries [29,30]. One of the present authors (D.P.) gave a formal lecture to FAO Fisheries Department staff on April 5, 2012, on “*Re-assessing the actual and potential contribution of marine fisheries to food security*”. Also, the second author (D.Z.) briefed senior FAO statistical staff during the previous COFI in 2014 on the upcoming global catch reconstruction results. Also, many of the colleagues involved in reconstructions interacted for several years with FAO staff about multiple catch data sets and their interpretations.

In mid-2015, the *Sea Around Us* website was updated ([www.seaaroundus.org](http://www.seaaroundus.org)) with the reconstructed data for the years 1950–2010 and the documentation of catch reconstructions for all maritime countries and territories, 273 separate EEZ-entities plus high seas in all. Each of these reconstructions is documented in terms of its data sources and methodology via a publicly available chapter in a *Fisheries*

<sup>2</sup> In line with the general definition used by FAO, we define ‘fish’ as representing ‘finfish’ as well as ‘aquatic invertebrates’.

<sup>3</sup> While FAO data do include a symbol for a few cases of ‘no data’ (i.e., ‘...’) such non-numeric symbols are always omitted as soon as catch amounts are summed up for regional or global presentations, as symbols are by their very nature not additive.



**Fig. 2.** Comparison of three graphs illustrating the status of marine fisheries stocks, each covering different time periods, with (A) the original analytical method as derived by the former senior FAO staff members Grainger and Garcia [17], (B) the widely available Stock-Status Plots of the *Sea Around Us*, based on Froese and Kesner-Reyes [18] and Kleisner, Zeller [19], and (C) the most recent iteration as presented by FAO in the 2016 SOFIA [4]. All three graphs show the same general pattern of worsening stock status trends. Note that graphs should be read horizontally, i.e., the trend direction of the category separation lines matter, not the vertical percentage values.

Centre Research Reports or as a Fisheries Centre Working Paper [see Supplementary Table 5 in the Online Supplementary Material of 6]. All of these reports cite FAO because all of them use FAO data or their underlying national data as starting points. Of the 273 separate EEZ-entity catch data reconstructions described in 247 reports, 100 EEZ entity reconstructions (i.e., 37%) were published in 38 peer-reviewed publications in the primary literature by the end of 2015 [see Supplementary Table 5 in the Online Supplementary Material of 6], with 8 more peer-reviewed papers documenting catch reconstructions for 10 additional countries having been published in the primary literature since. Publication efforts are continuing.

Thus, at the time that SOFIA 2016 was finalized (i.e., early 2016), there were over 100 EEZ reconstructions in well over 40 scientific

papers available in the peer-reviewed literature that corrected, complemented, augmented or commented on catch data reported by FAO. Furthermore, prior to the publication of the global catch reconstruction paper in January 2016 [6], we specifically shared the upcoming paper and conducted a phone-briefing with FAO staff on our forthcoming publication and its implications. Yet, SOFIA 2016 [4] managed to cite none of the reconstruction papers and completely ignored the process that has led to these publications. It seems unfortunate that the opportunity to utilize a large body of established scientific knowledge was not seized upon by FAO to enhance its explicit mandate to assemble the best available global data and inform the world about real fisheries catches and their trends.

#### 1.4. What is up with aquaculture?

The press release that accompanied SOFIA 2016 and which formed the basis for many media stories throughout the world emphasized that for the first time aquaculture produced “as much as marine fisheries”. This is also stated in SOFIA proper, which states (Page 22, Part 1, Aquaculture Production) that “[i]n terms of global production volume, that of farmed fish and aquatic plants combined surpassed that of capture fisheries in 2013. In terms of food supply, aquaculture provided more fish than capture fisheries for the first time in 2014”, although if one excludes the production of marine plants (much of which is not used for direct or even indirect human consumption), then “[w]orld aquaculture production of fish accounted for 44.1% of total production (including for non-food uses) from capture fisheries and aquaculture in 2014” (page 18, Part 1, Aquaculture Production). However, this is not correct, as fisheries catches are actually much higher than FAO reports [see Figs. 1 and 5 of 6], while aquaculture (or at least mariculture) statistics appear not to be as much miss-estimated [31,32].

Moreover, much of global aquaculture production occurs in China [62% in 2014, Table 8 in 4] and a small number of other countries (India: 6.6%, Indonesia: 5.7%, Vietnam: 4.6%, Bangladesh: 2.6%). This implies that outside of China and the few additional ‘major’ producers, aquaculture is much smaller and often not growing rapidly. Indeed many regions have declining or stagnating aquaculture production over the last years, e.g., North America (2010–2014: 1.2–0.8%), Western Europe (2010–2014: 0.6–0.4%), or the Caribbean (2010–2014: 0.06–0.05%).

More importantly, combining aquaculture statistics and capture fisheries statistics implies serious double counting will occur unless clear data adjustments are done. This is because a sizable fraction of aquaculture relies on fishmeal and fish oil or other fish products for feed in their operation. Thus, around 22% of total global fisheries landings are used for non-direct human use [33], including fishmeal and direct feed purposes.

Thus, if for example 4 t of wild caught anchovies are required as feed or fishmeal to produce one tonne of aquaculture-raised salmon, one cannot say that humanity has 5 t of fish production. Humanity has either 4 t of anchovies [which, incidentally, are excellent eating and highly nutritious; see also 34] or one tonne of salmon, but not both.

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. It is probably correct that aquaculture will generally continue to grow and contribute to the food provision of more and more people, despite SOFIA clearly showing that non-fed aquaculture production is more or less stagnating since 2010 at around 20 million tonnes [Part 1, Figure 8 on page 24 in source 4]. However, aquaculture cannot do this if it relies on fish that can also be eaten directly by people. This truism would become more visible if FAO made this abundantly clear and ceased to double count the fish used as feed in aquaculture.

Finally, the declining trend in global marine fisheries catches documented in Pauly and Zeller [6] raises the specter of increased malnutrition in many maritime developing countries [see 34]. With few exceptions, these countries are heavily dependent on wild capture fisheries for fundamental nutrition and livelihoods [35], yet these are also the countries whose domestic fisheries are experiencing the biggest competition from illegal foreign fishing [36], limited management and governance capacities, and lack of detailed knowledge of resource status, all combined with human population pressures and growing climate change impacts [37]. It is also these same countries where fish play a crucial role in avoiding diseases due to malnutrition, and given the often lower nutritional value of the more affordable aquaculture products compared to wild caught fish [38], especially the often preferred small-pelagic species, makes aquaculture a less than ideal substitute for vibrant domestic wild-capture fisheries. This suggests that FAO (and other organizations) need to re-focus their global

attention towards treating developing countries fish resources and fisheries as a human health issue requiring nutrition-sensitive policy actions, rather than contributions to ill-defined economic growth.

## 2. Conclusion

The most recent release of the biannual *State of the World Fisheries and Aquaculture* report (SOFIA) was published by FAO in June 2016 [4], and provides a global overview of fisheries and aquaculture. The present article comments on four points in SOFIA that could be of interest to the fisheries and marine policy audience.

It is argued here that the vaunted ‘stability’ of catches from wild capture fisheries (or ‘production’ in FAO terminology) repeatedly stressed by FAO staff in SOFIA is a myth (and is even contradicted within SOFIA), and that global catches have actually been declining since peak global catches in the mid-1990s [6]. It is demonstrated that poor and incomplete statistics from virtually all fishing countries, but especially missing retroactive corrections as a response to improved statistical reporting systems over time (i.e., time-series biases) are to blame for the incorrect global trends derived from data submitted annually to and reported by FAO. The resultant misrepresentation of global catch trends have important ramifications for global marine capture fisheries policy and governance, as well as marine conservation concerns.

It is also noted that the status of fisheries stocks that are analyzed by FAO, largely based on methods derived by FAO staff [17], continue to show a detrimental trend, one of declining status across the board. This matches the Stock-Status Plots made available by the *Sea Around Us* for all Exclusive Economic Zones and other spatial entities, based on a nearly identical, but simplified method [18,19]. In essence, it is argued that both the FAO analyses conducted over the last decades, as well as the *Sea Around Us* analyses support a highly criticized earlier publication [25] that warns of the risks to the status of fisheries resources by mid-century, if current trends continue. We call on FAO to become far more engaged and outspoken on this problematic development and the required solutions.

Furthermore, the reasons for SOFIA ignoring the catch reconstruction process that has been ongoing for the last decade [5] is being questioned. This process has been well described [30] and documented in the peer-reviewed scientific literature, and it has been repeatedly brought to FAO’s attention. Yes, it paints a different picture than official reported fisheries data as submitted to FAO by its member countries. However, the reasons for this are clearly documented and have been validated repeatedly, and the findings of these reconstructions should lead to changes in FAO data requests and procedures, as well as in the projects FAO may undertake with countries on their data systems. Pretending that a well-established and widely documented scientific process that has major impacts on fisheries statistics and policy does not exist is not going to help FAO fulfill its data mission, nor will it improve its scientific credibility.

Finally, concerns about the notion that the growing aquaculture industry may replace capture fisheries for global food security purposes are highlighted. Potential problems with the distribution of aquaculture developments and growth are also emphasized, and the inherent food security, human health and malnutrition problems highlighted that will ensue if capture fisheries are allowed to continue to decline.

## Acknowledgements

The authors are supported by the *Sea Around Us*, funded by the Paul G. Allen Family Foundation. The funder had no part in or influence on study design, analysis and interpretation of data, in the writing of the manuscript or in the decision to submit the article for publication. We thank the entire past and present *Sea Around Us* team for their tireless and dedicated work. We also thank Mr. Gordon Tsui and Ms. Evelyn Liu for preparing Figs. 1 and 2, respectively.

## References

- [1] FAO, Production and fishing craft (1947), FAO Yearbook of Fishery Statistics, vol. I. Rome: Food and Agriculture Organization, 1948.
- [2] FAO, *The State of World Fisheries and Aquaculture – 1994* (SOFIA), Rome, Italy: Food and Agriculture Organization, 1995.
- [3] D. Pauly, R. Froese, Comments on FAO's *State of Fisheries and Aquaculture, or 'SOFIA 2010'*, *Mar. Policy* 36 (2012) 746–752.
- [4] FAO, *The State of World Fisheries and Aquaculture 2016* (SOFIA): Contributing to food security and nutrition for all, Rome: Food and Agriculture Organization, 2016, pp. 200.
- [5] D. Pauly, D. Zeller, *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*, Island Press, Washington, DC, 2016, p. 497.
- [6] D. Pauly, D. Zeller, Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining, *Nat. Commun.* 7 (2016) 10244.
- [7] M.D. Mastrandrea, C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, et al., Guidance note for lead authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, Intergovernmental Panel on Climate Change (IPCC) (2010), Available at: ([www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf](http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf)).
- [8] D. Pauly, R. Watson, Adjusting for context in evaluating national fisheries statistics reporting systems, in: J. Alder, D. Pauly (Eds.), *A Comparative Assessment of Biodiversity, Fisheries and Aquaculture in 53 Countries' Exclusive Economic Zones 16*, Fisheries Centre Research Reports, Vancouver, 2008, pp. 57–61.
- [9] J. Alder, S. Cullis-Suzuki, V. Karpouzi, K. Kaschner, S. Mondoux, W. Swartz, et al., Aggregate performance in managing marine ecosystems in 53 maritime countries, *Mar. Policy* 34 (2010) 468–476.
- [10] FAO, *The State of World Fisheries and Aquaculture* (SOFIA), Rome: Food and Agriculture Organization, 2014, pp. 223.
- [11] S. Booth, D. Pauly, Myanmar's marine capture fisheries 1950–2008: expansion from the coast to the deep waters, In: S. Harper, D. O'Meara, S. Booth, D. Zeller, D. Pauly (Eds.), *Fisheries Catches for the Bay of Bengal Large Marine Ecosystem since 1950*, Phuket, Report prepared by the *Sea Around Us* for the Bay of Bengal Large Marine Ecosystem Project, BOBLME-2011-Ecology-16, 2011, pp. 101–34.
- [12] D. Pauly, F. Le Manach, Tentative adjustments of China's marine fisheries catches (1950–2010). Vancouver, Fisheries Centre Working Paper #2015-28, University of British Columbia, 2015, pp. 16.
- [13] D. Pauly, D. Belhabib, R. Blomeyer, W.W.L. Cheung, A. Cisneros-Montemayor, D. Copeland, et al., China's distant water fisheries in the 21st century, *Fish Fish* 15 (2014) 474–488.
- [14] R. Watson, D. Pauly, Systematic distortions in world fisheries catch trends, *Nature* 414 (2001) 534–536.
- [15] L. Pang, D. Pauly, Chinese marine capture fisheries for 1950 to the late 1990s: the hopes, the plans and the data, In: R. Watson, L. Pang, D. Pauly (Eds.), *The Marine Fisheries of China: Development and Reported Catches*, Vancouver, Canada, Fisheries Centre Research Reports 9 (2), Fisheries Centre, University of British Columbia, 2001, pp. 1–27.
- [16] D. Zeller, S. Harper, K. Zylich, D. Pauly, Synthesis of under-reported small-scale fisheries catch in Pacific-island waters, *Coral Reefs* 34 (2015) 25–39.
- [17] R.J.R. Grainger, S.M. Garcia, *Chronicles of marine fishery landings (1950-1994): trend analysis and fisheries potential*, Rome, FAO Fisheries Technical Paper 359, 1996, pp. 51.
- [18] R. Froese, K. Kesner-Reyes, Impact of fishing on the abundance of marine species, ICES CM2002/L:12. Copenhagen, Denmark, 2002, pp. 1.
- [19] K. Kleisner, D. Zeller, R. Froese, D. Pauly, Using global catch data for inferences on the world's marine fisheries, *Fish Fish* 14 (2013) 293–311.
- [20] T. Carruthers, C. Walters, M.K. McAllister, Evaluating methods that classify fisheries stock status using only fisheries catch data, *Fish. Res.* 119–120 (2012) 66–79.
- [21] R. Froese, D. Zeller, K. Kleisner, D. Pauly, Worrying trends in global stock status continue unabated: a response to a comment by R.M. Cook on "What catch data can tell us about the status of global fisheries", *Mar. Biol.* 160 (2013) 2531–2533.
- [22] R. Froese, D. Zeller, K. Kleisner, D. Pauly, What catch data can tell us about the status of global fisheries, *Mar. Biol.* 159 (2012) 1283–1292.
- [23] R. Froese, A. Stern-Pirlot, K. Altieri, K. Kesner-Reyes, Out of new stocks in 2020: a comment on "Not all fisheries will be collapsed in 2048", *Mar. Policy* 33 (2009) 180–181.
- [24] L. Garibaldi, The FAO global capture production database: a six-decade effort to catch the trend, *Mar. Policy* 36 (2012) 760–768.
- [25] B. Worm, E.B. Barbier, N. Beaumont, J.E. Duffy, C. Folke, B. Halpern, et al., Impacts of biodiversity loss on ocean ecosystem services, *Science* 314 (2006) 787–790.
- [26] C. Costello, D. Ovando, T. Clavelle, C.K. Strauss, R. Hilborn, M.C. Melnychuk et al., Global fishery prospects under contrasting management regimes, in: *Proceedings of the National Academy of Sciences*, 2016, 113:5125–9.
- [27] U.R. Sumaila, V.W.Y. Lam, D. Miller, L. Teh, R. Watson, D. Zeller, et al., Winners and losers in a world where the high seas is closed to fishing, *Nat. Sci. Rep.* 5 (2015) 8481. <http://dx.doi.org/10.1038/srep08481>.
- [28] D. Zeller, P. Rossing, S. Harper, L. Persson, S. Booth, D. Pauly, The Baltic Sea: estimates of total fisheries removals 1950–2007, *Fish. Res.* 108 (2011) 356–363.
- [29] D. Zeller, D. Pauly, Marine fisheries catch reconstruction: definitions, sources, methods and challenges, in: D. Pauly, D. Zeller (Eds.), *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*, Island Press, Washington, DC, 2016, pp. 12–33.
- [30] D. Zeller, M.L.D. Palomares, A. Tavakolie, M. Ang, D. Belhabib, W.W.L. Cheung, et al., Still catching attention: *Sea Around Us* reconstructed global catch data, their spatial expression and public accessibility, *Mar. Policy* 70 (2016) 145–152.
- [31] B. Campbell, J. Alder, P. Trujillo, D. Pauly, A global analysis of mariculture production and its sustainability, 1950–2030, in: D. Pauly, D. Zeller (Eds.), *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*, Island Press, Washington, DC, 2016, pp. 137–151.
- [32] B. Campbell, D. Pauly, Mariculture: a global analysis of production trends since 1950, *Mar. Policy* 39 (2013) 94–100.
- [33] T. Cashion, *The end use of marine fisheries landings*, Vancouver: Fisheries Centre Research Reports 24(3), *Sea Around Us*, Institute for the Oceans and Fisheries, University of British Columbia, 2016, pp. 108.
- [34] C.D. Golden, E. Allison, W.W.L. Cheung, M. Dey, B. Halpern, D.J. McCauley, et al., Fall in fish catch threatens human health, *Nature* 534 (2016) 317–320.
- [35] D. Belhabib, U.R. Sumaila, D. Pauly, Feeding the poor: contribution of West African fisheries to employment and food security, *Ocean Coast. Manag.* 111 (2015) 72–81.
- [36] D. Belhabib, A. Mendy, Y. Subah, N.T. Broh, A.S. Jueseah, N. Nipey, et al., Fisheries catch under-reporting in The Gambia, Liberia and Namibia, and the three large marine ecosystems which they represent, *Environ. Dev.* 17 (2016) 157–174.
- [37] D. Belhabib, V.W.Y. Lam, W.W.L. Cheung, Overview of West African fisheries under climate change: impacts, vulnerabilities and adaptive responses of the artisanal and industrial sectors, *Mar. Policy* 71 (2016) 15–28.
- [38] S.H. Thilsted, A. Thorne-Lyman, P. Webb, J.R. Bogard, R. Subasinghe, M.J. Phillips, et al., Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era, *Food Policy* 61 (2016) 126–131.