Global Sustainability

cambridge.org/sus

Intelligence Briefing

Cite this article: Zeller D, Pauly D (2019). Viewpoint: Back to the future for fisheries, where will we choose to go? *Global Sustainability* **2**, e11, 1–8. https://doi.org/10.1017/sus.2019.8

Keywords:
fisheries; food security; industrial activities; natural resources (biological and non-biological); policies; politics and governance

Author for correspondence:
Dirk Zeller, E-mail: dirk.zeller@uwa.edu.au

Viewpoint: Back to the future for fisheries, where will we choose to go?

Dirk Zeller[1] and Daniel Pauly[2]

[1]Sea Around Us – Indian Ocean, School of Biological Sciences, University of Western Australia, Crawley, 6009, Australia and [2]Sea Around Us, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, V6T 1Z4, Canada

Abstract

We present a view on global marine fisheries that emphasizes mitigating the conflict between sustainability and the scale of industrial exploitation driven by the demand of continuous economic growth. We then summarize the current state of global fisheries. Finally, we advocate strongly for scaling back industrial fisheries, most of which are non-sustainable. This can be achieved through eliminating the harmful, capacity-enhancing subsidies that prop up industrial fisheries to continue operating despite declining fish stocks. Instead, we propose to support well-managed, locally owned and operated small-scale fisheries, which generally contribute more to local employment and food security. We stress that contrary to deep-seated opinion in the fishing industry and among politicians, reducing overfishing by eliminating overcapacity in fishing fleets will actually lead to greater, not reduced catches. This would address part of the increased global seafood demand over the coming decades, which is driven by population and wealth growth. This seems counterintuitive, but is supported by fisheries science, data and experiences. Thankfully, we are beginning to see that some of these changes are being pursued by a growing number of countries and international institutions.

Social media summary

Reducing industrial overcapacity and encouraging well-managed small-scale marine fisheries could save seafood supply.

1. Where we came from in fisheries

Humanity has been fishing for at least 90,000 years (Yellen, Brooks, Cornelissen, Mehlman, & Stewart, 1995). However, despite Europeans having fished in the waters off North America for centuries (Kurlansky, 1997, 1999) and Japanese early industrial fishing for tuna around Pacific Islands in the early twentieth century (Gillett, 2007), the majority of marine fishing, for thousands of years, was undertaken by small-scale fishers in nearshore waters using mainly passive fishing gears (Cashion, Al-Abdulrazzak *et al.*, 2018).

The growth of industrial (i.e., large-scale) fishing after World War II was largely driven by two factors: (1) the reliance on and availability of cheap fossil fuels; and (2) the gradual incorporation of technologies developed for warfare (e.g., radar, echo sounders, satellite positioning, etc.; i.e., 'peace dividend') (Pauly *et al.*, 2002). While both of these factors may also have influenced some small-scale fisheries more recently, this industrialization rapidly turned most marine fisheries from generally local and domestic affairs into the expanding, global corporate enterprise it has now become (Pauly, 2018b; Swartz, Sala, Tracey, Watson, & Pauly, 2010). Other factors clearly also played a role in this development, notably increased demand driven by growing disposable incomes.

This development of industrial fishing fleets often ignored the fact that the rapidly increasing fishing capacity depleted the accumulated and until then largely sustainably renewing fish biomass along the coastlines of developed countries. Therefore, in order to maintain and grow the industrial fisheries, a spatial expansion by industrial fleets occurred until essentially the majority of the world's ocean areas were accessed or accessible (Pauly, 2018b; Swartz *et al.*, 2010), including in the Arctic (Zeller, Booth, Pakhomov, Swartz, & Pauly, 2011) and around Antarctica (Ainley & Pauly, 2014).

The spatial expansion by roving industrial fleets was soon considered an encroachment on the marine resources of coastal countries, particularly where nearshore resources were concerned. This became a serious issue during the 'cod wars' off Iceland between the late 1950s and mid-1970s (Bonfil *et al.*, 1998; Kurlansky, 1997; Steinsson, 2016). Thankfully, in the two decades following World War II, the newly created United Nations system provided a venue for the rational discussion on the governance of fisheries and other maritime affairs.

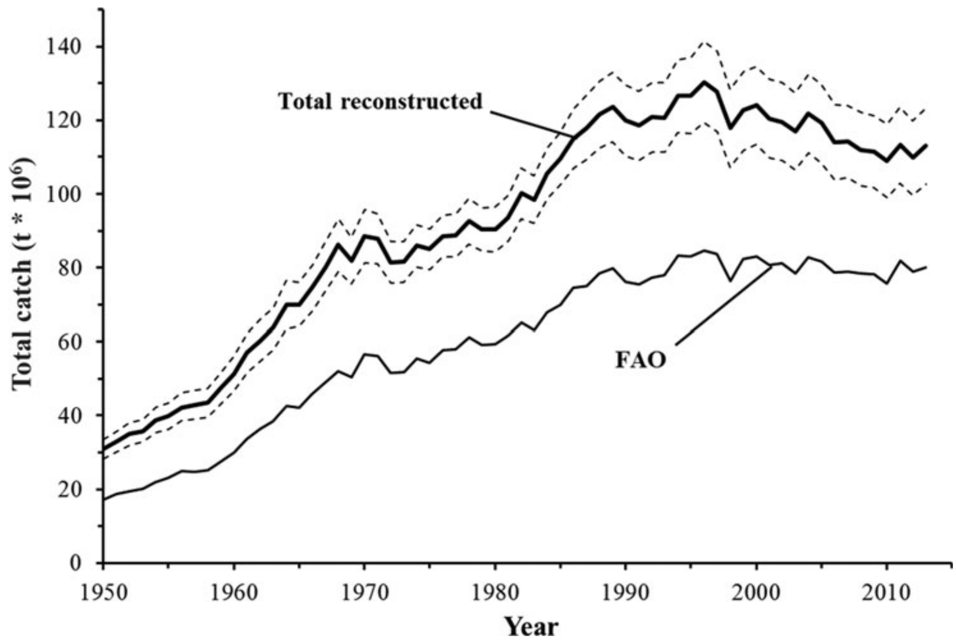

Fig. 1. Global total reconstructed marine fisheries catch (± 95% confidence intervals), including discards (Zeller *et al.*, 2018), based on the sum of the national catch reconstructions performed or inspired by the *Sea Around Us* (Pauly & Zeller, 2016a, 2016c), and global catches (landings only) as reported by the Food and Agriculture Organization (FAO) based on the submissions of its member countries (reported by countries and by the FAO without confidence intervals, despite being estimates and sampled data). The approximate confidence intervals of reconstructed data (dashed lines) were estimated by combining for each year, using a Monte Carlo method, the uncertainty associated with each sector in each national reconstruction into an overall 95% confidence interval (Pauly & Zeller, 2016b, 2017a), which was then doubled to counter the tendency of Monte Carlo methods to underestimate the confidence interval of sums. All data represent wild capture fisheries (no aquaculture production) and exclude plants, corals, sponges, reptiles and marine mammals (Zeller *et al.*, 2016).

This eventually resulted in the Law of the Seas (UNCLOS), arguably the most important international legal ocean instrument (Holbrook Smith, 2017). Besides many other topics, UNCLOS provides the principles, legal framework and conflict resolution mechanism (Rothwell, 2003) for countries to declare Exclusive Economic Zones (EEZs) of up to 200 nautical miles (370 km) from their coasts, within which countries have resource ownership, but also management and conservation responsibilities.

EEZs enabled countries that wished to be host to foreign fishing fleets to gain compensation for the extraction of their resources, generally via foreign fishing access agreements or joint venture operations (although generally for meagre amounts; see e.g., Belhabib, Sumaila *et al.*, 2015; Kaczynski & Fluharty, 2002). However, far too often, the enforcement capacity by developing countries is inadequate, which leads to agreement violations and illegal fishing by foreign industrial fleets (e.g., Cashion, Glaser, Persson, Roberts, & Zeller, 2018; Seto *et al.*, 2017).

The growth and expansion of the global industrial fleets, 'fuelled' by large government subsidies (Sumaila *et al.*, 2010; Sumaila, Lam, Le Manach, Swartz, & Pauly, 2016), seemed to have approached its limits by the 1990s, when global fisheries catches reached their peak (Figure 1). Importantly, global expansion in the marine space appears to have reached its zenith also around that time (Figure 2).

Unfortunately, official reported statistics on the landed catch of the world, as reported annually by the Food and Agriculture Organization of the United Nations (FAO) on behalf of its member countries (see Figure 1), largely masked this fact (FAO, 2016). This masking is mainly due to: (1) the confounding of declining reported landings from countries with reasonably accurate and reliable statistics by data from a group of countries that largely have questionable statistics with an ever-increasing trend (Pauly & Zeller, 2016a, 2017b); and (2) structural issues with national data collection and reporting systems (e.g., the 'presentist bias'; Zeller & Pauly, 2018) that are unintended and easily correctable by-products of data collection system development (FAO, 2018: p. 8). While some disagreements may still exist regarding the estimation of total global catches or their interpretation (Pauly & Zeller, 2017a; Ye *et al.*, 2017), or other criticisms (Belhabib, Koutob, *et al.*, 2015; Chaboud *et al.*, 2015) or misunderstandings (Al-Abdulrazzak & Pauly, 2014; Garibaldi, Gee, Tsuji, Mannini, & Currie, 2014), the decline of overall catches is no longer among them (FAO, 2018).

Thus, in essence, over the last six decades, fisheries have undergone the largest transformation in the history of fishing. In many developed and emerging economies, fisheries moved from largely sustainable, small-scale fisheries with a local focus in terms of fishing capacity, ownership, control and livelihood, to a system of largely corporate-owned and controlled and heavily tax payer-subsidized fleets that can roam the world's oceans, accessing developing countries' resources (legally or illegally). The new system contributes to the increased marginalization of small-scale fisheries (Pauly, 1997, 2006, 2018a; Pauly & Charles, 2015) and endangers the food and nutritional security of millions in developing countries (Golden, Allison, *et al.*, 2016).

2. Where we are now

It is disturbing, in a world prone to food and nutritional insecurity (Barrett, 2010; Golden, Allison, *et al.*, 2016; Golden, Chen, *et al.*, 2016) that nearly a third of global marine landings is not used for direct human consumption (Cashion, Le Manach, Zeller, & Pauly, 2017). Rather, this third of global marine landings is used for fishmeal or animal feed, including for feedlot-type aquaculture operations that produce carnivorous fish (e.g., Atlantic salmon, *Salmo salar*) for developed-world consumers. Crucially important in this context is that 90% of all fish destined for uses other than direct human consumption consist of food-grade or even prime food-grade fish species, and much of this is caught in some of the poorest and most food-insecure regions in the world (Africa, Asia and South America; Cashion *et al.*, 2017). This represents a substantial redirection of food and essential nutrients from low-food-secure countries to rich, high-food-secure countries.

At the same time, there is growing evidence that the downward trend of fisheries is not likely to be reversed easily, notably

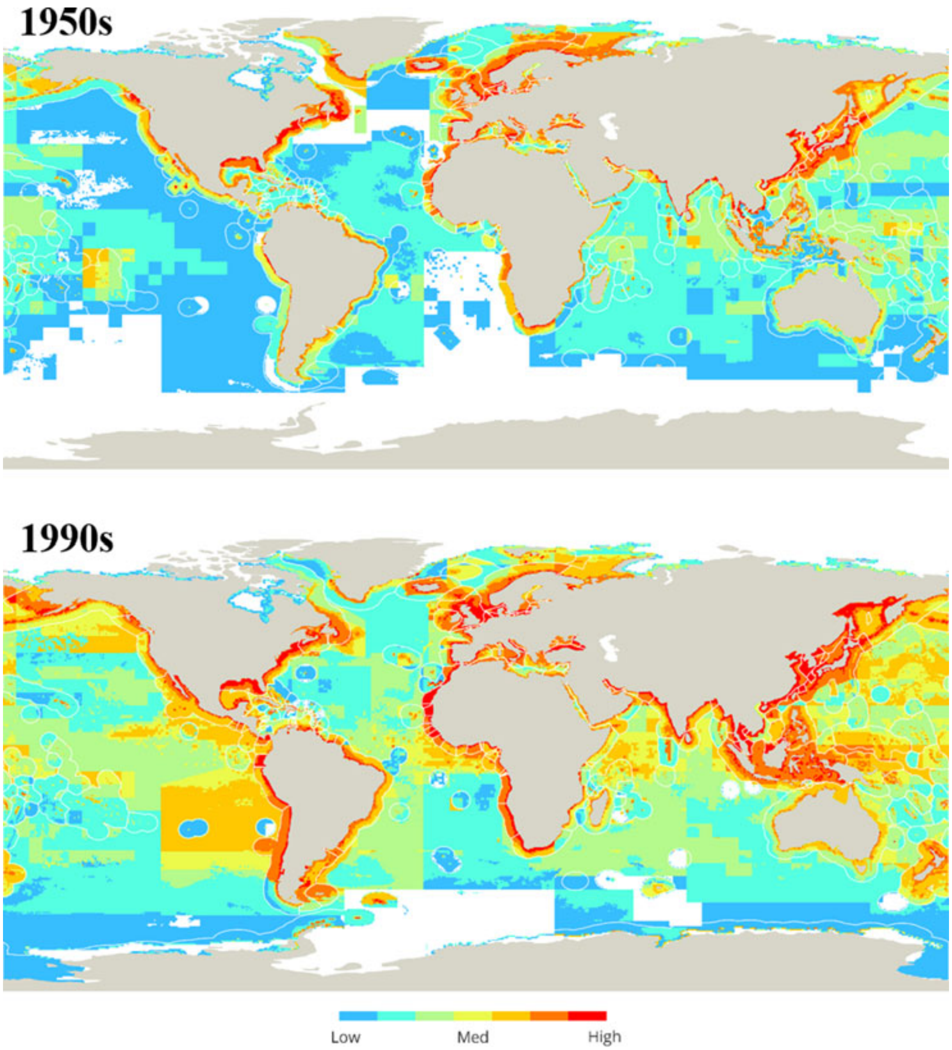

Fig. 2. Average decadal reconstructed fisheries catches for the start of globally reported time series (1950s) and for the decade of peak global catches (1990s), mapped onto a global 0.5° × 0.5° grid-cell system by the *Sea Around Us* through consideration of biological distributions of each taxon in the catch data and observed or permitted fishing access to each country's Exclusive Economic Zone (Zeller *et al.*, 2016).

because they seem to have reached the limits of spatial expansion (Swartz *et al.*, 2010; Tickler, Meeuwig, Palomares, Pauly, & Zeller, 2018). While virtually no waters are too deep (Devine, Baker, & Haedrich, 2006; Koslow, 1997; Koslow *et al.*, 2000) or too remote (e.g., deep southern ocean and Antarctic fisheries; Agnew, 2000; Kock, 1992) for human technical ingenuity and determination to reach and exploit, not all remote areas are fished all the time. Economic considerations of profitability, driven by a balance between the ex-vessel value of their catch (Sumaila, Marsden, Watson, & Pauly, 2007; Swartz, Sumaila, & Watson, 2013) and cost of fishing (predominantly driven by fuel and labour; Lam, Sumaila, Dyck, Pauly, & Watson, 2011), determine when and whether it is worthwhile to fish remote or deep waters. However, such cost–benefit calculations are heavily skewed by cost minimization provided through: (1) the large, harmful subsidies paid to industrial and distant-water fleets (Sumaila *et al.*, 2010; Sumaila *et al.*, 2016); (2) illegal fishing by distant-water fleets in the EEZ waters of other countries without any or, if fishing legally, often inappropriate levels of compensation for extracting their resources (Kaczynski & Fluharty, 2002; Schiller, Alava, Grove, Reck, & Pauly, 2015; Seto *et al.*, 2017); and (3) growing evidence of rampant labour abuses and even modern slavery (Walk Free Foundation, 2016, 2018) in a growing number of fishing fleets (Kittinger *et al.*, 2017; Simmons & Stringer, 2014; Stringer, Simmons, Coulston, & Whittaker, 2014; Stringer, Whittaker, & Simmons, 2016). Thankfully, efforts are being made to address some of these influences (FAO, 2018: p. 183), while others have only recently started attracting the required attention (Tickler, Meeuwig, Bryant, *et al.*, 2018).

Formal fisheries stock assessments (i.e., the estimation of the biomass of a given exploited species of fish in the ocean on an annual or regular basis by means of often complex and data-demanding population dynamics models) allow estimation of likely sustainable catch limits year on year (Hilborn & Walters, 1992). Such stock assessments contribute to the information systems underlying fisheries management decisions in some countries, although political decisions driven by societal choices and expedience may influence or redirect ultimate management decisions. However, many of these traditional stock assessment approaches are, by and large, technically and financially challenging for most developing countries to invest in on an ongoing, regular basis. Not even wealthy, developed countries undertake such assessments for all their fished stocks (e.g., in Europe, around 40% of total fish catches come from stocks that have no formal stock assessments undertaken; www.eea.europa.eu/data-and-maps/indicators/status-of-marine-fish-stocks-2/assessment).

Thankfully, methods have now been developed that permit more streamlined and simpler assessments of stocks to be undertaken with less demanding data and analytical requirements (e.g., Froese, Demirel, Coro, Kleisner, & Winker, 2017; Froese *et al.*, 2018; ICES, 2014, 2015; Martell & Froese, 2013; Rosenberg *et al.*, 2014). In our opinion, one of the most suitable and most widely applicable of these methods is the 'CMSY' method (Froese *et al.*, 2017; Martell & Froese, 2013), which at the minimum requires only reliable catch data and basic, species-specific biological population parameters easily obtained either from local studies or from global, online biodiversity databases such as FishBase (www.fishbase.org) for finfish or SeaLifeBase (www.sealifebase.org) for non-finfish marine life (Froese & Pauly, 2000, 2017; Palomares & Pauly, 2017). The beauty of this approach is that it can also use and incorporate any additional stock biomass-related data that may be available from other assessments and data sources, thus clearly making it far more versatile than the unfortunate misnomer of being a 'catch-only' method or even a 'data-limited' assessment method may suggest.

The considerations above do not deny that some well-managed fisheries exist, notably in Alaska, USA, such as on Alaska pollock (*Gadus chalcogrammus*, see assessments at, e.g., www.afsc.noaa.gov/REFM/Docs/2017/aipollock.pdf) and salmon (*Oncorhynchus* spp., www.adfg.alaska.gov/fedaidpdfs/sp15-04.pdf). These well-managed fisheries exist because the core underlying US legal instrument, the Magnuson–Stevens Fishery Conservation and Management Reauthorization Act (Macpherson, 2001; MSA, 2007), and its execution are clear and harsh with regards to overfishing and legally binding actions. However, while some other jurisdictions seem also to have excellent management rules and policies (e.g., Australia; HSP, 2018), how well these are actually implemented and enforced seems uncertain or even questionable given the state of some of these resources (Edgar, Ward, & Stuart-Smith, 2018). Given this rather disconcerting and pessimistic assessment given here by us, the core question arises: where do we go from here? Obviously, there are various options, as already expounded on by the Millennium Ecosystem Assessment in the early 2000 (e.g., Millennium Ecosystem Assessment, 2005), and currently again as part of the UN's Sustainable Development Goals (e.g., UN, 2017).

3. Where we should be going

We live on a single, finite planet (at least for now; see Shiga, 2008) whose ability to produce services and products that we need for our survival is ultimately limited. Fishing does not 'produce' fish the way agriculture produces a crop, given largely human-controlled inputs such as seeds, water, fertilizers and so on. Fishing vessels only collect the fish that nature produces without our input, free of charge. Hence, when collecting fish becomes unprofitable (and declines), nature is sending us a very clear message: we are taking too much.

Thus, we need to stop paying lip service to the concept of sustainability and actually address it. Declining catches in the general absence of effective management, as is the case in most parts of the world, are indicative of a lack of fisheries sustainability, and the farming of carnivorous species will not solve this issue. Indeed, while the production of farmed salmon or other carnivorous species can be further increased by using zooplankton as feed, such as copepods from waters around Jan Mayen, Norway (or 'red feed'; Tiller, 2010), or krill from around Antarctica (Olsen, 2011), the likely price to pay via disrupted food webs could be extremely high. Thus, such steps provide substantial political, environmental and ethical ramifications and concerns (Tiller, 2010).

Similar concerns also apply to lanternfish (Myctophidae) and other mesopelagic fishes (i.e., mainly inhabiting the twilight zone at depths between 200 and 1000 m) that are increasingly viewed as a resource for the future and that some might argue should be targeted in order to realize the extravagant catch projection involving hundreds of millions of tonnes proposed some decades ago (Gulland, 1971). Here, again, what is threatened is the very fabric of the oceanic food webs that support tuna and other large pelagic fishes currently already heavily, fully or over-exploited, many of which feed on mesopelagics (Alverson, 1963; Battaglia *et al.*, 2013; Karakulak, Salman, & Oray, 2009; McHugh, 1952; Olafsdottir, MacKenzie, Chosson-P, & Ingimundardottir, 2016; Potier *et al.*, 2007).

In our opinion, instead of trying to continue expanding our fisheries, what is needed is to stop the expansion and overcapacity of most industrial fisheries. Stopping and eliminating this expansion and overcapacity would involve: (1) rebuilding the fish populations and ecosystems in the areas where industrial fisheries began (e.g., in Western European seas, off New England and eastern Canada, around Japan, etc.); (2) creating enough no-take marine reserves to secure the continued existence of our most sensitive marine species (O'Leary *et al.*, 2018; Roberts, Bohnsack, Gell, Hawkins, & Goodridge, 2001; Roberts *et al.*, 2017); and (3) halting the provision of harmful, capacity-enhancing subsidies to fisheries in order to shrink our fishing fleets to economically viable and ecologically sustainable levels. This would also help address the growing overfishing challenges faced by developing countries, often due to foreign fleets.

It is largely fuel subsidies that enable a small number of countries to deploy large distant-water fleets (Sala *et al.*, 2018; Tickler, Meeuwig, Palomares, *et al.*, 2018) that can threaten and even devastate the resource base of mainly developing countries that let them operate in their EEZs, usually for low access fees (Belhabib, Sumaila, *et al.*, 2015; Kaczynski & Fluharty, 2002), or that cannot prevent them from accessing their waters illegally (Agnew *et al.*, 2009). Without fuel subsidies and other harmful subsidies, many distant-water fleets would not be able to operate profitably (Sala *et al.*, 2018). Instead, developing maritime countries, such as in Africa, should be assisted in developing their own carefully managed, domestically owned, controlled and operated fisheries and, if they so choose, could themselves develop seafood export capacity to the countries now fielding distant-water fleets.

Finally, the very idea of continuing with the excessive subsidization of industrial fisheries is incompatible with social equity and ecological as well as economic sustainability, because (Figure 3): (1) industrial fisheries employ relatively few people compared with small-scale fisheries; (2) they often use more fuel per tonne of fish landed; (3) they generate around 10 million tonnes of discards annually (Zeller, Cashion, Palomares, & Pauly, 2018); and (4) they land fish of which a third is destined to become animal feed (Cashion *et al.*, 2017). Thus, we strongly support all efforts by countries and the World Trade Organization (WTO) to reduce and eliminate harmful (i.e., capacity-enhancing) fisheries subsidies, which support the existing massive overcapacity in global industrial fishing fleets (Pauly & Zeller, 2019; Sala *et al.*, 2018; Sumaila *et al.*, 2016; Sumaila & Pauly, 2007; Tickler, Meeuwig, Palomares, *et al.*, 2018).

The overcapitalized industrial fisheries have overshot the optimum level of fishing effort (i.e., that associated with 'Maximum Sustainable Yield') of far too many stocks around the world, which has resulted in the declining catches we have been seeing

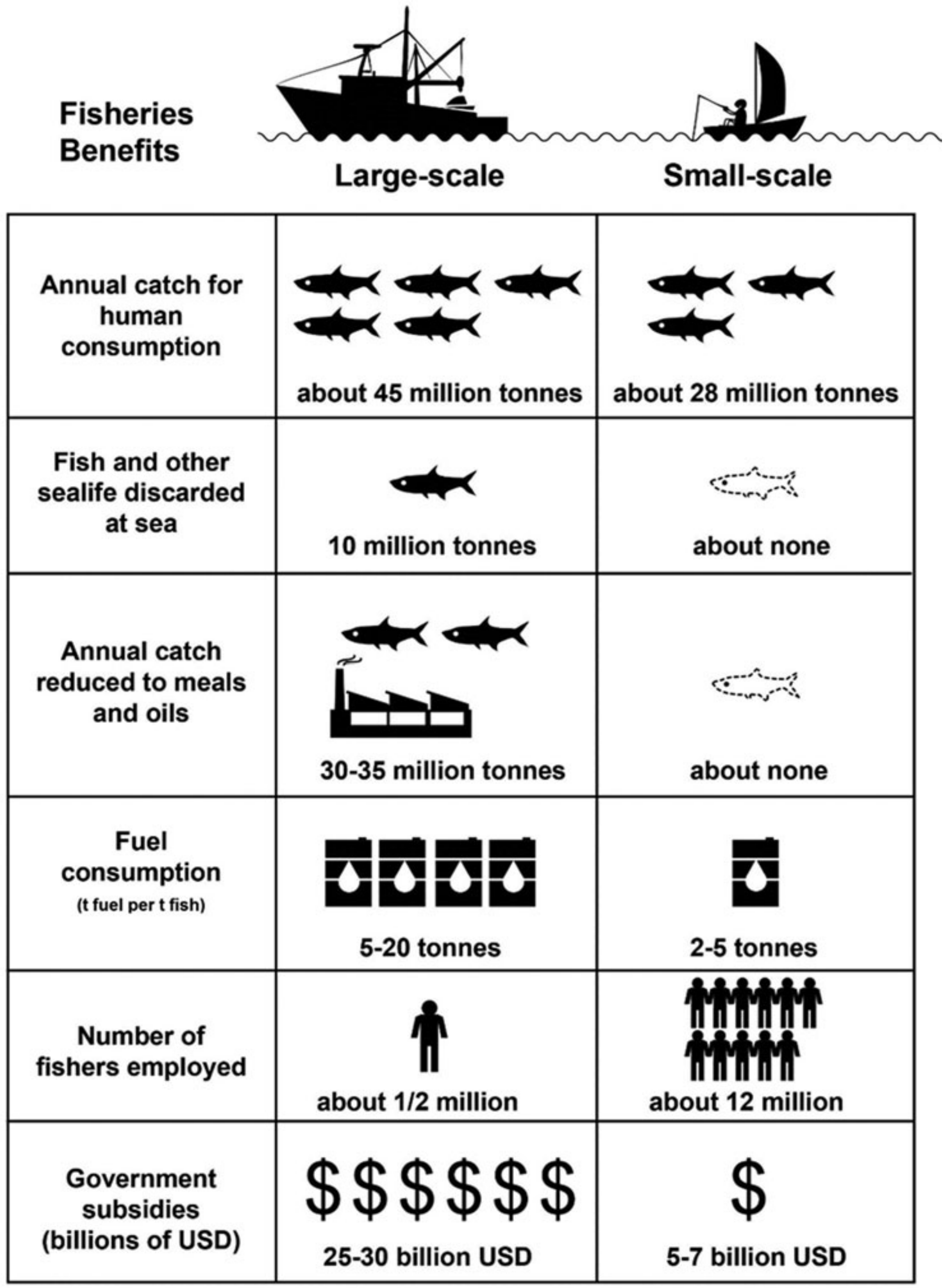

Fig. 3. Contrasting large-scale (i.e., industrial) and small-scale (artisanal and subsistence) fisheries for several key criteria through a Thompson graph (Pauly, 2006; Thompson, 1988). The definitions of large-scale (industrial), often mislabelled as 'commercial', and small-scale, often mislabelled as 'traditional', as used also in Pauly and Zeller (2016a), are those prevailing in each country, although they do not differ much (Chuenpagdee & Pauly, 2008). The data for annual fishmeal-destined catches (Cashion *et al.*, 2017) and fuel consumption per tonne of catch (Greer, 2014; Greer *et al.*, 2019a; 2019b; Tyedmers, Watson, & Pauly, 2005) were scaled up from nominal reported landings data. The numbers for annual discards (Zeller *et al.*, 2018), fishers employed (Teh & Sumaila, 2013) and subsidies (Sumaila *et al.*, 2016) were split into large- and small-scale (Jacquet & Pauly, 2008). Graph updated from figure 14.4 in Pauly and Zeller (2016b).

around the world since at least the mid-1990s (Pauly & Zeller, 2016a, 2017a, 2017b, 2019; Ye *et al.*, 2017). Reducing overfishing by eliminating the excessive overcapacity that is maintained by harmful subsidies will contribute to the rebuilding of fish stocks to levels that can support 'Maximum Sustainable Yield', and thus produce greater, yet sustainable catches with fewer industrial boats and less fishing effort than we currently use. This capacity reduction needs to be accompanied by serious implementation of monitored and enforced no-take marine reserves, which have unambiguously been shown to serve as biodiversity and biomass pools that benefit surrounding fisheries (Edgar *et al.*, 2018; O'Leary *et al.*, 2018; Roberts *et al.*, 2017; Zeller, 2005), even for high seas fisheries (Schiller, Bailey, Jacquet, & Sala, 2018; Sumaila *et al.*, 2015; White & Costello, 2014). This apparent paradox of 'fish less and catch more' when excess effort leads to overfishing is little understood or emphasized by most decision-makers and industry supporters, or civil society. Yet, the science is unambiguous on this, as is the economics.

In addition to massively reducing industrial overcapacity to allow stock rebuilding, we should encourage carefully managed, owner-operated, small-scale fisheries operating in home-country waters, because they are the ones generating the benefits we should expect from a fishery (i.e., local employment and the provision of long-term sustainable and varied seafood for human consumption; i.e., food security) (Teh & Pauly, 2018). This is also one of the main drivers behind the FAO's 'Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication' (FAO, 2015). Thus, we argue that going 'back to the future' is the right direction for humanity to take in terms of marine fisheries.

Author ORCIDs. Dirk Zeller, 0000-0001-7304-4125.

Acknowledgements. We thank all current and former members of the *Sea Around Us* and the *Sea Around Us* – Indian Ocean at the University of British Columbia and the University of Western Australia, respectively, for their dedication and contributions over the years. A special thank you is given to Sarah Popov for preparation of the maps in Figure 2.

Author contributions. DZ conceptualized the topic and drafted the outline, DZ and DP co-wrote the manuscript.

Financial support. *Sea Around Us* research and activities have been generously supported for many years by The Pew Charitable Trusts, and more recently the Paul G. Allen Family Foundation and its technical executive arm, Vulcan, Inc. For current funding, the *Sea Around Us* and the *Sea Around Us* – Indian Ocean thank the Minderoo Foundation, the Oak Foundation, the Marisla Foundation, the Paul M. Angell Family Foundation, the MAVA Foundation, the David and Lucile Packard Foundation, Bloomberg Philanthropic and Oceana.

Conflict of interest. None.

Ethical standards. This research and article complies with *Global Sustainability*'s publishing ethics guidelines.

References

Agnew, D. J. (2000). The illegal and unregulated fishery for toothfish in the Southern Ocean, and the CCAMLR catch documentation scheme. *Marine Policy*, *24*(5), 361–374.

Agnew, D. J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J., & Pitcher, T. J. (2009). Estimating the worldwide extent of illegal fishing. *PLoS ONE*, *4*, e4570.

Ainley, D. G., & Pauly, D. (2014). Fishing down the food web of the Antarctic continental shelf and slope. *Polar Record*, *50*(1), 97–107.

Al-Abdulrazzak, D., & Pauly, D. (2014). Ground-truthing the ground-truth: reply to Garibaldi et al.'s comment on "Managing fisheries from space: Google Earth improves estimates of distant fish catches". *ICES Journal of Marine Science*, *71*(7), 1927–1931.

Alverson, F. G. (1963). The food of yellowfin and skipjack tunas in the eastern tropical Pacific Ocean. *Inter-American Tropical Tuna Commission Bulletin*, *7*(5), 293–396.

Barrett, C. B. (2010). Measuring food insecurity. *Science*, *327*(5967), 825–828.

Battaglia, P., Andaloro, F., Consoli, P., Esposito, V., Malara, D., Musolino, S., … Romeo, T. (2013). Feeding habits of the Atlantic bluefin tuna, *Thunnus thynnus* (L. 1758), in the central Mediterranean Sea (Strait of Messina). *Helgoland Marine Research*, *67*(1), 97–107.

Belhabib, D., Koutob, V., Sall, A., Lam, V. W. Y., Zeller, D., & Pauly, D. (2015). Counting pirogues and missing the boat: Reply to Chaboud et al.'s comment on Belhabib et al. "Fisheries catch misreporting and its implications: the case of Senegal". *Fisheries Research*, *164*, 325–328.

Belhabib, D., Sumaila, U. R., Lam, V., Zeller, D., Le Billon, P., Kane, E. A., & Pauly, D. (2015). Euros vs. Yuan: Comparing European and Chinese fishing access in West Africa. *PLoS ONE*, *10*(3), e0118351.

Bonfil, R., Munro, G., Sumaila, U. R., Valtysson, H., Wright, M., Pitcher, T., … Pauly, D. (1998). Impacts of distant water fleets: an ecological, economic and social assessment. In WWF (ed.), *The Footprint of Distant Water Fleet on World Fisheries* (pp. 11–111). [Also issued separately, with same title, as Bonfil *et al.* (eds) (1998) Fisheries Centre Research Reports 6(6), University of British Columbia, 111 pp.]. Endangered Seas Campaign, WWF International.

Cashion, T., Al-Abdulrazzak, D., Belhabib, D., Derrick, B., Divovich, E., Moutopoulos, D. K., … Pauly, D. (2018). Reconstructing global marine fishing gear use: Catches and landed values by gear type and sector. *Fisheries Research*, *206*, 57–64.

Cashion, T., Glaser, S., Persson, L., Roberts, P. M., & Zeller, D. (2018). Fisheries in Somali waters: Reconstruction of domestic and foreign catches for 1950–2015. *Marine Policy*, *87*(C), 275–283.

Cashion, T., Le Manach, F., Zeller, D., & Pauly, D. (2017). Most fish destined for fishmeal production are food-grade fish. *Fish and Fisheries*, *18*(5), 837–844.

Chaboud, C., Fall, M., Ferraris, J., Fontana, A., Fonteneau, A., Laloë, F., … Thiao, D. (2015). Comment on "Fisheries catch misreporting and its implications: The case of Senegal". *Fisheries Research*, *164*, 322–324.

Chuenpagdee, R., & Pauly, D. (2008). Small is beautiful? A database approach for global assessment of small-scale fisheries: preliminary results and hypotheses. In J. L. Nielsen, J. J. Dodson, K. Friedland, T. R. Hamon, J. Musick, & E. Vespoor (eds), *Reconciling Fisheries with Conservation: Proceedings of the Fourth World Fisheries Congress* (pp. 575–584). American Fisheries Society.

Devine, J. A., Baker, K. D., & Haedrich, R. L. (2006). Deep-sea fishes qualify as endangered. *Nature*, *439*, 29.

Edgar, G. J., Ward, T. J., & Stuart-Smith, R. D. (2018). Rapid declines across Australian fishery stocks indicate global sustainability targets will not be achieved without an expanded network of 'no-fishing' reserves. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *28*, 1337–1350.

FAO (2015). *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication*. Food and Agriculture Organization of the United Nations.

FAO (2016). *The State of World Fisheries and Aquaculture 2016 (SOFIA): Contributing to Food Security and Nutrition for All*. Food and Agriculture Organization of the United Nations.

FAO (2018). *The State of World Fisheries and Aquaculture (SOFIA) – Meeting the Sustainable Development Goals*. Food and Agriculture Organization of the United Nations.

Froese, R., Demirel, N., Coro, G., Kleisner, K. M., & Winker, H. (2017). Estimating fisheries reference points from catch and resilience. *Fish and Fisheries*, *18*(3), 506–526.

Froese, R., & Pauly, D. (eds) (2000). *FishBase 2000: Concepts, Design and data sources*. ICLARM (updates available at www.fishbase.org).

Froese, R., & Pauly, D. (eds) (2017). *FishBase*. Retrieved from www.fishbase.org.

Froese, R., Winker, H., Coro, G., Demirel, N., Tsikliras, A. C., Dimarchopoulou, D., … Pauly, D. (2018). A new approach for estimating stock status from length frequency data. *ICES Journal of Marine Science*, *75*(6), 2004–2015.

Garibaldi, L., Gee, J., Tsuji, S., Mannini, P., & Currie, D. (2014). Comment on: "Managing fisheries from space: Google Earth improves estimates of distant fish catches" by Al-Abdulrazzak and Pauly. *ICES Journal of Marine Science*, *71*(7), 1921–1926.

Gillett, R. (2007). *A Short History of Industrial Fishing in the Pacific Islands*. Asia-Pacific Fishery Commission, Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific.

Golden, C. D., Allison, E., Cheung, W. W. L., Dey, M., Halpern, B., McCauley, D. J., … Myers, S. S. (2016). Nutrition: Fall in fish catch threatens human health. *Nature*, *534*, 317–320.

Golden, C. D., Chen, O. L., Cheung, W. W. L., Dey, M., Halpern, B., McCauley, D. J., … Allison, E. (2016). Reply to Belton *et al.*: Are farmed fish just for wealthy markets? *Nature*, *538*, 171.

Greer, K. (2014). Considering the 'Effort Factor' in Fisheries: A Methodology for Reconstructing Global Fishing Effort and CO2 Emissions, 1950–2010 (Master of Science). University of British Columbia.

Greer, K., Zeller, D., Woroniak, J., Coulter, A., Palomares, M. L. D., & Pauly, D. (2019a). Global trends in carbon dioxide (CO_2) emissions from fuel combustion in marine fisheries from 1950–2016. *Marine Policy*, in press.

Greer, K., Zeller, D., Woroniak, J., Coulter, A., Palomares, M. L. D., & Pauly, D. (2019b). Reply to Ziegler *et al.* "Adding perspectives to: Global trends in carbon dioxide (CO_2) emissions from fuel combustion in marine fisheries from 1950–2016" and addressing concerns of using fishing effort to predict carbon dioxide emissions. *Marine Policy*, in press.

Gulland, J. A. (1971). *The Fish Resources of the Oceans*. FAO/Fishing New Books.

Hilborn, R., & Walters, C. J. (1992). *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty* (1st ed. Vol. 1). Chapman & Hall.

Holbrook Smith, L. (2017). To accede or not to accede: An analysis of the current US position related to the United Nations law of the sea. *Marine Policy*, *83*, 184–193.

HSP (2018). *Commonwealth Fisheries Harvest Strategy Policy*. Department of Agriculture and Water Resources, Australian Government.

ICES (2014). *Report of the Workshop on the Development of Quantitative Assessment Methodologies Based on Life-history Traits, Exploitation Characteristics, and Other Relevant Parameters for Data-limited Stocks (WKLIFE IV), 27–31 October 2014, Lisbon, Portugal*. International Council for the Exploration of the Sea.

ICES (2015). *Report of the Fifth Workshop on the Development of Quantitative Assessment Methodologies Based on Life-history Traits, Exploitation Characteristics, and Other Relevant Parameters for Data-limited Stocks (WKLIFE V), 5–9 October 2015, Lisbon, Portugal*. International Council for the Exploration of the Sea.

Jacquet, J., & Pauly, D. (2008). Funding priorities: Big barriers to small-scale fisheries. *Conservation Biology*, *22*(4), 832–835.

Kaczynski, V. M., & Fluharty, D. L. (2002). European policies in West Africa: Who benefits from fisheries agreements? *Marine Policy*, *26*, 75–93.

Karakulak, F. S., Salman, A., & Oray, I. K. (2009). Diet composition of bluefin tuna (*Thunnus thynnus*, L. 1758) in the Eastern Mediterranean Sea, Turkey. *Journal of Applied Ichthyology*, *25*, 757–761.

Kittinger, J. N., Teh, L. C. L., Allison, E. H., Bennett, N. J., Crowder, L. B., Finkbeiner, E. M., … Aulani Wilhelm, T. (2017). Committing to socially responsible seafood. *Science*, *356*(6341), 912–913.

Kock, K. H. (1992). *Antarctic Fish and Fisheries*. Cambridge University Press.

Koslow, J. A. (1997). Seamounts and the ecology of deep-sea fisheries. *American Scientist*, *85*(2), 168–176.

Koslow, J. A., Boehlert, G. W., Gordon, J. D. M., Haedrich, R. L., Lorance, P., & Parin, N. (2000). The impact of fishing on continental slope and deep-sea ecosystems. *ICES Journal of Marine Science*, *57*, 548–557.

Kurlansky, M. (1997). *Cod: A Biography of the Fish That Changed the World*. Knopf.

Kurlansky, M. (1999). *The Basque History of the World*. Walker.

Lam, V. W. Y., Sumaila, U. R., Dyck, A., Pauly, D., & Watson, R. (2011). Construction and first applications of a global cost of fishing database. *ICES Journal of Marine Science*, *68*(9), 1996–2004.

Macpherson, M. (2001). Integrating ecosystem management approaches into federal fishery management through the Magnuson–Stevens Fishery Conservation and Management Act. *Ocean and Coastal Law Journal*, *6*, 1–32.

Martell, S., & Froese, R. (2013). A simple method for estimating MSY from catch and resilience. *Fish and Fisheries*, *14*(4), 504–514.

McHugh, J. L. (1952). The food of albacore (*Germo alalunga*) off California and Baja California. *Bulletin of the Scripps Institution of Oceanography*, *6* (4), 161–172.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being: Synthesis*. Millennium Ecosystem Assessment.

MSA (2007). *Magnuson–Stevens Fishery Conservation and Management Reauthorization Act of 2006*. Office of the Federal Register.

O'Leary, B. C., Ban, N. C., Fernandez, M., Friedlander, A. M., García-Borboroglu, P., Golbuu, Y., … Roberts, C. M. (2018). Addressing criticisms of large-scale marine protected areas. *Bioscience*, *68*(5), 359–370.

Olafsdottir, D., MacKenzie, B. R., Chosson-P, V., & Ingimundardottir, T. (2016). Dietary evidence of mesopelagic and pelagic foraging by Atlantic bluefin tuna (*Thunnus thynnus* L.) during autumn migrations to the Iceland Basin. *Frontiers in Marine Science*, *3*, 108.

Olsen, Y. (2011). Resources for fish feed in future mariculture. *Aquaculture Environment Interactions*, *1*, 187–200.

Palomares, M. L. D., & Pauly, D. (eds) (2017). *SeaLifeBase*. Retrieved from www.sealifebase.org.

Pauly, D. (1997). Small-scale fisheries in the tropics: marginality, marginalization, and some implications for fisheries management. In E. K. Pikitch, D. D. Huppert, & M. P. Sissenwine (eds), *Global Trends: Fisheries Management* (pp. 40–49). American Fisheries Society.

Pauly, D. (2006). Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. *Maritime Studies (MAST)*, *4*(2), 7–22.

Pauly, D. (2018a). The future of artisanal fishing. *Science*, *360*(6385), 161.

Pauly, D. (2018b). A vision for marine fisheries in a global blue economy. *Marine Policy*, *87*, 371–374.

Pauly, D., & Charles, T. (2015). Counting on small-scale fisheries. *Science*, *347*, 242–243.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., … Zeller, D. (2002). Towards sustainability in world fisheries. *Nature*, *418*, 689–695.

Pauly, D., & Zeller, D. (2016a). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications*, *7*, 10244.

Pauly, D., & Zeller, D. (2016b). Towards a comprehensive estimate of global marine fisheries catches. In D. Pauly & D. Zeller (eds), *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts* (pp. 171–181). Island Press.

Pauly, D., & Zeller, D. (eds) (2016c). *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*. Island Press.

Pauly, D., & Zeller, D. (2017a). The best catch data that can possibly be? Rejoinder to Ye et al. "FAO's statistic data and sustainability of fisheries and aquaculture". *Marine Policy*, *81*, 406–410.

Pauly, D., & Zeller, D. (2017b). Comments on FAOs State of World Fisheries and Aquaculture (SOFIA 2016). *Marine Policy*, *77*, 176–181.

Pauly, D., & Zeller, D. (2019). Agreeing with FAO: Comments on SOFIA 2018. *Marine Policy*, *100*, 332–333.

Potier, M., Marsac, F., Cherel, Y., Lucas, V., Sabatié, R., Maury, O., & Ménard, F. (2007). Forage fauna in the diet of three large pelagic fishes (lancetfish, swordfish and yellowfin tuna) in the western equatorial Indian Ocean. *Fisheries Research*, *83*(1), 60–72.

Roberts, C. M., Bohnsack, J. A., Gell, F., Hawkins, J. P., & Goodridge, R. (2001). Effects of marine reserves on adjacent fisheries. *Science*, *294* (5548), 1920–1923.

Roberts, C. M., O'Leary, B. C., McCauley, D., Castilla, J. C., Cury, P., Duarte, C. M., … Lubchenco, J. (2017). Marine reserves can mitigate and promote adaptation to climate change. *Proceedings of the National Academy of Sciences*, *114*(24), 6167–6175.

Rosenberg, A. A., Fogarty, M. J., Cooper, A. B., Dickey-Collas, M., Fulton, E. A., Gutiérrez, N. L., … Ye, Y. (2014). *Developing New Approaches to Global Stock Status Assessment and Fishery Production Potential of the Seas*. Food and Agriculture Organization of the United Nations.

Rothwell, D. R. (2003). The International Tribunal for the Law of the Sea and marine environmental protection: Expanding the horizons of international oceans governance. *Ocean Yearbook*, *17*, 26–55.

Sala, E., Mayorga, J., Costello, C., Kroodsma, D., Palomares, M. L. D., Pauly, D., … Zeller, D. (2018). The economics of fishing the high seas. *Science Advances*, *4*(6), eaat2504.

Schiller, L., Alava, J. J., Grove, J., Reck, G., & Pauly, D. (2015). The demise of Darwin's fishes: Evidence of fishing down and illegal shark finning in the Galápagos Islands. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *25*(3), 431–446.

Schiller, L., Bailey, M., Jacquet, J., & Sala, E. (2018). High seas fisheries play a negligible role in addressing global food security. *Science Advances*, *4*(8), eaat8351.

Seto, K., Belhabib, D., Mamie, J., Copeland, D., Michael Vakily, J., Seilert, H., … Pauly, D. (2017). War, fish, and foreign fleets: The Marine Fisheries Catches of Sierra Leone 1950–2015. *Marine Policy*, *83*, 153–163.

Shiga, D. (2008). Stephen Hawking calls for Moon and Mars colonies. *New Scientist*, April 21.

Simmons, G., & Stringer, C. (2014). New Zealand's fisheries management system: Forced labour an ignored or overlooked dimension? *Marine Policy*, *50*, 74–80.

Steinsson, S. (2016). The Cod Wars: A re-analysis. *European Security*, *25*(2), 256–275.

Stringer, C., Simmons, G., Coulston, D., & Whittaker, D. H. (2014). Not in New Zealand's waters, surely? Linking labour issues to GPNs. *Journal of Economic Geography*, *14*, 739–758.

Stringer, C., Whittaker, D. H., & Simmons, G. (2016). New Zealand's turbulent waters: The use of forced labour in the fishing industry. *Global Networks*, *16* (1), 3–24.

Sumaila, U. R., Khan, A., Dyck, A., Watson, R., Munro, R., Tyedmers, P., & Pauly, D. (2010). A bottom-up re-estimation of global fisheries subsidies. *Journal of Bioeconomics*, *12*, 201–225.

Sumaila, U. R., Lam, V., Le Manach, F., Swartz, W., & Pauly, D. (2016). Global fisheries subsidies: An updated estimate. *Marine Policy*, *69*, 189–193.

Sumaila, U. R., Lam, V. W. Y., Miller, D., Teh, L., Watson, R., Zeller, D., … Pauly, D. (2015). Winners and losers in a world where the high seas is closed to fishing. *Nature Scientific Reports*, *5*, 8481.

Sumaila, U. R., Marsden, A. D., Watson, R., & Pauly, D. (2007). A global ex-vessel fish price database: Construction and applications. *Journal of Bioeconomics*, *9*, 39–51.

Sumaila, U. R., & Pauly, D. (2007). All fishing nations must unite to end subsidies. *Nature*, *450*, 945.

Swartz, W., Sala, E., Tracey, S., Watson, R., & Pauly, D. (2010). The spatial expansion and ecological footprint of fisheries (1950 to present). *PLoS ONE*, *5*(12), e15143.

Swartz, W., Sumaila, U. R., & Watson, R. (2013). Global ex-vessel fish price database revisited: A new approach for estimating 'missing' prices. *Environmental Resource Economics*, *56*, 467–480.

Teh, L. C. L., & Pauly, D. (2018). Who brings in the fish? The relative contribution of small-scale and industrial fisheries to food security in Southeast Asia. *Frontiers in Marine Science*, *5*, 44.

Teh, L. C. L., & Sumaila, U. R. (2013). Contribution of marine fisheries to worldwide employment. *Fish and Fisheries*, *14*(1), 77–88.

Thompson, D. (1988). The world's two marine fishing industries – How they compare. *Naga, The ICLARM Quarterly*, *11*(3), 17.

Tickler, D., Meeuwig, J. J., Bryant, K., David, F., Forrest, J. A. H., Gordon, E., … Zeller, D. (2018). Modern slavery and the race to fish. *Nature Communications*, *9*, 4643.

Tickler, D., Meeuwig, J. J., Palomares, M. L. D., Pauly, D., & Zeller, D. (2018). Far from home: Distance patterns of global fishing fleets. *Science Advances*, *4*(8), eaar3279.

Tiller, R. G. (2010). *New Resources in Old Waters. The Potential of National and International Conflicts Deriving from the Future Harvest of* Calanus finmarchicus (PhD). Norwegian University of Science and Technology.

Tyedmers, P., Watson, R., & Pauly, D. (2005). Fueling global fishing fleets. *AMBIO: A Journal of the Human Environment*, *34*(8), 635–638.

UN (2017). *The Sustainable Development Goals Report 2017*. United Nations.

Walk Free Foundation (2016). *The Global Slavery Index 2016*. The Minderoo Foundation.

Walk Free Foundation (2018). *The Global Slavery Index 2018*. The Minderoo Foundation.

White, C., & Costello, C. (2014). Close the high seas to fishing? *PLoS Biology*, *12*(3), e1001826.

Ye, Y., Barange, M., Beveridge, M., Garibaldi, L., Gutierrez, N., Anganuzzi, A., & Taconet, M. (2017). FAO's statistic data and sustainability of fisheries and aquaculture: Comments on Pauly and Zeller (2017). *Marine Policy*, *81*, 401–405.

Yellen, J. E., Brooks, A. S., Cornelissen, E., Mehlman, M. J., & Stewart, K. (1995). A middle stone-age worked bone industry from Katanda, Upper Semliki Valley, Zaire. *Science*, *268*(5210), 553–556.

Zeller, D. (2005). From *Mare Liberum* to *Mare Reservarum*: Canada's opportunity for global leadership in ocean resource governance. In A. Chircop & M. McConnell (eds), *Ocean Yearbook* (pp. 1–18). University of Chicago Press.

Zeller, D., Booth, S., Pakhomov, E., Swartz, W., & Pauly, D. (2011). Arctic fisheries catches in Russia, USA and Canada: Baselines for neglected ecosystems. *Polar Biology*, *34*(7), 955–973.

Zeller, D., Cashion, T., Palomares, M. L. D., & Pauly, D. (2018). Global marine fisheries discards: A synthesis of reconstructed data. *Fish & Fisheries*, *19*(1), 30–39.

Zeller, D., Palomares, M. L. D., Tavakolie, A., Ang, M., Belhabib, D., Cheung, W. W. L., … Pauly, D. (2016). Still catching attention: *Sea Around Us* reconstructed global catch data, their spatial expression and public accessibility. *Marine Policy*, *70*, 145–152.

Zeller, D., & Pauly, D. (2018). The 'presentist bias' in time-series data: Implications for fisheries science and policy. *Marine Policy*, *90*, 14–19.