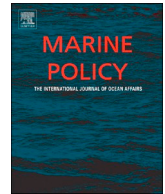




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Reply to Ziegler et al. “Adding perspectives to: Global trends in carbon dioxide (CO₂) emissions from fuel combustion in marine fisheries from 1950-2016” and addressing concerns of using fishing effort to predict carbon dioxide emissions

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ABSTRACT

There are currently two separate approaches for estimating global CO₂ emissions from marine fishing. One approach uses catch-based fuel use intensity (FUI) estimates for well-studied areas/fisheries to estimate FUI in data poor regions. The second approach, effort-based FUI, uses reconstructed fishing effort data to estimate fuel use based on vessel size and fishing times. Both methods utilize assumptions which are inherently uncertain; the advantages and disadvantages of each method are discussed. The two approaches are found to be complementary to one another, not contradictory, and global estimates of CO₂ emissions from marine fishing should be based on a combination of both approaches, depending on the data locally available.

For the estimation of CO₂ emissions, the ability to use reported fuel data from specific fishing operations is always superior to attempts at modelling fuel use from fishing. Unfortunately, fuel consumption figures are usually not considered to be an important part of fisheries data collection, and thus do not exist for many fisheries around the world. However, we are fortunate to now have two distinct approaches for the estimation of the CO₂ emissions by marine fisheries, namely Parker et al. [2]; centred around catch-based fuel use intensity (FUI) estimates from well-studied areas/fisheries, and Greer et al. [1] using effort-based FUI to estimate fuel use based on vessel size and fishing times. These two approaches allow for the advantages and disadvantages of modelling fuel use from fishing effort to be compared with reported fuel data from fishing operations.

The approach presented in Parker et al. [2], and supported by Ziegler et al. [9], has merit in that it uses location- and fishery-specific data on fuel use for a subset of countries and fisheries. These data should indeed be used wherever they are available. On the other hand, their extrapolation to areas and fisheries for which such data do not exist is often flawed, as indicated in Greer et al. [1]. Similarly, modelling fuel use from fishing effort [1], while having its own advantages, also has major sources of uncertainty. The Fuel Use and Energy Database (FUED [3]) used in Parker et al. [2] to estimate CO₂ emissions

contains 1083 records for Europe, Canada, Oceania (essentially Australia and New Zealand only) and the USA, but only 2 records for Latin America, 7 records for Africa, and 34 records for Asia, in spite of the enormous fisheries around these 3 continents. Moreover, small-scale fisheries are underrepresented in the FUED [3], even though they are dominant in many, particularly low-income countries. In such cases, Parker et al. [2], ‘substitute’ known fisheries and their FUI for unknown fisheries, often between continents and development status of countries, which introduces considerable uncertainty.

For example, finfish have 320 records in FUED for periods after 1990, 146 of which are for European fisheries targeting a single species, Atlantic cod (*Gadus morhua*; [3]). The catch-based method of estimating Fuel Use Intensity (FUI) for finfish around the world, including, e.g., in Africa, is thus largely based on data from cod in the North Atlantic. Another example is provided by Oceania, for which there are a considerable number of fishery specific records (n = 286). However 151 (52%) of these records are for trawl fisheries which, in Oceania, are predominantly practiced in Australia and New Zealand, and to a much lesser extent in Papua New Guinea and New Caledonia. The vast majority of the other 20 countries and territories in Oceania do not use this fuel-intensive gear to exploit their reef and pelagic fisheries. This suggests that due to the over representation of trawling FUI in the fuel use

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estimation for Oceania in Parker et al. [2], catch-based FUI may have been overestimated twofold (see Table 6 in Greer et al. [1]). We suggest that our approach (i.e. [1]), of carefully reconstructing fishing effort in each country over time as the foundation for fuel use and CO₂ emissions may provide some advantages, especially for the very large numbers of developing countries and emerging economies with poor or no directly measured fuel use data.

Our effort-based approach for estimating FUI and subsequent CO₂ emissions is not without its own problematic assumptions. This is the reason why Greer et al. [1] attempted to correct for systematic bias by calibrating effort-based FUI with those regions in Parker et al. [2] (i.e., Europe and North America) where reliable fishery-specific fuel use data exist. This, however, is only a temporary correction and should be improved upon through future research. Fishing days and engine run times, as required for the Greer et al. [1] method of modelling fuel consumption, as well as the specific fuel consumption rates of different gears, need greater attention. And this is exactly the nature of reconstructed data – the current estimation is a first best attempt that should be followed up over time with gradual improvements to the underlying data as they become available. This is also the same approach being used to improve the reconstructed catch data of the *Sea Around Us* through an open and collaborative data policy. Future iterations of the *Sea Around Us* fuel consumption and CO₂ emissions data should include better refinements of assumptions, such as differentiation of small-scale fishing and engine run times and fuel use between developing and developed countries, as correctly identified in Ziegler et al. [9]. Small-scale fisheries operations, boats and gears do differ considerably between these two broad types of countries.

Ziegler et al. [9] suggest that the division of fisheries into two broad sectors (industrial and small-scale) is confusing. However, the sectoral approach used in Greer et al. [1] has the advantage that it was applied in a globally structured manner that matches the data structures, definitions and data parameters of all the *Sea Around Us* data, which went through a similar phase of sectoral criticism with a focus on perceived uncertainty around reconstructed catch data (see [4–6,8] but see also [7]).

The case study presented in Ziegler et al. [9] did not apply the method suggested in Greer et al. [1] to estimate fuel use correctly; for example, the fuel use calibration step is not included. The data used in the analysis are not made explicit, and the conclusion that the aggregated global total carbon dioxide emissions in Greer et al. [1] are over estimated is based on the erroneous assumption the effort-based FUI is affected by the disproportionately higher amount of global catch taken by industrial fishers. Greer et al. [1] did estimate “missing fishing effort” which amount to less than 2% in any year for both sectors, and less than 1% for any year in the industrial sector alone (see methods section in Greer et al. [1]). The results in fuel use, and subsequently CO₂, if the extrapolation of fishing effort had not been done would decrease the results by less than 2% for any given year. Effort-based FUI is firmly rooted in fishing effort, namely the number and size of vessels operating, not catch. To conclude then that the global fuel use estimate in Greer et al. [1] is too high because “globally catch is dominated by the industrial sector” does not have any meaning with regards to the model presented in Greer et al. [1].

We acknowledge that [9] in support of [2] have greatly contributed to this research topic using valuable data from the industry itself; however, such data are not available for many fisheries, particularly those outside of Europe and North America. Greer et al. [1] present a complementary approach, not a replacement, to estimating fuel use and carbon dioxide emissions when direct fuel use data are not available. While there are a number of assumptions being made in order to convert fishing effort into fuel use and carbon dioxide emissions, the resulting global carbon dioxide emissions for 2011 estimated by Greer et al. [1] are only 31% higher than those estimated by Parker et al. [2]. And as presented in Table 6 in Greer et al. [1], the main drivers of this difference seem to rest with the fisheries included in each respective study and regional differences in fuel use. We view these two approaches and the underlying data as complementary, not contradictory; indeed, one could view the Parker et al. [2] estimate as representing a likely lower limit and the Greer et al. [1] estimate as a likely upper limit of CO₂ emissions from marine fisheries. Greer et al. [1] support the use of both methods depending on which data are available and urge managers to routinely collect fuel use data in addition to other important fishery statistics.

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