Post-print of Ziegler, F., O. R. Eigaard, R. W. R. Parker, P. H. Tyedmers, E. S. Hognes and S. Jafarzadeh (2019). "Adding perspectives to: "Global trends in carbon dioxide (CO2) emissions from fuel combustion in marine fisheries from 1950 - 2016"." Marine Policy 107: 103488.

Adding perspectives to: Global trends in carbon dioxide (CO_2) emissions from fuel combustion in marine fisheries from 1950-2016

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Abstract

A contribution in this issue, Greer et al. (2019), models carbon dioxide emissions from fuel combustion in global fisheries. This is done based on a method using data on fishing effort, presenting results for two sectors: small-scale and industrial fisheries. The selection of these sectors is not motivated in relation to studying fuel use, and it is well-documented that other factors more accurately predict fuel use of fisheries and would constitute a more useful basis for defining sub-sectors, when the goal of the study is to investigate fuel use. Weakly grounded assumptions made in the translation of fishing effort into carbon dioxide emissions (e.g. the engine run time per fishing day for each sector) systematically bias results towards overestimating fuel use of “industrial” vessels, underestimating that of “small-scale”. A sensitivity analysis should have been a minimum requirement for publication. To illustrate how the approach systematically misrepresents the fuel use and emissions of the two sectors, the model is applied to Australian and New Zealand rock lobster trap fisheries and compared to observed fuel use. It is demonstrated how the approach underestimates emissions of small-scale fisheries, while overestimating emissions of industrial fisheries. As global fisheries are dominated by industrial fisheries, aggregate emissions are considerably overestimated. Effort-based approaches can be valuable to model fuel use of fisheries in data-poor situations, but should be seen as complementary to estimates based on direct data, which they can also help to validate. Whenever used, they should be based on transparent, science-based data and assumptions.

Key words: carbon dioxide, fisheries, fuel efficiency, fuel intensity, fuel use, greenhouse gas emissions

Introduction

Modelling carbon dioxide emissions from fuel combustion of global fisheries over time is both challenging and important. Addressing climate change necessitates a shift towards a low-carbon future. To this end, informing stakeholders – from industry to regulators to consumers – requires careful modeling of diverse systems, and it is critical that these models be rigorous, grounded in robust data, and forthcoming of their uncertainties. Greer et al. (2019) in this issue present a model to estimate the carbon dioxide emissions of global fisheries that does not fulfil these requirements.

Substantial work has been undertaken over the past two decades to estimate fuel inputs to fisheries (e.g. Schau et al. 2009, Cheilari et al. 2013, Avadí et al. 2014, Fréon et al. 2014a, Parker & Tyedmers 2015, Jafarzadeh et al. 2016) and to assess fisheries' contributions to global warming via emissions (e.g. Tyedmers et al. 2005, Parker et al. 2018). To date, much of the data underpinning this work has been collected directly from industry, ranging from direct fuel consumption data to cost-revenue structures to horsepower and hours fished. In the paper, Greer et al. (2019) rely on global fishing effort data, reconstructed by the Sea Around Us Project, to estimate the fuel use and fuel-related carbon dioxide emissions of global fisheries and how these metrics have developed over time. To go from fishing effort (in days at sea) to fuel-related carbon dioxide emissions, requires a number of steps involving either the use of additional empirical data or a set of assumptions with a large influence on results and conclusions. Further, the authors divide the global industry into two broad sectors ("small-scale" and "industrial"), a dichotomy that, while useful in some analyses of fishery-related challenges, is not justifiable in modeling of fuel use and greenhouse gas emissions. The authors' choice to broadly group fisheries into small-scale and industrial and apply coarse assumptions to each of these, means their results are heavily influenced by the assumptions in their model rather than by data. As such, their results, not surprisingly, differ substantially from those derived based on more directly calculated fuel consumption rates. Below the approach and assumptions used in the paper are discussed, together with our main concerns. The intention is not to provide an exhaustive picture of effort- vs. fuel use-based modelling of fuel use and greenhouse gas emissions of fisheries, only to draw the readers' attention to important limitations and uncertainties of the approach used by Greer et al. (2019). To illustrate the inherent biases present in the approach, a simple application of the model to a fishery, for which detailed vessel-level data was available, is presented. The intention is to guide the direction of further research in this area and alert readers and users of the paper to its limitations and uncertainties, which are not well communicated.

Dividing global fisheries into small-scale and industrial

A central aspect of the analysis of Greer et al. (2019) is to divide global fisheries into two mutually inconsistent sub-sets: industrial fisheries and small-scale fisheries. They achieve this by first adopting each country's own definition of these two sectors where such a distinction exists, meaning that what is considered small-scale in one country can be defined as industrial in another, which is inconsistent and leads to difficulties in interpreting results. For countries lacking such a binary subdivision of fishing fleets into these two sectors, Greer et al. (2019) use a mix of vessel length, fishing gear and motorization to allocate vessels into these two categories (i.e. small-scale fleets include all vessels under 16m length except trawlers, plus all non-motorized vessels). No rationale is provided to underpin the adoption of this specific binary subdivision of the global fleet and the two sectors identified are neither applied consistently nor empirically linked to the phenomena of interest (scale of fuel combustion). Unless a link between the basis for stratification of the fleet and the parameter studied (fuel use) exists, studying the fuel use of small-scale vs. industrial fisheries would be like studying the size of apples in the world by comparing the size of red and green apples, while size depends on variety, not colour. There are more relevant subdivisions of the global fishing fleet that are demonstrably linked to fuel combustion (see e.g. typology analysis in Fréon et al. 2014b). For example, fishing gear, has been known (together with stock status) to be the main determinant of the fuel intensity of fisheries for decades (Watanabe & Okubo 1989, Thrane 2004, Avadí & Fréon 2013, Fréon et al. 2014a, Jafarzadeh et al. 2016, Parker & Tyedmers 2015, Ziegler et al. 2016a). Greer et al. (2019) actually do consider gear and estimate fishing effort of each gear type for each region of the world, but in the subsequent calculations (described below), effort is treated equally even across highly different fishing methods (a fishing day by a purse seiner leads to equal emissions as a fishing day of a demersal trawler with a similarly sized engine), which means that they don't distinguish between fishing methods. In our opinion, this conflation of how engines are used and fuel is burned between vessels employing different gears does not give a meaningful result and contradicts much empirical evidence (e.g. Thrane 2004, Driscoll & Tyedmers 2010, Fréon et al. 2014a, Jafarzadeh et al. 2016). Perhaps most notably, no distinction is made between pelagic and demersal trawlers, which are found at each end of the scale of fuel use intensity spectrum amongst motorized fisheries (Parker & Tyedmers 2015), nor is any distinction made between active and passive gear types.

Estimating engine hours per day at sea

In operationalizing their method of estimating fuel use from effort data, Greer et al. (2019) start from fishing effort data recorded as days at sea. They then convert days at sea to estimates of run-time hours for all industrial vessels (defined as all trawlers irrespective of size and all other motorized vessels over 16m when no national definition was available) on the assumption that their engines operate 24h per day for every day that they are at sea. This assumption has major implications on their results. The only reference used to back up this assumption is a report, co-authored by two of us, with data from the Norwegian fishing fleet. However, the report does not anywhere mention that industrial fishing vessels on average are operated 24h per day, in fact it does not differentiate between small-scale and industrial fisheries at all (Winther et al. 2009). The proportion of vessels operating 24h/day only comprises around 3% of the Norwegian fishing fleet (and it is impossible to understand how the roughly 5000 Norwegian fishing vessels have been sorted into small-scale and industrial by Greer et al. as the Norwegian fleet is divided into segments based on gear type, where they operate and vessel length). In contrast, all small-scale vessels, regardless of gear type or fishery are assumed to use their engines only 4h per day at sea, an estimate that seems to be based on fisheries in tropical regions only, is very low compared to our joint experience of temperate coastal small-scale fisheries. This assumption automatically discounts fuel use by small-scale fisheries by 83% relative to their industrial counterparts, while small-scale fisheries, in a rigorous research effort, have actually been shown to be less fuel efficient than industrial fisheries (Fréon et al. 2014a). The basis for these two critical data points – 24 h/day vs 4 hr/day operational run time - is weak. The Winther et al. (2009) report does, as mentioned, not support this assumption, and the other references used are non-peer-reviewed reports and conference proceedings. In contrast, peer-reviewed examples indicating much more nuanced operational realities are ignored (Ziegler & Hornborg 2014). To avoid doubts whether the values were chosen to achieve a desired outcome, a minimum requirement would have been to present a sensitivity analysis demonstrating how the results and conclusions depend on these coarse assumptions.

Estimating engine capacity from vessel length

Engine capacity is, as evident from the above, a critical parameter in the Greer et al. (2019) translation of estimated fishing effort in engine run-time hours to imputed fuel combustion. Since no data on engine power of the global fishing fleet is available, the paper instead uses *vessel length* as the basis upon which to infer engine power. While larger vessels on average have more powerful engines than small vessels, this relationship has mainly been documented for industrial fleets (Thrane 2004, Bastardie et al. 2010, Reid et al. 2011; Ziegler and Hornborg 2014). Vessel displacement is a far better determinant of resistance to be overcome by the propulsive engine than length, all other things being equal. Global fishing fleets are hugely diverse and the general assumption of a direct relationship between length and engine power, while ignoring all other factors including fleet segment, hull proportions and shape, etc. adds additional uncertainty to the results.

Specific fuel consumption rate

Once Greer et al. (2019) estimated engine power (in kW) and effort (in total run time hours) for a specific fleet they applied a fuel consumption rate factor to arrive at an estimated amount of fuel combusted for a resultant catch. This factor is not a constant, not even for a specific engine, but depends on the engine load (Jafarzadeh & Schølberg 2018), which again partly depends on which gear is used and speed. The authors present a few figures regarding this factor called the specific fuel rate (SFR), but do notexplain how they go from the data points found to their estimations. For industrial fisheries they find a SFR of 170-260 g/kWh and then use 200 g/kWh as "the average, standardized SFR". For small-scale fisheries, they find two values 350 and 400 g/kWh and they use 350 g/kWh. This factor is again highly important for the outcome, and this parameter should also have been part of a sensitivity analysis.

Discussion and Conclusion

Due to the arbitrary and non-functional stratification of global fisheries with regard to analyzing fuel use, the lack of critical data related to many of the steps described above - and the major influence on the model outcomes, results and conclusions of the analysis are highly uncertain. A sensitivity analysis to inform the importance for results and conclusions should have been a minimum requirement for publication. Analyzing scenarios would be an alternative option, and although it may be impossible to estimate uncertainties when a model is this coarse, these need at least to be discussed. To be able to ground-truth the results against direct fuel use data, it would have been much more useful to break down the results by species group and gear than per region, the latter being a factor that hardly matters at all compared to species and gear. Providing numbers for e.g. tunas or crustaceans or small pelagics would allow meaningful comparison between approaches, but results are only presented for the aggregated total and the small-scale and industrial sectors.

Overall, the results, especially the aggregate estimate of global emissions, but also the conclusions drawn regarding the performance of the two arbitrarily selected fleet sectors and temporal trends, are subject to considerably higher uncertainty than communicated by the authors. Consequently, the main conclusion of the paper that emissions have been underestimated in previous research does not hold (e.g. Tyedmers et al. 2005, Parker et al. 2018).

One of the important data gaps in this field of research has been data from small-scale fisheries and developing countries. The efforts of the authors in addressing this issue are therefore welcome, and effort-based calculations can certainly provide an opportunity to fill in those gaps where direct fuel consumption data are not available- or to validate industry data. Indeed, similar approaches have been used previously (Tyedmers 2001, Ziegler & Hornborg 2014; Ziegler et al. 2016b). However, the link between effort and fuel use is much weaker in passive fisheries (using coastal/static gear) than for active fishing methods such as trawling (Tyedmers 2001, Ziegler & Hornborg 2014). In cases where both types of data of high quality have been available (e.g. Ziegler et al. 2016b, Ziegler et al. 2018), the effort-based indirect estimation (in the case of Ziegler et al. 2018 this was done after publication in connection to more recent work) has consistently resulted in considerably higher estimations than actual direct fuel use data. Whenever such an effort-based approach is defined, though, it is critical that it is based on a sound stratification of fisheries, based on parameters that matter for fuel use, as well as on sound, transparent and science-based, assumptions.

To illustrate the major effect the assumptions of Greer et al. (2019) regarding engine run time have on resulting fuel use, the approach suggested by Greer et al. (2018) was applied to a fishery for which detailed data both on fuel use and fishing effort was available, the Australian and New Zealand rock lobster trap fisheries (case study described in Parker et al. 2017). Including only vessels for which both engine power and fishing effort were available, 14 vessels greater than 16m in length and 33 vessels under 16m were included. Hours fished ranged from 5 to 16 h/day, and engine power from 37 to 1193 kW and the days at sea from 35 to 220 per year. The following data were used in the calculation: 0.7457 kWh per kW, the kW per vessel size class in Greer et al. Table 1, 0.0002t fuel per kWh converted to 0.235 L per kWh and 24 h engine time per day at sea (industrial) and 0.00035t fuel per kWh converted to 0.411 L per kWh and 4h engine time per day at sea (small-scale).

In Figure 1, it is evident that applying the assumptions and data used in the Greer et al. model (grey) underestimates emissions from the smaller vessels (by 49%) and overestimates emissions from larger vessels (by 174%) in the rock lobster fishery, compared to the observed fuel use (white). The fact that the fuel use of small-scale fisheries is underestimated vs. that of industrial fisheries is also illustrated by an example given by Greer et al. in the discussion where they say that ten 12m fishing vessels replaced by one 35m vessel will give the same emissions, while ten 12m fishing vessels each fishing 10% of the catch of a 35m fishing vessel will always result in larger a larger fuel intensity than the larger vessel (see e.g. Fréon et al 2014a).

The extent to which a global aggregate estimate of all fisheries is skewed using the method outlined by Greer et a. (2019) will depend on how much is underestimated vs. overestimated. Since most of the world's catch is coming from the industrial sector, the approach presented by Greer et al. (2019) overestimates the emissions of global fisheries considerably.

(Figure 1)

Basing fuel use estimations on a theoretical model will always be further from reality and fails to incorporate aspects that are known to influence fuel efficiency, such as weather, skipper and crew experience and transiting speed (Ruttan & Tyedmers 2007). Therefore, direct observed data on fuel use is always preferable over indirect theoretical estimations. There is always a risk that fuel use, just like any other data, may be misreported, and several strategies exist when collecting this type of data to cross-check and validate it. However, it is important to recognize that the economic incentives affecting many fisheries actually operate against this happening. For example, where tax exemptions are provided for fuel burned while fishing (i.e. in most countries), companies are incentivized to overreport fuel use by including fuel used for other purposes than for fishing. In contrast, incentives often exist to underreport catches, which according to Greer et al. (2019) leads to the systematic underestimation of the fuel use intensity as evidenced by their explanation of the differences in results (that they find higher emissions than previous studies) due to "*the inclusion of unreported catch and effort data*" (see e.g. abstract). In contrast, it is actually the opposite: that if the fuel use is known – through robust third-party reporting or based on the automated and continuous recording of fuel use in many fisheries - underreporting of catch will lead to an overestimation of the fisheries fuel use intensity, based on official landings. Given the central role that direct fuel consumption plays in many important aspects of modern fisheries including their economic performance, their greenhouse gas emissions and in some instances a range of other environmental impacts (Ziegler et al. 2016a), it is surprising that it is still not regular practice to monitor fuel use of fisheries. Procedures to check reliability and validate data from different sources are therefore much needed and further research in this area is much needed.

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