TECHNICAL COMMENT

FISHERIES

Comment on “Tracking the global footprint of fisheries”

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Kroodsma *et al*. (Reports, 23 February 2018, p. 904) mapped the global footprint of fisheries. Their estimates of footprint and resulting contrasts between the scale of fishing and agriculture are an artifact of the spatial scale of analysis. Reanalyses of their global (all vessels) and regional (trawling) data at higher resolution reduced footprint estimates by factors of >10 and >5, respectively.

Kroodsma *et al.* (*1*) used automatic identification system (AIS) data to track vessels they classified as “fishing” and estimated that fishing activities occurred in 55% of the world’s oceans in 2016. We show how strongly their results depend on the spatial scale of analysis. Their method gridded the ocean into large cells of 0.5° at the equator (~3100 km^2) and counted every cell with any assumed fishing event of any duration in 2016 as fished, thus contributing its total area to fishing footprint.

We accessed the 0.01° grid fishing data made available by Global Fishing Watch (*2*) and reanalyzed these data at resolutions of ~3100, ~123, and ~1.23 km^2 (corresponding to 0.5°, 0.1°, and 0.01° at the equator), giving footprint estimates of 49%, 27%, and 4% of ocean area, respectively. Thus, higher-resolution analyses reduced their global fishing footprint estimates by a factor of >10. Our estimate of footprint at 0.5° (49%) differs from that reported by Kroodsma *et al.* (55%) because they improved their algorithm to identify fishing by squid jiggers after publication and updated data in the current release. Also, the method we used to reallocate fishing activity to grids differed slightly from that in Kroodsma *et al.*, leading to small differences in absolute footprint estimates, but these do not affect the relative relationships between footprints across spatial scales.

Kroodsma *et al.* also state that their 55% fishing footprint is larger than that of agriculture by a factor of 4. However, this comparison is strongly biased by the different scales of analysis and different criteria used to assign grid cells to fishing or farming. The estimates of agricultural land-use footprint they use for comparison are gridded at higher resolution (5′, ~86 km^2 versus ~3100 km^2) and also account for the fraction of farmed or grazed area within each grid cell (*3*). Thus, the agricultural footprint describes only the area directly affected by farming, ignoring any wider area subject to diffuse environmental impacts. Our more comparable high-resolution fishing footprint is less than the agriculture footprint by a factor of approximately 3.5.

All human activities have diffuse impacts that extend beyond the area of activity. However, for fishing activities, using a spatial grid of an arbitrary low resolution does not provide an appropriate or consistent quantitative assessment of diffuse impact. For example, some diffuse impacts would be assessed more effectively using catch and bycatch data and population or community analyses that account for the diverse movements and life histories of affected populations and species, as well as the different rates of mortality that result from their varied interactions with fishing activities (*4*–*6*).

We also quantified the effects of grid resolution on trawl fishing footprints with the Global Fishing Watch data (*2*). We focused on trawling because footprint is a consistent and well-defined concept for trawling vessels, which tow a net or nets directly behind the vessel(s) and for which gear dimensions are known or can be estimated more reliably. Further, high-resolution footprints for bottom trawling (although Kroodsma *et al.* did not distinguish bottom trawls from trawls

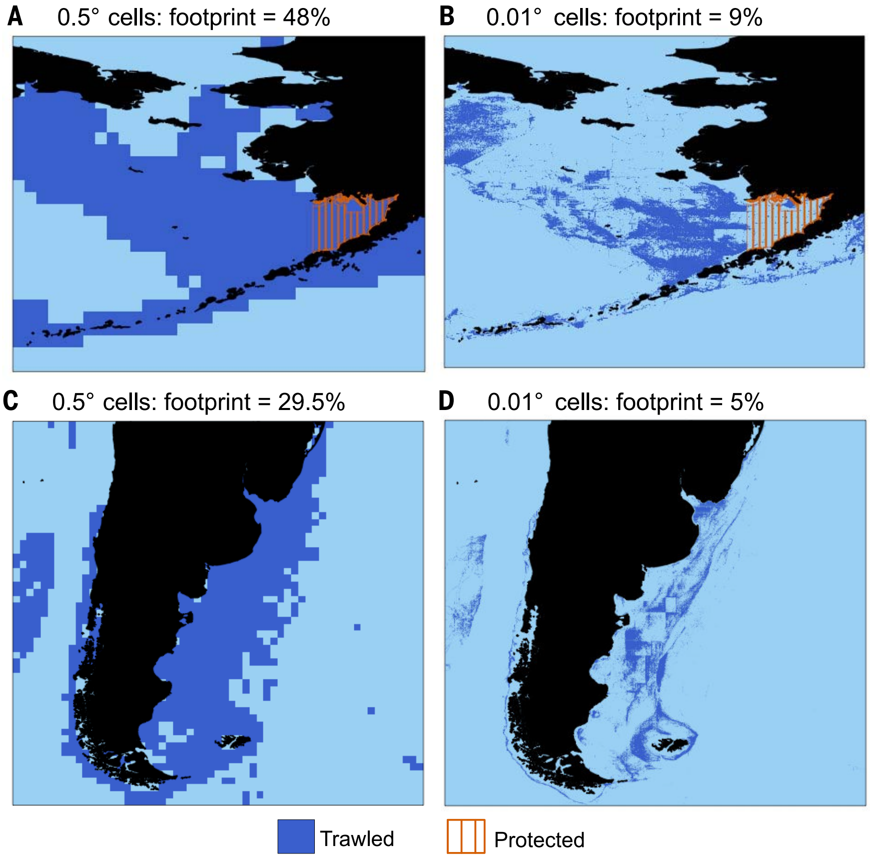

Fig. 1. Effect of grid resolution on the perception of fishing footprint. The areas in dark blue show the trawling footprints estimated for 2016 with (**A** and **C**) an equal-area grid with 0.5° resolution at the equator; (**B** and **D**) an equal-area grid with 0.01° resolution at the equator. The hatched area shows an example region of the North Pacific where all trawling was prohibited.

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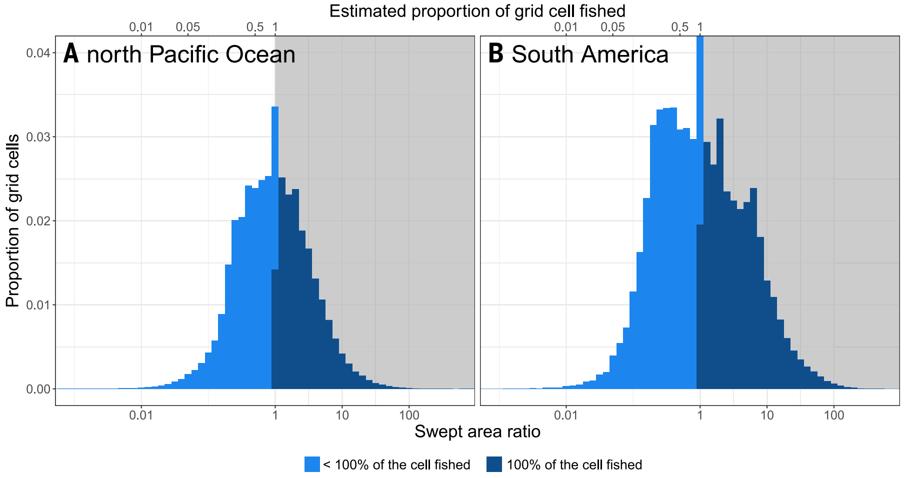

Fig. 2. Estimated distribution of the swept-area ratio within 0.01° grid cells contributing to the trawling footprint. (**A**) North Pacific and (**B**) South America regions during 2016. Light blue bars show estimated proportions of the grid cells where trawling covered less than 100% of the cell.

that do not contact the seabed) have long been used as metrics to assess fishing impacts on seabed habitats [e.g., (*7*–*9*)].

To illustrate the effects of grid resolution on trawling footprints, we considered regions of the north Pacific Ocean and off southern South America. For each region, trawling footprint (as proportion of the ocean area) was calculated using equal-area grids of 0.5° and 0.01° at the equator (Fig. 1). At the higher resolution of analysis, the estimated footprints in these regions fell by factors of 5.3 (48% to 9%) and 5.9 (29.5% to 5%), respectively. Further, if we take as an example a region of the north Pacific Ocean where trawling was banned in 2016 (*10*) (Fig. 1, A and B), then 100% of this area (59,000 km^2 of ocean) was incorrectly classified as trawled at 0.5° resolution. For such reasons, many published analyses of trawling footprints are conducted at higher resolution (*11*–*13*).

Even our highest-resolution regional analyses (0.01°) overestimate trawling footprint. This is because the grid-based method assumes that any trawling recorded in a cell justifies adding the entire cell area to the footprint. More sophisticated approaches for assessing footprint already account for trawling distributions within cells (*14*, *15*). Untrawled area in a cell is a function of the swept-area ratio (SAR). SAR is defined as the total area swept by trawling in the cell divided by the cell area. For the two example regions, we converted trawling effort in hours per cell into SAR, assuming conservatively high values for trawling speed (4 knots) and trawled path width (trawl door spread of 200 m). In existing analyses of trawling footprints, towing speed and door spread are usually allocated by vessel or by fleet to account for differences in gear type (*8*, *9*), although such specifications were not available for the Global Fishing Watch data (*2*). Overall, 53% of 0.01° cells in the north Pacific and 52% of 0.01° cells off South America have SAR < 1 and could not have been fully trawled in 2016 (Fig. 2). Conservatively assuming that trawling activity was spread uniformly within each cell, the trawling footprint in each region fell further to 6.5% (factor of 7.4 reduction relative to 0.5° gridded approach) and 3% (factor of 9.8 reduction), respectively.

A coarse gridding of the positions of fishing vessels (globally or regionally) that ignores differences in catching power among vessels and gear, or ignores the scale of their direct and diffuse impacts, leads to footprint estimates that are primarily driven by the spatial resolution of analysis. Such analyses are unlikely to be a good proxy for the footprint of fishing or the status of species or ecosystems affected by fishing. The high temporal resolution of AIS data can provide valuable insight into the behavior of individual vessels and allowed Kroodsma *et al.* to classify different types and patterns of fishing activity. These analyses alone are an interesting achievement, but the footprint estimates and comparisons with agriculture highlighted in their report are misleading.

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ACKNOWLEDGMENTS

D. Kroodsma provided guidance and assistance with the interpretation and correct use of the database. **Funding:** Supported by the David and Lucile Packard Foundation, the Walton Family Foundation, the Alaska Seafood Cooperative, American Seafoods Group U.S., Blumar Seafoods Denmark, Clearwater Seafoods Inc., Espersen Group, Glacier Fish Company LLC U.S., Gorton's Seafood, Independent Fisheries Limited N.Z., Nippon Suisan Inc. (USA), Pesca Chile S.A., Pacific Andes International Holdings Ltd., San Arawa S.A., Sanford Ltd. N.Z., Sealord Group Ltd. N.Z., South African Trawling Association, and Trident Seafoods (R.O.A.); the Agencia Nacional de Promoción Científica y Tecnológica, Argentina (project PICT 2016-0218) (A.M.P.); the Commonwealth Scientific and Industrial Research Organization (C.R.P.); the National Oceanic and Atmospheric Administration (R.A.M.); and the International Council for the Exploration of the Sea (S.J.). **Author contributions:** R.O.A., A.M.P., C.R.P., R.A.M., and S.J. conceived the study; R.O.A., A.M.P., and S.J. wrote the manuscript with further input from all authors; and R.O.A. performed the data analyses and produced the figures. **Competing interests:** Authors declare no competing interests. **Data and materials availability:** All the data used for these analyses are available from the Global Fishing Watch webpage (*2*).

27 March 2018; accepted 25 July 2018
10.1126/science.aat6713

Science

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Science **361** (6404), eaat6713.
DOI: 10.1126/science.aat6713
