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Mapping nearly a century and a half of global marine fishing: 1869–2015

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ABSTRACT

Understanding global fisheries patterns contributes significantly to their management. By combining harmonized unmapped data sources with maps from satellite tracking data, regional tuna management organisations, the ranges of fished taxa, the access of fleets and the logistics of associated fishing gears the expansion and intensification of marine fisheries for nearly a century and half (1869–2015) is illustrated. Estimates of industrial, non-industrial reported, illegal/unreported (IUU) and discards reveal changes in country dominance, catch composition and fishing gear use. Catch of industrial and non-industrial marine fishing by year, fishing country, taxa and gear by 30-min spatial cell broken to reported, IUU and discards is available. Results show a historical increase in bottom trawl with corresponding reduction in the landings from seines. Though diverse, global landings are now dominated by demersal and small pelagic species.

1. Introduction

Commercial or industrial fishing arguably started before recorded history when the immediate needs of fishers were sated allowing their excess catch to be traded for benefits before it perished. Now a widely traded global commodity [1], seafood is vital to world food security and prosperity, with expectations that its importance will only continue to grow with human population and climate challenges. Individual populations of harvested species can come under pressure and accessing their status and applying sufficient management control is challenging and often controversial [2]. More broadly though, in natural marine systems, there are many limitations to seafood production including the solar-powered primary productivity of supporting ecosystems [3,4] and the need to maintain the irreplaceable biodiversity of these systems. The range of global industrial fleets has expanded to encompass most areas of the world's oceans [5,6]. When has the need to get up-to-date strategic overviews of global fishing operations ever been more pressing?

Several attempts at mapping broad global fishing patterns [7,8] have demonstrated how this information can inform fisheries management as well as marine conservation. Past efforts have concentrated on enhancements to foundation data sources such as the United Nation's Food and Agriculture Organization (FAO) [9] which countries have contributed to since 1950. In recent years, however, a wider range of Supporting data sources have become available which includes specialist regional management organisations (rFMO) such as for tuna fisheries, and exciting improvements in the tracking of fishing vessels from satellites [10]. Harmonization of data from all possible sources can only improve data quality, and for mapping, it's possible spatial precision.

Although mapped catch is now available for periods after 1950 [7,8] this means that important fishing patterns prior to the 2nd world war are usually ignored. Here available data from 1869 is used in combination with a new and extended compilation of novel data sources including the latest satellite data such as the widely used Automatic [vessel] Identification Systems (AIS) [10] to map and visualize global fishing patterns. The scale and patterns of change for the last century and a half are revealed through a new dataset, which not only separates industrial fishing from other fishing, but documents by fishing country and associated fishing gear, the entire catch including estimates of illegal, unreported and discarded catch.

2. Methods

2.1. Data sources, scope and overview

Input data was sourced from publicly available websites (Table 1.). All sources but the tuna regional management organization's (tuna rFMO) data and Global Fishing Watch's (GFW) vessel Automatic Identification System (AIS)-based data [10] were used initially in a similar fashion to [7] and summarised below to map reported landings to candidate 30-min spatial cells with a global grid (Supplementary Fig. 1). This included a separation of deemed industrial from non-industrial reported landings. Following this there was reevaluation and

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Table 1
Data sources used in data compilation.

Source	Description	Link
FAO	FAO Global Fishery and Aquaculture Production Statistics v2017.1.0 Global Capture Production (Release date: March 7th, 2017)	www.fao.org
ICES	International Committee for the Exploration of the Sea 1950–2015 Historical data 1903–1949	www.ices.dk
NAFO	Northwest Atlantic Fisheries Organization Catch and Effort 21B 1960–2015 (Updated 1 June 2017)	www.nafo.int
SEAFO	Southeast Atlantic Capture Production 1975–2015 (FAO Regional Capture Fisheries Statistics v2017.2.0 Release date: 15 June 2017)	www.seafo.org
GFCM	General Fisheries Commission for the Mediterranean Capture production 1970–2015 STATLANT 37A (Release date: Sept 2017)	http://www.fao.org/gfcm/data/capture-production-statistics/en/
CECAF	Fishery Committee for the Eastern Central Atlantic Capture production 1970–2015 (FAO Regional Capture Fisheries Statistics v2017.2.0 Release date: 15 June 2017)	www.fao.org/fishery/rfb/ecaf
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources Statistical Bulletin 2017 vol. 29 1970–2015	www.ccamlr.org
SAUP	Sea Around Us project – records for FAO area 18 (Arctic) v2 1950–2014 (extrapolated to 2015)	www.seaaroundus.org
WCPFC	Western & Central Pacific Fisheries Commission 1950–2014 (Data accessed June 2017)	https://www.wcpfc.int/
IOTC	Indian Ocean Tuna Commission 1952–2015 (Data accessed June 2017)	http://www.iotc.org/
ICCAT	International Commission for the Conservation of Atlantic Tunas 1956–2015 (Data accessed June 2017)	https://www.iccat.int/en/
IAATC	Inter-American Tropical Tuna Commission 1954–2015 (Data accessed June 2017)	https://www.iattc.org/HomeENG.htm
CCSBT	Commission for the Conservation of Southern Bluefin Tuna 1965–2015 (Data accessed June 2017)	https://www.ccsbt.org/
GFW	Global Fishing Watch AIS global data 2016	http://globalfishingwatch.org/
Mitchell, B.R.	International Historical Statistics: The Americas 1750–1988 International Historical Statistics: Africa, Asia & Oceania, 1750–1993	

filtering of reported landings initially assigned to candidate spatial cells through the use of distributional information related to the associated fishing gear used, and where applicable, the tuna rFMO and AIS positional data (Table 1.) Subsequently this map of reported landings was extended through estimates for reported, Illegal, Unreported and Unregulated (IUU) catch and associated discards for both the industrial and non-industrial sectors. The global Human Development Index (HDI) [11] was used to assist estimation of IUU associated with non-industrial fisheries, and served as a simple available proxy for reporting likelihood.

Only records of taxa with a marine origin were used - although some are found in other habitats. Where possible, aquaculture production was excluded, as were records describing shells, coral, amphibians, reptiles, birds and mammals.

2.2. Initial mapping

FAO data for the period 1950–2015 was combined and coded with a range of other input sources for reported fisheries landings as described in [7] (Table 1.). Overlapping records were removed, and only the most spatially specific data was retained. Mapping involved using all means to identify the most specific taxonomy of the reported landing datum because this established both the potential range of fished spatial cells, but also a gradient based on the rough abundance of the fished taxa related to critical habitats, ocean depths etc. [12]. Within the statistical area reported in source databases, usually only a subset of spatial cells were accessible to the fishing fleets of the reporting country [13]. This is because most global catch is taken within the claimed exclusive economic zone (EEZ) waters of countries where the access of foreign fishing fleets is regulated and usually documented.

2.3. Separation to industrial and non-industrial sectors

The separation of landings from industrial and non-industrial fishing was based on a number of factors. The first was whether the taxa had a clear association to fishing gear typically not used in non-industrial fishing such as with tuna purse seine operations. Additionally, for each country the division was further derived by the relative association of the taxon described as landing by the two fishing sectors during the period of fishing by published catch reconstructions [8]. In addition, where the fishing occurred was considered important to the likely association with a fishing sector. Non-industrial fishing is typically accepted to occur within 200 km of shore and within 50 m of depth [14]. Division to sectors is acknowledged to be an imperfect science without detailed and specific data such as from logbooks, surveys etc. which unfortunately are not available for a global assessment.

2.4. Estimation of IUU and associated discards

As in [7], estimates of IUU and associated discards were made for each record of reported landings. For the industrial sector records the current procedure was largely unchanged. The relative association of landings with a range of fishing gears was made based on the fishing country, the year of fishing and the fished taxa [15]. This allowed published data on rates of IUU and discarding to be used [16,17] to guide estimation of the missing components so that the complete catch could be estimated, and not simply reported landings.

For the non-industrial sector it was clear that in order to achieve the published catch rates [14], as well as the national estimates for this sector published as country reconstructions [8], that the unreported component (IUU) of non-industrial fishing was significant. It was decided that the level of non-reporting in this sector to FAO and other parties was influenced by the national resources available for government monitoring. Therefore, the estimation of IUU for this sector was adjusted by country HDI [11], with poorer countries having relatively a larger portion of unreported landings. This expected association was verified by examining the breakdowns within country reconstructions [8] where a significant relationship with $R^2 = 0.29$ was found.

2.5. Adjustment for associated fishing gear logistics

It was possible to associate each fishing record with a range of fishing gears using the fishing year, country and the fished taxon as described in [7,15]. Each fishing gear was deemed to have a general global pattern of probable spatial distribution largely based on distance offshore, depth of water and the distributions of target taxa as summarised from previous mapping of catch and fishing effort [7,18]. For non-industrial fishing, a single distribution was considered, which favoured the published association with nearshore and shallow areas [14].

The fishing gear logistics distribution was used to filter and redistribute catch associated with spatial cells in earlier processing. This further processing did, for example, rule out sites far off shore for non-industrial fishing by proportionately increasing landings associated