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Reconstructing global marine fishing gear use: Catches and landed values by gear type and sector

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ABSTRACT

The interaction between fishing gears and the marine environment define 'fisheries,' and the effect of gears on marine ecosystems and fish stocks has been the source of much debate. Here, we present the first summary of globally reconstructed fisheries catches by major gear categories for 1950–2014. We used the *Sea Around Us* reconstructed global catch database that accounts for reported and unreported fisheries catches, and associated all catches to a fishing gear category. We assigned all industrial (i.e., large-scale) fisheries catches to industrial gear categories by fishing country, taxon, year and the area of fishing. Additionally, we derived catches by individual small-scale gear types for the most-important small-scale fishing countries in each of nine regions around the world, and applied their gear use to similar countries in each of the regions, to serve as a preliminary small-scale catch-by-gear assignment that can be improved upon over time. The combination of these account for gear use for all marine fisheries globally. We found that two industrial gear types, bottom trawling and purse seining, jointly account for over 53% of all catches, while bottom trawling alone dominated discarded catches. In the small-scale sector, over 60% of catches were caught by gillnets, various line gear, and encircling nets. Small-scale fisheries contributed most to the value of landed catches, while industrial bottom trawlers were responsible for discarding large amounts of potentially valuable catches. Catches by purse seines fluctuated over time, mainly due to variability of the underlying species, e.g., anchovies and sardines. The distribution and scale of use of different fishing gears, combined with knowledge of their divergent environmental impacts should allow a new wave of research into the global impacts of fisheries.

1. Introduction

Fishing gears enable fishers to interact with finfishes and marine invertebrates (hereafter 'fish') in the marine environment; this interaction between gears and fish is the fundamental definition of 'fisheries'. There is a wide diversity of fishing gears that have been employed by fishers around the world over the last 60+ years, from simple small-scale gears operated with one's hands like spears, traps, handlines or a variety of beach seines and gillnets, to industrial-scale bottom- and midwater-trawls the size of large aircrafts, and mechanically powered seine nets that can match the size of several Olympic swimming pools (Gabriel et al., 2005). There are major concerns regarding the use of fishing gears including by-catch of non-target organisms (Alverson et al., 1994), often leading to substantial discarding (Zeller et al., 2018), habitat alterations and destruction (Turner et al., 1999; Watling and Norse, 1998), and associated high fuel use (Parker and Tyedmers, 2015).

While many detailed, local studies exist on fishing gears used in

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fisheries, little research exists on a global scale on the total patterns and trends in their use. An exception is the earlier work of the *Sea Around Us* research initiative (Pauly and Zeller, 2015), which produced an assignment of fishing gears associated with officially reported landings data, largely as assembled and reported by the Food and Agriculture Organization of the United Nations (FAO) on behalf of it member countries (Watson et al. 2006a, 2006b) This approach did not account for unreported catches, nor could it allocate catches to different fishing sectors such as small-scale commercial (i.e., artisanal) as compared to large-scale commercial (i.e., industrial).

However, recently the *Sea Around Us* completed their global reconstructions of marine catch data for all countries in the world (Pauly and Zeller, 2016a, 2016b), which augmented the officially reported landings data with complete time-series estimates of unreported catches over the last 60+ years, including commonly un- or under-reported small-scale sectors (e.g., Zeller et al., 2015), recreational fisheries (e.g., Smith and Zeller, 2016), as well as major discards (Zeller et al., 2018). These country-level reconstructions were further complemented with a global reconstruction and harmonization of catches by the industrial large pelagic fisheries in each ocean basin that are administered by Regional Fisheries Management Organizations (RFMOs), mainly for tuna, billfishes and pelagic sharks (Le Manach et al., 2016). In addition to comprehensively reconstructing total reported and unreported catch data, all catches are spatially allocated to a global half degree ocean grid system across the world's marine waters, taking into account biological probability distributions for each taxon in the data (Palomares et al., 2016) as well as known and derived foreign fishing access information to national EEZ waters in each country (Zeller et al., 2016).

The species-gear associations derived earlier by the *Sea Around Us* (Watson et al., 2006a, 2006b) can now be replaced with a new, detailed and improved catch-by-fishing gear dataset that accounts for country, species and annual changes in gear use by fishing sector. We synthesized the global findings of this new and comprehensive global fishing gear database that harmonizes with and links directly to the globally reconstructed catch data of the *Sea Around Us*. We are now able to examine all catches (whether reported or unreported) by gear types, by fishing sector, and by country, in space and time back to 1950. These freely available data will allow all users to evaluate and analyze a variety of policy questions around marine fisheries and gear use over the last 65+ years, and will hopefully assist in better understanding trends in global fisheries and gear use.

2. Materials and methods

We used the reconstructed *Sea Around Us* catch data (Pauly and Zeller, 2016a, 2016b), available at www.seaaroundus.org, by fishing sector, taxon and fishing country to assign fishing gear types to the catch data. All gear types and categories assigned here are listed in Tables 1A and 1B . The catch reconstructions for each country or territory used country- or region-specific definitions to assign catches to either large-scale (i.e., industrial) or small-scale sectors (i.e., artisanal, subsistence, recreational). However, all fishing gears that are moved through the water or across the seafloor using engine power were defined as industrial (Martín, 2012), irrespective of vessel size. Thus, some trawl or purse seine operations defined as 'small-scale' by a given country due to vessel length were re-assigned as industrial sector fisheries in the *Sea Around Us* database (Zeller et al., 2016).

The *Sea Around Us* reconstructed catch data are composed of millions of catch records, each consisting of a catch tonnage for a particular taxon, particular fishing country and year, caught in a particular area (e.g., a certain EEZ, FAO or RFMO area), by a particular fishing sector, and which is either landed or discarded catch, and either deemed reported or unreported. The *Sea Around Us* catch data are structured into three distinct data layers: domestic fisheries, foreign fisheries, and industrial tuna and other large pelagic species fisheries. The distinction between these layers, and thus generally where fisheries operate (i.e., in a country's home EEZ, or other countries' EEZs, or High Seas areas), was used in part to inform potential gear types for different countries. All gear assignments were made while considering temporal and geographical changes for the respective fishing country and taxon. We addressed the gear use in three different segments: industrial non-tuna gears (i.e., excluding industrial tuna and large pelagic fisheries), industrial tuna and large pelagic gears, and artisanal (i.e., small-scale) gears.

2.1. Industrial non-tuna gears

For all industrial catch data records, we first determined the likely gear types or gear categories that an industrial catch record could be assigned to, based on the definitions of fishing gears in Gabriel et al. (2005). Second, we assigned all data rows that have gear information already included (e.g., from catch data reconstructions) to the appropriate gear categories, while confirming and validating this choice based on additional information in the reconstruction and its source material. Examples where this was done include the domestic fisheries in the EEZs of countries around the Red Sea (Tesfamichael and Pauly, 2016) where gears were assigned that readily allowed standardized gear categories to be associated. Third, we assigned all taxa that are caught by a single gear by a fishing country in a geographic region in a given year. Examples of this include taxa that are only caught by one industrial gear type by a country, such as the use of purse seines for anchoveta (*Engraulis ringens*, Engraulidae) in Peru (Mendo and Wosnitza-Mendo, 2014). Fourth, we assigned gear types to all taxa that are caught by multiple gears by the same fishing country in the same geographic area. This required assigning proportions of the different gear types to the mixed gear category for each unique fishing country, year, taxon and geographic region. In this way, catches of Atlantic cod (*Gadus morhua*, Gadidae) by the United Kingdom could be separated into Danish seines, bottom trawls, gillnets, and line gear.

These identified major gear types were assigned to one of the major gear categories defined here (Tables 1A and 1B). The details of the gear-to-catch matching results for each country and region (e.g., national EEZ, territory, high seas area) can be found in the Supplemental methods (S1).

2.2. Tuna and large pelagic gears

The industrial tuna, billfish and other large pelagic fisheries that are

Table 1A
Large scale. Gear categories and gear types with descriptions (adapted from Gabriel et al., 2005).

Gear category	Gear types	Description (Gear type)
Bottom trawl	Bottom trawl, Shrimp trawl, Beam trawl, Otter trawl	Nets dragged by vessels in contact with the seabed
Pelagic trawl	Pelagic trawl	Nets dragged by vessels not in seabed contact and targeting pelagic or semi-pelagic taxa
Longline	Lines, Pole and line, Longline, Hand line	Includes all gears where lines of any kind are the primary fishing gear
Purse seine	Encircling nets, Purse seine	All net-based gears that encircle their catch rather than entangle it
Gillnets	Gillnet, Trammel net	All net-based gears that entangle their catch rather than encircle it
Other	Dredge, Other, Pots or traps, Other nets, Other lines, Dragged gear, Mixed gear, Unknown class	Other gears which are not major contributors to global industrial catches and do not fit into the major gear categories