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Fishing gear associated with global marine catches
I. Database development

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Abstract

Fishing gears, instrumental to the fishing process, can exert direct impacts on marine communities and habitats. The database described here allows for the analysis of global fishing patterns, by associating all reported global catch with fishing gear types. The fine spatial detail of the Sea Around Us project's catch database allows for the construction of maps showing subtle changes in the use of fishing gears annually since 1950. Maps included in this report chronicle the expansion of these and other gears in ways that will inform the current debate over their impacts, and provide critical information to shape policy development and management choices.

Keywords: Fishing gear; Database; Fish catch; Trawl; Dredge; Purse seine

1. Introduction

Fishing gears are an intrinsic part of the fishing process. Without these tools we would be very ineffective predators in the marine environment. Therefore, any assessment of the impacts of fishing on marine environments requires, at a minimum, a time series of fisheries catches related to the gear that caught them. Global statistics are generally poor when it comes to identifying the species taken and the actual location where they are taken. Worse yet, are records of how much fishing 'effort' was expended, and even these seldom describe which types of fishing gear were used. In this paper, our goal was to associate the types of fishing gear employed with spatially disaggregated global fishing catch statistics since 1950 and in this way start assessing the scope and intensity of potential impacts by different fishing gear on marine habitats and species.

As a prerequisite for this work, the Sea Around Us project (SAUP) has prepared and published maps showing the catch since 1950 of all commercial species globally using a spatial grid of half degree by half degree cells (Watson et al., 2004). This database, available on the internet (Watson et al., 2005), provides details of the catching country's identity and that of the species captured, but does not currently provide details of which gear was used to take the catch. To allow this, a database had to be created that associated the catch of each nation, by year, to the gear types used to take each species reported.

Though the database described here is already a powerful tool, it will be further refined and strengthened with additional expert input that will follow from its publication on the internet. It will allow the interaction of fishing gears and critical habitats to be examined in time, and with considerable spatial resolution. It promises to provide policy makers and user groups with the information they require to inform future debates over the impacts of fishing on the marine environment.

2. Methods

2.1. Data sources and documentation

We recorded up to five different gears that were employed, and their relative importance, for each organism or group

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of organisms reported in the global catch database developed by the SAUP based on data sourced from the Food and Agriculture Organization of the United Nations (FAO) and elsewhere (Watson et al., 2004). If possible, gear associations were qualified by the country reporting the catch, the geographical location, and the year. Our research was based primarily on commercial gear. Artisanal gear types, however, were recorded when the artisanal fishery provided the bulk of the reference information for a species in a given family (e.g., Drums or Croakers—Sciaenidae). The search for gear associations with fish catches was primarily structured along taxonomic lines. That is, we attempted to find in books, journals, and on the internet, documentation of the use of a particular gear to catch a particular species of fish, crustacean or mollusc. If this was possible, we then attempted to qualify this association by the countries nominated, or the region (we used the 18 major FAO statistical areas), or the range of years described. The internet proved a rich source of, at least recent, gear associations. For the major species there were many references available. Many fishing gear manufacturers advertise their products by documenting which species are effectively targeted. Minor species were more problematic, but there were many webpages giving gear associations by broad groups of fishes. Often the region where the gear association exists was documented, but in other cases, we had to assume that references described at least the major fishing areas of the countries listed. Often, there was no specific reference to the years when the gear was employed which we assumed to mean that the association currently exists and probably has existed for a number of years. Though regulations can change the use of fishing gears quickly, changes in gear usually take several years to be completed. Unless we found specific ranges of years (see Table 1) we assumed that all years were the same.

The coding system used for gear type was the hierarchical system described by von Brandt (1984). For each gear used to catch a given organism or group of organisms, the database had provision to record an internet worldwide web address and also the name of a Portable Document Format (PDF) file if this was used to archive reference material, ensuring proper documentation, and future ease for updating and fact checking. When PDF documents were available these were downloaded and cached. Otherwise the materials linked to the internet web addresses were captured as PDF documents to ensure future availability. The database also allows the recording of the countries or group of countries (e.g., the European Union) that employed the gear for catching that organism or group of organisms. In addition, we described time periods with different mixtures of gears even for the same country and organism. Seldom were there more than three different gears employed to catch an organism by a specified country in a defined region and time period.

Table 1
Breakdown of global fisheries catch by the specificity of gear association available

What? Taxon	Where? FAO area	Who? country	When? year	Percent of catch
Broad	–	–	–	0.02
Broad	X	–	–	0.83
Broad	–	X	–	0.07
Broad	X	X	–	4.53
Broad	–	X	X	–
Broad	X	–	X	–
Broad	X	X	X	–
Specific	–	–	–	30.08
Specific	X	–	–	18.62
Specific	–	X	–	3.11
Specific	X	X	–	42.72
Specific	–	X	X	0.01
Specific	X	–	X	–
Specific	X	X	X	0.01

Percent of catch by weight shown for each group.

2.2. Assignment procedures

The gear database described above was used with an interpolation process to ensure that all catch records from our global catch database (Watson et al., 2004), regardless of the organism, country, region, and year, would have documented fishing gear associations. Given that gear associations for much of the world's catches were available specifically from the gear database described above it was possible to use a structured interpolation process to simply fill in cases not matched exactly by our database initially. The general process of interpolation was one of replacing general gear associations with more specific ones where they were available. This process assumed that the type of organism was the primary determinant of the gear used. Following this, in no particular order, were the country fishing and the FAO statistical area where the gear was employed. Lastly, we considered the year when the catches were reported. At each step in the interpolation process, the level of specificity in the documentation was recorded. If a more specific association for a catch record occurred in a subsequent step in the process, then this gear association, and its record of specificity, was overwritten. In this way, all catch records recorded in the global database were matched with the most specific and relevant gear association record in the gear database or weighted averages of these (weighted by their individual specificity) when several were available.

2.3. Mapping results

The spatial database of global fisheries catch of the SAUP (Watson et al., 2004,2005; www.seaaroundus.org) was used. This database comprises nearly half a billion records of catch rates for global half-degree latitude and longitude spatial cells, for all reported organisms and countries from 1950 to 2001. The spatial database is based on a consolidation of several major data sources such as the FAO capture fisheries and its regional bodies, the International Council for the Exploration of the Seas (ICES) STATLANT database (www.ices.dk/fish/statlant.htm), the Northwest Atlantic Fisheries Organization (NAFO; www.nafo.ca/), as well as data provided from the Canadian, United States, and other governments. Using this catch database and the gear association database described above, it was possible to associate all catches taken in each spatial cell with the appropriate fishing gear code. Maps of the use of fishing gear by year, country, or many other descriptors were then possible. There is great variation in the amount and detail of fisheries data available globally. For some countries, this database will be very useful—for others, much of this data exists, and so it is less useful at a national level. At a global level it provides a very useful tool for meta-analyses and understanding global and regional patterns.

3. Results and conclusions

3.1. Specificity of gear associations

Following the assignment procedure described above a global catch-gear association database resulted. In this database, each global catch record was associated with up to five different fishing gear types and their relative importance noted. An analysis of the final gear associations revealed that the majority of catch records (based on tonnage) had an association based on a specific organism, usually qualified by region (Table 1). For more than half of total catch (tonnage) the country was also specified. In only a small number of cases were the range of years specified (as indicated by an X in the Country column of Table 1). The largest category of association was for specific organism, FAO areas, and countries but being generalized across fishing years which accounted for more than 42% of all historical landings. Having all of these factors specified occurred for less than one percent of global catch by weight, however, within the range of years assessed (1950–2001) this is not considered a major weakness.

3.2. Global catches by gear

Using the gear association database, it was possible to look at the specific or the general gear types used to capture the world's fish catches. For clarity, we will present results here divided into eight general gear types, as there were in total 42 specific gears in total associated with global catches.

Since 1950, there has been a dramatic rise in the catch taken with both seine and midwater trawl gears (Fig. 1). Though the catch using trawl and dredge gears has risen steadily (Watson et al., this volume), that of seine gear (which includes purse seine) has fluctuated considerably. In large part, this is due to the impact that climatic events such as El Niño have had on stocks targeted by this gear such as the Peruvian anchoveta (*Engraulis ringens*). At lower catch levels, but still noteworthy, the catches from hook and line gear have been slowly increasing and are now near levels associated with gillnets. Still, at present, it is the fifth most important general gear type in terms of the contribution to the total catch. Much less catch is associated with dredge, traps, and all other gears combined which we list here as 'other'.

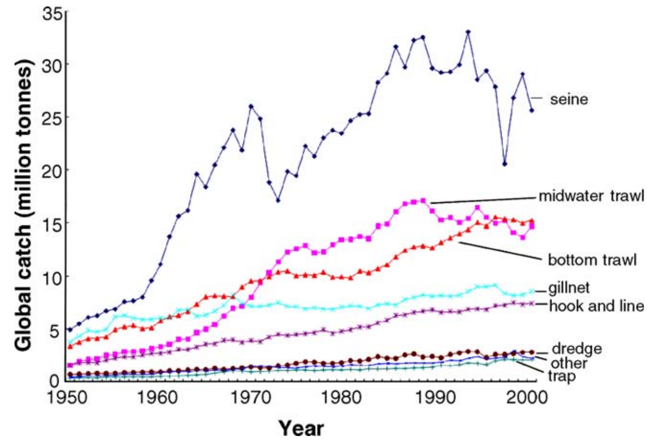

Fig. 1. Annual global catch (million tonnes) taken by general fishing gear types.

Despite the change in the relative rankings of general gear types in the late 1960s suggested by catch associated with gears in Fig. 1, it can be seen in Fig. 2 that the relative catch taken by each gear type other than mid-water trawl has remained remarkably constant since 1950. An explanation may be that since 1950 very little historical data was available on the relative importance of each gear type, forcing us to assume that there has been relatively little change in their use. There has, however, been a change in the relative importance of the species being targeted since 1950, which has been well documented by Pauly et al. (1998), and others. Therefore, the constancy of relative gear use might exist simply because the use of fishing gears is maintained by fleets despite the changes in target species required when stocks collapse.

3.3. Gear use by country—an example

The database we assembled also allows us to follow the use of gear by individual countries over time. In some there have

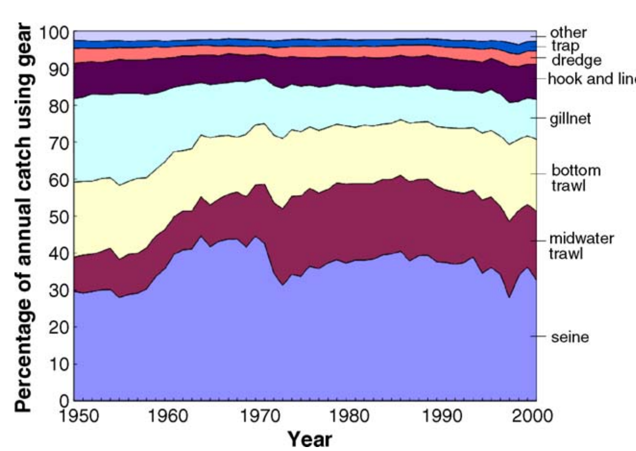

Fig. 2. Percent of annual global catch taken by the top eight gear types.

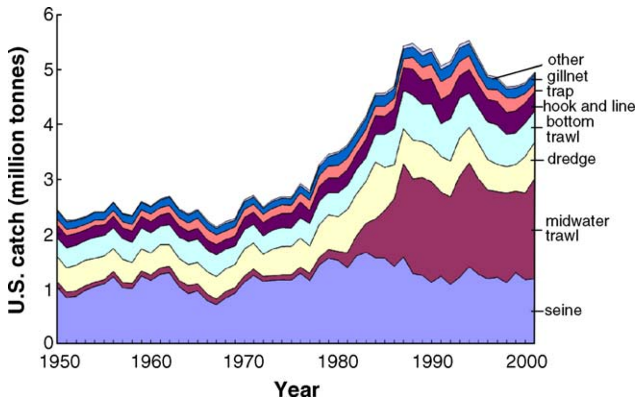

Fig. 3. Annual catch (million tonnes) reported by the U.S. broken down by the top eight gear types.

been large changes in catch, which appear to be associated with the introduction of specific gear types. For example, the U.S. fleets (Fig. 3) show a considerable increase in catches at the time when the use of mid-water trawls was expanded in the mid-1980s. The dominant target group associated with the use of this gear are small tunas, jacks, and pompanos, taken predominately in subtropical and tropical waters. By the late 1980s, more catch was reported for the species caught with mid-water trawl than for seine gear. Catch associated with seine gear here were largely caught using purse seine gear. Though there has been some expansion in catch by bottom trawl and dredge gear (Watson et al., this volume), the relevant importance of most gears has remained relatively static.

3.4. Gear use by major fishing countries

In the 1950s, the catches by major countries were dominated by those taken by gillnet, seine, and bottom trawl (Fig. 4). The relative catch by the major countries (as determined by bottom trawl catches in the 1950s) changed in subsequent decades, as did their relative use of gears. By the 1970s, the catch of these major fishing countries by gillnet gear decreased, while their use of midwater trawl gear increased. This trend, however, was not well reflected in the balance of catch taken by ‘other’ countries whose relative gear use was relatively static. By the 1990s, the importance of midwater trawl had decreased for most countries, with the exception of the nations comprising the former Soviet Union, where relative catch associated with midwater trawl actually

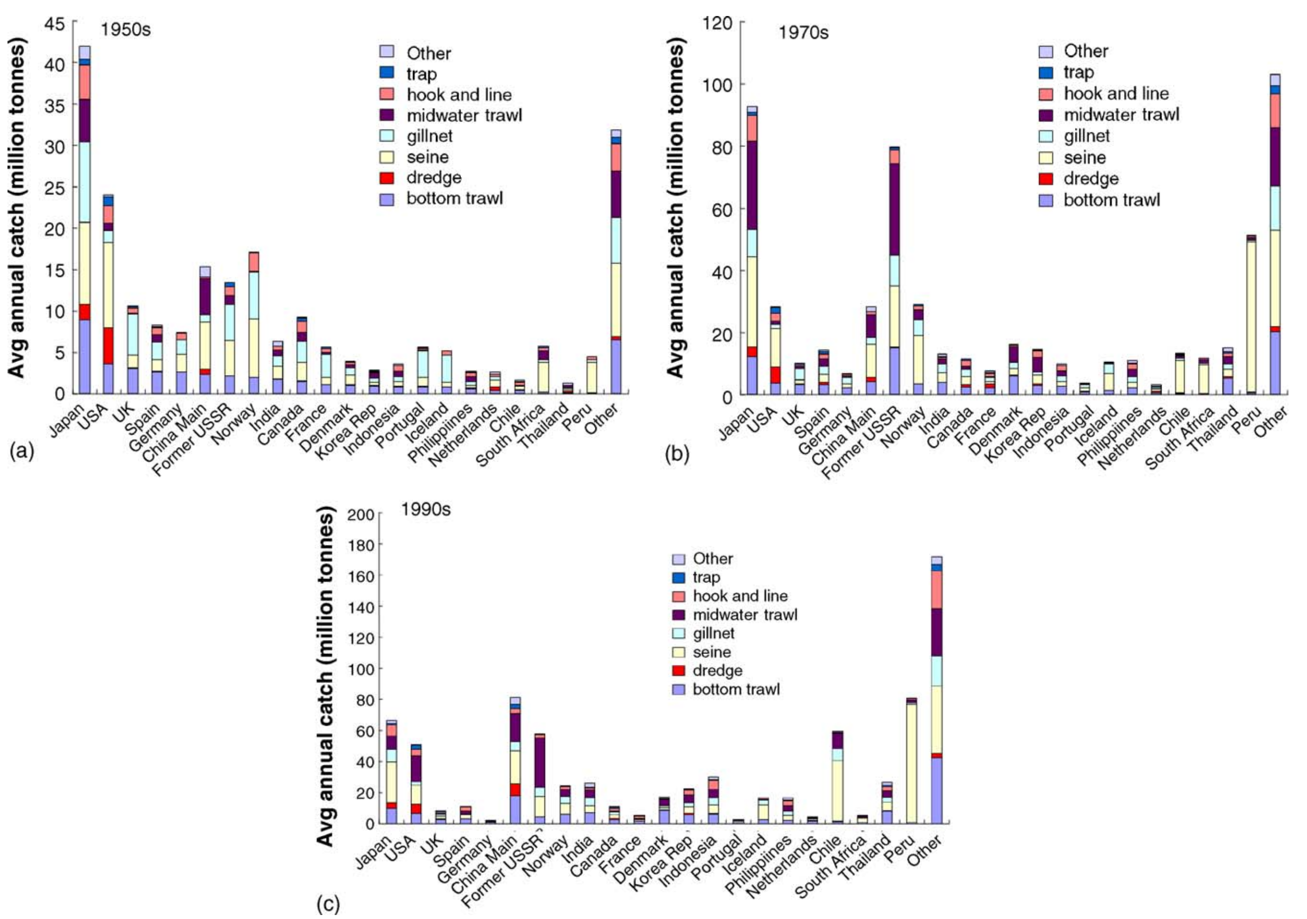

Fig. 4. Catch (million tonnes) by major fishing countries broken down by general fishing gears for three decades (a) 1950s, (b) 1970s, and (c) 1990s (ordered by the tonnage taken with bottom trawl gear in the 1950s).

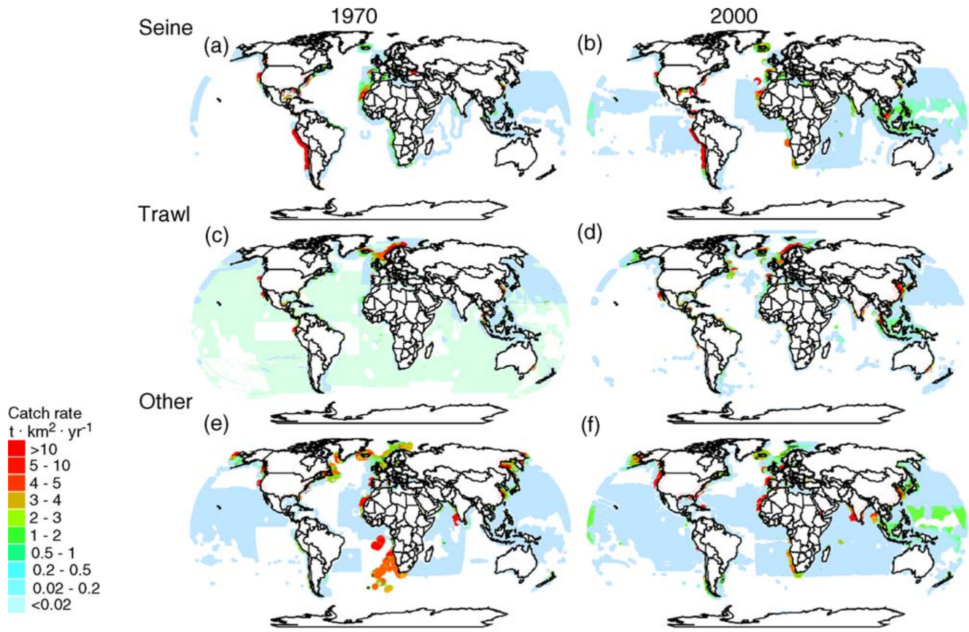

Fig. 5. Maps of catch associated with seine, trawl, and other gears in 1970 and 2000.

increased. Seine gear, largely purse seine, continued to be important in the 1990s. This was particularly so for those relatively new leaders in fish catch such as Chile and Peru, whose fleets target Peruvian anchoveta (*Engraulis ringens*), used largely for reduction to fishmeal.

3.5. Mapping catch taken by major gear types

Maps can be constructed showing the catch rates associated with different gear types (Fig. 5). Seine gear was associated with large coastal catches in all years, and especially along the coasts of Chile, Peru, and the eastern coast of the United States. There were changes from 1970 to 2000 primarily through increases around India and Southeast Asia. Catches associated with trawl gear increased over the same period along the coast of China and Southeast Asia but also in eastern Canada following the collapse of Atlantic cod stocks. All ‘other’ gears showed reductions in many areas except the coast of China and the south Pacific.

3.6. Trophic and size composition of catch by gear type

The potential impact of different gear types on marine communities differs. As different gear types target different organisms, often at different positions in the food chain, any change in their use can also signal changes in the marine community available for commercial fishing. Catch taken by major gear types can be characterized by a range or ‘envelope’ of maximum length and trophic level (Fig. 6). Gears which concentrate on invertebrates, often crustaceans, such as bottom trawl, dredge, and trap gear take smaller animals at a lower tropic level. As these gears in general account for an increasing part of global landings (Fig. 1), this reduction in size and trophic level reflects important changes in the composition of the available marine fauna and the marine ecosystem itself as documented by Pauly et al. (1998) and Pauly and Watson (2003).

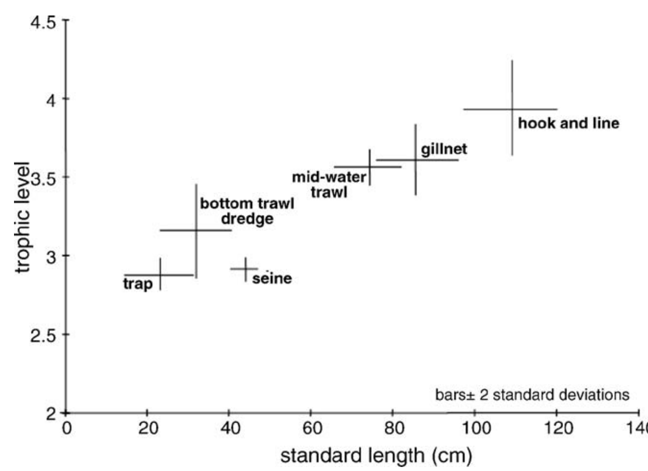

Fig. 6. The trophic level and standard length (cm) of catch by major gear type. Bars represent ± two standard deviations.

4. Conclusions

The usefulness of creating a database associating fishing gear with the catch of organisms with reference to the country fishing, the location of the fishing operation and the year, can be demonstrated by the interesting results that emerge when this database is associated with a global spatial database of fisheries catch such as the one developed by the SAUP. The combination allows all catch data since 1950 to be associated with the documented use of fishing gears, providing the ability to generate historical statistics in ways not seen before. In addition, it is possible to map the changing use of fishing gears globally such as bottom trawl and dredge gear (Watson et al., this volume). This type of detailed spatial information will be instrumental in investigating changes in the use of fishing gears with impacts on marine habitats and communities. For example, correlations between the increase in hook and line gear use and seabird bycatch, or changes in benthic communities and the use of bottom trawl and dredging in the past could be assessed.

Already there is considerable interest in this database as it reveals which fishing gears are used on the high seas, what types of gears are being used in critical habitat such as areas of deepwater corals, seamounts, etc. It also allows for discovery of spatial overlaps between the distributions of marine mammals (Kaschner et al., in press), seabirds, and fishing by specific gear types.

Future versions of the fishing gear database will incorporate finer spatial and temporal precision than the version described here. In turn, this will allow an analysis of the overlaps and interactions between fishing gears and sensitive marine habitats such as seagrasses, coral reefs, and seamounts. With the continued expansion of fishing gears into deeper waters and remote areas, this type of analysis will be extremely valuable to inform policy development and to help develop future management options.

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