SubsidyExplorer – Methods

The Sustainable Fisheries Group at the University of California, Santa Barbara

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Introduction

This document contains a detailed account of the materials and methods underlying the analysis done by the Sustainable Fisheries Group (SFG) at the University of California, Santa Barbara to evaluate possible outcomes resulting from fisheries subsidies reforms being negotiated by the World Trade Organization (WTO) between 2018 - 2020. The accompanying interactive toolkit entitled "SubsidyExplorer" (https://sfg-ucsb.shinyapps.io/SubsidyExplorer/) was created with the purpose of allowing delegates to (1) explore existing data on fisheries subsidies and (2) visualize how different fisheries subsidies disciplines might impact fishing effort and fish biomass if they were to be implemented.

The structure of this document mirrors the structure of the toolkit, discussing the data sources and methods used in each section.

Global fisheries subsidies today

The purpose of the first section is to synthesize existing data on fisheries subsidies and to put this information in context using other fisheries data.

Data sources

Data for this portion of the analysis came from the following sources:

- estimates of global fisheries subsidies generated by Rashid Sumaila at the University of British Columbia (estimates are unpublished updates of those found in Sumaila et al. (2016));
- Food and Agriculture Organization (FAO) of the United Nations' global production database;
- ex-vessel prices compiled by Melnychuk et al. (2017);
- estimates of fisheries subsidies from the Organization for Economic Co-operation and Development (OECD) fisheries support estimate (FSE) database;
- population and gross domestic product (GDP) statistics from the World Bank's World Development Indicators (WDI) database;
- estimates of the number of fishers from the FAO Yearbook of fishery and aquaculture statistics;
- estimates of the number of persons employed in marine capture fisheries from Teh and Sumaila (2011);
- estimates of global fishing effort from Global Fishing Watch (GFW),

Global fisheries subsidies: An updated estimate - Sumaila et al. (2016)

Sumaila et al. (2016) identified and compiled published information on financial transfers provided to the fishing sector by governments and estimated the likely magnitudes of fisheries subsidies (in 2009 US$) in states for which this information was not available. The classification scheme for fisheries subsidies used by Sumaila et al. (2016) comes from Sumaila et al. (2010). They define fisheries subsidies as financial transfers, direct or indirect, from public entities to the fishing sector, which help the sector to be more profitable than it would be otherwise. Fisheries subsidies are then divided into thirteen different categories, depending on the (1) policy objective, (2) description, (3) scope, coverage and duration, (4) annual US$ amount, (5) source(s) of funding; (6) administering authority, (7) recipients, and (8) mechanisms of transfer associated with the subsidy program.

Each category is associated with one of the three subsidy types described in Sumaila et al. (2010): beneficial ("good") subsidies, capacity-enhancing ("harmful") subsidies, and ambiguous ("neutral") subsidies. This classification scheme is based on the potential impact of a subsidy on the sustainability of the fishery resource (harmful, good, neutral).

By definition, beneficial subsidies are those that lead to investment in natural capital assets (maximize economic rents). In the context of fisheries, these types of subsidies often aim to increase the growth of fish stocks via conservation, allow for improved monitoring of catch rates, or enhance fisheries management to achieve biologically or economically optimal use of the resource. Subsidies included in the following three categories are considered to be "good" subsidies: 1) fisheries management programs and services, 2) fishery research and development (R&D), and 3) marine protected areas (MPAs).

Capacity-enhancing subsidies are those lead to disinvestments in natural capital assets. In the fisheries context, "bad" subsidies allow for fishing capacity to develop beyond the point that would be sustainable in the long term by artificially increasing profits. This overcapacity can then compound overexploitation problems such as overfishing. Subsidies included in the following seven categories are considered to be "bad" subsidies: 1) fuel subsidies and tax exemptions, 2) boat construction, renewal, and modernization, 3) fishing port construction and renovation, 4) price and marketing support (processing and storage infrastructure), 5) fishery development projects and support services, 6) foreign access agreements, and 7) non-fuel tax exemptions.

Ambiguous subsidies are those may lead to either investment or disinvestment in the fishery resource, often depending on the specific mechanisms of the subsidy program. Subsidies included in the following three categories are considered to be "neutral" subsidies: 1) fisher assistance programs, 2) vessel buyback programs, 3) rural fishers' community development programs.

More details about the types of programs included in each of the thirteen categories are given in Table 1.

Table 1. Fishery subsidy classification system based on the potential impact of a subsidy on the sustainability of the fishery resource of from Sumaila et al. (2010).

Subsidy Type	Description
A. Beneficial subsidies ("good")	
A1. Fisheries management programs and services	These may include monitoring, control, and surveillance programs, stock assessment and resource surveys, fishery habitat enhancement programs, and stock enhancement programs.
A2. Fishery research and development (R&D)	These may include programs aimed at improving methods for fish catching and processing, as well as other programs aimed at improving fishery resources thought scientific or technical developments.
A3. Marine Protected Areas (MPAs)	These may include establishment, monitoring, or enforcement of areas where commercial fishing is prohibited.
B. Capacity-enhancing subsidies ("harmful")	
B1. Boat construction, renewal and modernization programs	These may include lending programs below market rate geared towards fishing vessel construction, renewal and modernization (loan guarantees, restructuring, and other lending programs) as well as public support programs to adopt new and/or improve fishing technology.
B2. Fishing port construction and renovation programs	These may include provision of public funds towards fishing landing site infrastructure, port improvements for fishing fleets, harbor maintenance, jetty and landing facilities, and reduced cost or free moorage for fishing fleets.
B3. Price and marketing support, processing and storage infrastructure programs	These may include market intervention programs such as value addition and price support, or infrastructure investment programs for processing, storage, and fish auction facilities.
B4. Fishery development projects and support services	These may include programs that support fisheries enterprises development or programs that provide institutional support and services, provision of baits, and search and rescue programs.
B5. Non-fuel tax exemptions	These may include rebate and other government funded insurance support programs that have a direct impact on profits such as income tax deferral for fishers, crew insurance, duty free imports of fishing inputs, vessel insurance programs, and other economic incentive programs.
B6. Foreign access agreements	These may include explicit monetary transfers, transfers of fishing technology, or the provision of market access in another state.
B7. Fuel subsidies	This is calculated as the difference between the price per litre of fuel paid by fishers and the national price applied to fuel purchase for other uses.
C. Ambiguous subsidies ("neutral")	

C1. Fisher assistance programs	These include payments to fishers to stop fishing temporarily or to supplement income during bad times which as income support programs, unemployment insurance, worker adjustment programs, fishery retraining, and other direct payments to fishers.
C2. Vessel buyback programs	These may include permit or gear buybacks, or license retirements.
C3. Rural fishers' community development programs	These may include programs with an overall objective of poverty alleviation and food sufficiency.

Rashid Sumaila and his team at the University of British Columbia have updated their subsidy estimates for 2018 US$. These estimates were used in this analysis, but are not yet published. The methodology of obtaining these estimates is the same as that presented in Sumaila et al. (2016).

FAO global production database

Released on April 4, 2019, version 2019.1.0 of the FAO global production database contains the volume of aquatic species caught by state or area, by species items, by FAO major fishing areas, and year, for all commercial, industrial, recreational and subsistence purposes from 1950 - 2017. This dataset can be accessed using the FishStatJ software (FAO, 2018) (http://www.fao.org/fishery/statistics/software/fishstatj/en) or downloaded directly as a CSV file (http://www.fao.org/fishery/statistics/global-production/en). The data used in this analysis was last downloaded on May 16, 2019.

The FAO global production database includes production of fish, crustaceans and mollusks, and other aquatic animals, plants, and mammals takens for commercial, industrial, recreational, and subsistence purposes. This dataset does include production from aquaculture and mariculture, but only capture fisheries production was used in this analysis. All aquatic organisims included in this database are classified according to ~2,100 commerical species items. These species items may compose a single species, genus, family, or higher taxonomic level. These species items are then classified according to the Aquatic Sciences and Fisheries Information System (ASFIS) list of species (12,751 items). Each species item is also classified into one of 50 different FAO International Standard Statistical Classification for Aquatic Animals and Plants (ISSCAAP) groups on the basis of taxonomic, ecological, and economic characteristics. These 50 groups constitate nine higher ISSCAAP divisions.

All capture production entries are also classified by fishing area. There are eight major inland fishing areas and 19 major marine fishing areas established for fishery statistical purposes (Figure 1, hereafter referred to as "FAO regions"). Most production statistics included in the FAO capture production database are reported to the FAO by national offices, but some entries are estimates made by the FAO from other available sources of information.

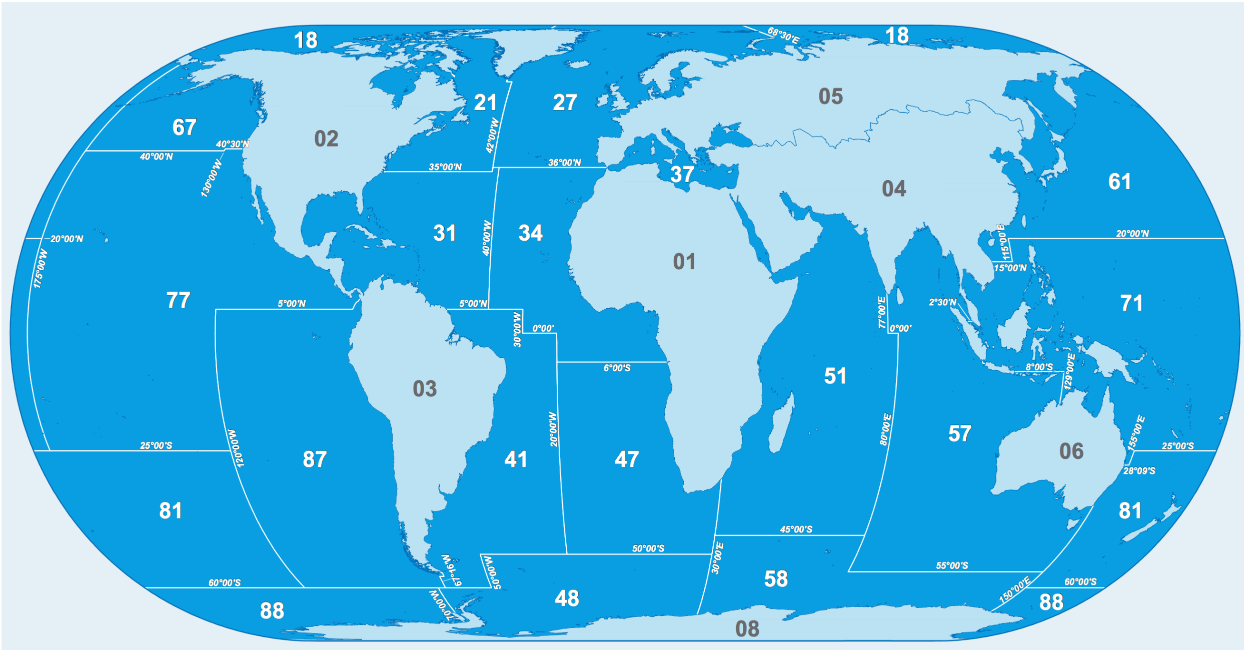

Figure 1. Map of FAO Major Fishing Areas

Reconstruction of global ex-vessel prices of fished species - Melnychuk et al. (2017)

Melnychuk et al. (2017) created a streamlined approach to estimate nominal ex-vessel fish prices for all species items reported in the FAO global capture production database. They use three datasets from FAO to reconstruct ex-vessel prices from 1976-2012: 1) global commodities production and trade (1976-2013), 2) world fishery production - estimated value by groups of species (1994-2012), and 3) global capture production (1950-2014).

Their method uses three linkage tables to equate export values of fishery commodities, generally reported as the intersection of species (or groups of species) with product types (e.g. fresh; frozen; dried), with landing records of species. First, they first pooled commodities across product types, removing commodities associated with ISSCAAP groups for which a mean ex-vessel price estimate was not available from the FAO. Second, they further aggregated the pooled commodities into ISSCAAP groups in order to compare estimated mean ex-vessel prices by group with those reported by the FAO. Lastly, they linked ASFIS species reported in the FAO global production database to one of the pooled commodities, providing an estimate of average ex-vessel price by year for 1861 of the 2033 ASFIS species associated with landings records. The 172 species for which ex-vessel price estimates were not available came from 14 out of the 50 possible ISSCAAP groups (4 groups of aquatic mammals; 4 groups of aquatic plants; frogs and other amphibians; crocodiles and alligators; turtles; corals; pearls and other shells; sponges).

OECD fisheries support estimate (FSE) database

The FSE database analyzes fisheries policies, and expresses the amount of support they provide to the fishing industry using support indicators, which are comparable across time and between countries. In order to be included in this database, a policy must generate a transfer to fishers, regardless of the nature, objectives or impacts of the policy. ‘Transfers’ can include budgetary payments such as direct payments to fishers and general support for the fishing sector in terms of management, harbors, and other infrastructure, as well as non-budgetary payments such as tax measures. In order to qualify as a ‘transfer’, there also must be a clear source (i.e. the group bearing the cost) and recipient (i.e. the group receiving the benefit) of the value. The FSE Manual specifies a very clear set of criteria for identifying the scope of fisheries policies that can be included in the FSE database (OECD, 2016).

The classification system used by the OECD to identify different types of policies first makes the distinction between non-budgetary transfers to individuals, budgetary transfers to individuals, transfers to the sector generally, and cost recovery charges. Within each of these four categories, policy measures are then classified according to implementation criteria, defined as the conditions under which transfers are provided to fishers (or the conditions of eligibility for the payment). The categories and sub-categories used in the FSE database, as well as brief descriptions of the types of programs included in each are given in Table 2.

Table 2. Fishery subsidy classification system based on the implementation criteria of a transfer from the OECD FSE Manual (OECD, 2016).

Subsidy Type	Description
0. Non-budgetary transfers to individual fishers	
0.A. Market price support	Transfers to fishers arising from policy measures that create a gap between domestic market prices and border prices.
0.B. Fuel tax concessions	These may include programs aimed at improving methods for fish catching and processing, as well as other programs aimed at improving fishery resources thought scientific or technical developments.
1. Budgetary transfers to individual fishers	
1.A. Transfers supporting fishing and vessel costs	Transfers to fishers based on the use of fishing inputs or factors of production
1.A.1. Variable costs	*Transfers reducing the cost of a specific variable input or a mix of variable inputs (not including fuel tax concessions)*
1.A.2. Fixed costs	*Transfers reducing investment costs to purchase or modernize fishing vessels, gear, or any other capital asset – can be further subdivided into transfers for 1) vessel construction or purchase, 2) modernization, or 3) other transfers*
1.B. Transfers based on a fisher’s income	Transfers to fishers based on their income or revenue
1.B.1. Income support	*Transfers based on income or revenue, including direct payments to vessel owners or crew.*
1.B.2. Special insurance system for fishers	*Includes measures reducing employers’ social security contributions and measures providing health insurance and pension schemes with preferential conditions or rates.*
1.C. Transfers based on the reduction of productive capacity	Transfers based on the removal of vessels and licenses from a fishery, including buyouts of quota and early retirement plans

1.D. Miscellaneous transfers to fishers	Transfers to fishers that cannot be disaggregated and allocated to the other categories
2. Transfers to the sector generally	
2.A. Payment for access to other countries' waters	These may include government-to-government payments for the right of access, for a country's fishing fleet, to operate in another country's EEZ
2.B. Provision of infrastructure	Transfers supporting the construction, management, and access to shared facilities, including port infrastructure and activities
2.B.1. Capital expenditures	
2.B.2. Subsidized access to infrastructure	
2.C. Marketing and promotion	Transfers financing assistance to marketing and promotion of fish products
2.D. Transfers supporting fishing communities	Transfers supporting the improvement of livelihoods in fisher's communities
2.E. Education and training	Transfers financing training and education in the fishery sector
2.F. Research and development	Transfers financing research and development of activities improving production
2.G. Management of resources	Transfers financing management activities improving the productivity or the sustainability of aquatic resources
2.G.1. Management expenditures	*Transfers financing the expenditures associated with management programmes*
2.G.2. Stock enhancement programmes	*Transfers financing stock-enhancement programmes*
2.G.3. Surveillance and enforcement expenditures	*Transfers financing enforcement of management measures*
2.H. Miscellaneous transfers to general services	Transfers financing other general services that cannot be disaggregated and allocated to the other categories
3. Cost recovery charges	
3.A. For resource access	Charges levied on fishers to grant access to a resource, including license fees, cost of permits, and other formalities
3.B. To access infrastructure	Charges levied on fishers to grant access to infrastructure such as harbor fees and other user charges for government-provided infrastructure
3.C. For management	Charges levied on fishers to finance management, research and enforcement expenditures, or fines levied in case of infraction
3.D. Resource rent taxes and charges	Fees, taxes, or payments collected from individual fishers according to resource rents generated by fishing activities, including profit taxes
3.E. Other	Other charges levied on fishers for which there is insufficient information to allocate them to appropriate categories

World Bank world development indicators (WDI) database

The World Bank WDI database (https://data.worldbank.org/) is a collection of global data, containing time series of 1,600 different indicators related to many different facets of development aggregated to the state, regional, and global level. The WDI data used in this analysis was last accessed through the `WDI` package for R on June 1, 2019. The following three indicators were extracted for all states between 2000-2018: total GDP in current US$ (NY.GDP.MKTP.CD), total population (SP.POP.TOTL), and the total value added from agriculture, forestry, and fishing in current US$ (NV.AGR.TOTL.CD).

FAO Yearbook of fishery and aquaculture statistics

In addition to containing the global production statistics discussed separately above, the FAO Yearbook of fishery and aquaculture statistics complies data on employment, commodities production and trade, apparent fish consumption and fishing fleets. The most recent issue of the Yearbook, released in 2018, contains data up through 2016. The number of fishers by state were extracted for 2010-2016 from the FAO Yearbook digital portal (http://www.fao.org/fishery/static/Yearbook/YB2016_USBcard/index.htm) on June 1, 2019 for this analysis.

Contribution of marine fisheries to worldwide employment – Teh and Sumaila (2011)

In response to the lack of available data on employment in marine fisheries, Teh and Sumaila (2011) created a database of marine fisheries employment (2003) for 144 coastal states. As part of creation of this database, they compiled available statistics from many sources and used models to quantify gaps. They then converted the number of marine fisheries jobs to full-time equivalent (FTE) units in order to provide a comparable unit of employment across all states.

Estimates of FTE jobs in the marine capture fisheries sector by state used in this analysis were obtained directly from Lydia Teh on May 22, 2019.

Global Fishing Watch (GFW)

Very few estimates of total fishing effort exist on a global scale, but GFW is a novel way of tracking fishing behavior in near real time on an individual vessel level (https://globalfishingwatch.org/). GFW has processed more than 22 billion automatic identification system (AIS) positions broadcast by fishing vessels across the world. Designed to help vessels avoid collisions, AIS broadcasts a vessel's identity, position, speed, and turning angle to nearby vessels, and these transmissions are also picked up by satellite- or land-based recievers allowing companies to store and distribute this information. GFW has identified more than 80,000 unique fishing vessels ranging in length from 6 - 146 m. GFW used data on 45,441 marine vessels listed on official fleet registries to train a convolutional neural network (CNN) to identify vessel characteristics. This model can use the behavior of vessels (as broadcast by AIS) to identify six classes of fishing vessels and six classes of nonfishing vessels with 95% accuracy and can predict vessel length, engine power, and gross tonnage.

As it only includes fishing vessels with AIS systems onboard, GFW does not represent the total global fishing effort. The International Maritime Organization (IMO) requires all vessels greater than 300 tons traveling in international waters to have AIS, though certain states also require smaller vessels to use the device. There is great uncertainty regarding the total number of active fishing vessels in the world, but Kroodsma et al. (2018) estimated that in 2016 the number of vessels with AIS comprised approximately 56% of all vessels larger than 24 m, 9% of vessels 12-24 m, and only 0.2% of vessels under 12 m. They also estimated that vessels with AIS likely contributed between 26% - 34% of the global fishing effort (KW hours expended) of all vessels in the world, with that value increasing to 50% - 70% for all vessels fishing more than 100 nautical miles from shore (halfway to the EEZ boundary).

Explore global fisheries subsidies

This tab contains a global map on which each state is colored by the total magnitude of fisheries subsidies (2018 US$) it provided. The user is asked to select which subsidy type(s) to include when calculating the total amount of subsidies provided. Hovering over each state on the map gives the amount of fisheries subsidies provided by each state (2018 US$) matching the selected type(s), which subsidy type(s) provided by that state match the selection, reported FAO capture production (2017, tonnes), and total estimated landed value (2018 US$).

The total magnitude of fisheries subsidies provided by each state came from data obtained directly from Rashid Sumaila on April 16, 2019. Fisheries subsidies are classified into thirteen categories which are the same as those defined by Sumaila et al. (2010).

Total reported capture production was calculated by summing production of all species groups included in the FAO global production database for each state. Both freshwater and marine capture production are included, however, production from aquaculture (freshwater, brackish, and marine) is not. Additionally, only capture production of species reported in tonnes is included. We used data from 2017, as this was the most recent year for which data was available as of May 16, 2019. We assume that reported landings for 2017 are representative of those for 2018 as more recent estimates of catches are not available.

We estimated total landed value for each state in 2018 US$ by combining the capture production data from the FAO with the database of ex-vessel prices from Melnychuk et al. (2017). Since this database of ex-vessel prices only goes through 2012, we extrapolated ex-vessel prices in 2012 to 2018 US$ using the Consumer Price Index (CPI). We aggregated the price data by year and ASFIS species classification, giving ex-vessel price estimates for 1947 unique species (or groups of species) from 45 ISSCAAP groups. Of those, 158 ASFIS species (from 10 ISSCAAP groups) did not have ex-vessel prices, and we therefore assumed a price of zero – these include aquatic plants and algae (seaweeds), corals, aquatic mammals, sponges, pearls/mother-of-pearl/shells, and some demersal fishes.

We matched the FAO global capture production data (aggregated by year, state, and ASFIS species classification) to the database of ex-vessel prices by ASFIS species. For landings of species (or species groups) reported in the FAO dataset, but not in the ex-vessel price database, Melnychuk et al. (2017) provide the ISSCAAP group for which to use the average ex-vessel price instead. There were 38 ASFIS species (from 6 ISSCAAP groups) in the 2017 landings data for which we could not match ex-vessel price. All of these entries cooresponded to aquatic mammals, turtles, crocodiles/alligators, and frogs/other amphibians, and we assumed these entries to have an ex-vessel price equal to zero. Total landed value was then calculated as the product of landings (in tonnes) and ex-vessel price (2018 US$/ton) for each ASFIS species group, summed by state.

Only the states included in Rashid Sumaila's database of fisheries subsidies are shown on this tab.

View fishery profiles by state

Building on the global summary statistics presented in the previous section, this tab allows the user to explore fisheries data by state in greater detail. Once a state is selected, the user is able to view estimates of fisheries subsidies from Sumaila et al. (unpublished) and from the OECD FSE database (if available), annual capture fisheries production from the FAO by species group, and demographic statistics from the World Bank WDI database.

In the first section, a bar plot shows the total magnitude of fisheries subsidies (2018 US$) by type provided by each state as estimated by Sumaila et al. (unpublished). As with the map on the previous tab, subsidy types are classified and colored based on the thirteen subsidy categories defined by Sumaila et al. (2010). Hovering over each subsidy type displayed on this plot also shows whether each estimate came from reported data, or was modeled (see Sumaila et al. (2016) for more information on the modeling process).

For OECD members (and selected non-members), estimates of fisheries subsidies from the FSE database are also shown on this bar plot, classified and colored according to a different classification system. OECD FSE estimates for each state are shown for the most recent year for which data was available from the database.

In the second section, annual capture production by ISSCAAP species group as reported in the FAO global production database for the selected state is shown (2000 – 2017, tonnes). Both freshwater and marine capture production are included, however, production from aquaculture (freshwater, brackish, and marine) is not. Additionally, only capture production of species reported in tonnes is shown.

In the final section, GDP (current US$) and total population from the World Bank WDI database for the selected state are shown (2000 – 2018). The World Bank WDI database also estimates the value added to GDP from forestry, agriculture, and fisheries, and this is shown alongside total GDP for comparison. Estimates of the total number of fishers from the FAO Yearbook of fishery and aquaculture statistics is shown alongside total population for comparison (if available). An estimate of the full-time equivalent jobs in the marine capture fisheries sector from Teh and Sumaila (2011) is also shown if available (2003).

As with the previous tab, only the states for which fisheries subsides estimates are available from Sumaila et al. (unpublished) are selectable on this tab.

Compare fishery statistics

This tab allows the user to compare some of the fishery statistics presented on the previous tab across states using interactive bar plots. Once a state is selected, the user is able to select from the following statistics: 1) total magnitude of fisheries subsidies (2018 US$) by type, 2) total reported capture production (2017, tonnes), 3) total estimated landed value (2018 US$), 4) fisheries subsidies per landed ton (2018 US$/tonne), 5) the ratio of fisheries subsidies to landed value, 6) fisheries subsidies per capita, and 7) ratio of fisheries subsidies to total GDP, and 8) fisheries subsidies per person employed in marine capture production (2018 US$/person). For each statistic, values for the selected state are shown alongside those for other states. The user is able to select whether they would like to compare the selected state to the 10 other states with the largest values for that statistic, or to up to 10 other states of their choosing. Hovering over each bar (or segment of a bar) provides the numerical values shown on the plot.

As with previous tabs, the total magnitude of fisheries subsidies (2018 US$) by type provided by each state are classified and colored based on the thirteen subsidy categories defined by Sumaila et al. (2010).

The methods for calculating total reported capture production and estimated landed value are the same as those described in the previous section.

Fisheries subsidies per landed ton (2018 US$/tonne) was calculated by dividing the total magnitude of subsidies (by type) for each state by the total magnitude its reported capture production. Similarly, the ratio of fisheries subsidies to landed value was calculated by dividing the total magnitude of subsidies (by type) for each state by the total estimated landed value of its catch. Fisheries subsidies per capita (2018 US$/person) was calculated by dividing the total magnitude of subsidies (by type) for each state by the estimate of that state's total population obtained from the World Bank WDI database. Of the states for which estimates of fisheries subsidies were available, population data was not available from the WDI database for Eritrea and Chinese Taipei so this statistic is not available for these two states. The ratio of fisheries subsidies to total GDP was calculated by dividing the total magnitude of subsidies (by type) for each state by the estimate of that state's total GDP obtained from the World Bank WDI database. GDP data was not available from the WDI database for Eritrea, Monaco, North Korea, Syria, Chinese Taipei, and Venezuela, so this statistic is not available for those six states. Demographic data is not available for many states for 2018, so data from 2017 was used for all states for consistency. Finally, fisheries subsidies per person employed in marine capture fisheries (2018 US$/person) was calculated by dividing the total magnitude of subsidies (by type) for each state by the estimated number of full-time equivalent workers in the marine capture fisheries sector from Teh and Sumaila (2011).

As with the previous tabs, only the states for which fisheries subsides estimates are available from Sumaila et al. (unpublished) are able to be compared on this tab.

Global fishing footprint

This tab allows the user to explore the global distribution of fishing effort included in the GFW dataset in 2018. Unlike the previous two tabs, the data presented on this tab does not only represent states for which fisheries subsidies estimates are available.

GFW assigns each vessel in its database with an identification number based on its AIS transciever, and has compiled a list of all unique vessels represented in the dataset. For each vessel, a number of characterisitics are assigned based on the following: 1) information recorded on official vessel registry lists, 2) information broadcast by the vessel, and 3) predictions made by machine learning models based on the vessel's behavior. If vessel characterisics are avilable from multiple sources, GFW makes a determination of the "best" characteristics for each vessel. These characteristics are reassigned each year for which a vessel is actively broadcasting its position with AIS.

We extracted all vessel information data for 2018, and removed all entries for vessels which GFW does not consider to be fishing vessels (e.g. research vessels, passenger vessels, cargo ships, etc.). We then extracted the following characteristics for all 82,929 fishing vessels in the GFW database that were active in 2018:

- unique vessel identification number;
- flag state of the vessel;
- vessel type;
- vessel length (m);
- vessel tonnage (gross tonnes);
- engine power (kW);
- ship name broadcast by the vessel;
- ship call sign broadcast by the vessel.

Of the 82,929 vessels on our list, we were unable to determine the flag state of 707 vessels. Vessel class, length, tonnage, and engine power were able to be determined for all vessels. There are 202 different flag states represented in the data for 2018.

Though we are only using 2018 GFW data for this analysis, we wanted to verify that vessel characteristics have remained relatively consistent throughout the past. 82,613 of the fishing vessels in our list had the same flag, class, length, tonnage, and engine power across all years for which they were present in the GFW data between 2014 - 2018. The only discrepancy in characteristics for the other 316 vessels was that they all had been flagged to both China and Chinese Taipei at some point. We therefore used the most recently reported flag for these vessels.

We then extracted the number of hours spent fishing by each of these vessels in different EEZs. Each AIS transmission included in the GFW data set is denoted by a numeric code representing the EEZ to which the location of the transmission corresponds. Transmissions made on the high seas were instead given a code corresponding to the relevant FAO statistical area. We matched each EEZ code to the ISO code of the administering state or territory. The following information was collected for each fishing vessel for 2018:

- total hours spent fishing;
- total hours spent outside of port;
- total hours that the AIS was transmitting;
- ISO three-letter code for the administering state or territory of each EEZ in which the vessel fished;
- ISO three-letter code for the sovereign state of each EEZ in which the vessel fished;
- total hours spent fishing in each EEZ;
- FAO region code for the high seas areas in which the vessel fished;
- total hours spent fishing in each FAO region of the high seas;

For the purposes of visualizing the global distribution of fishing effort, fishing effort was aggregated by EEZ (or FAO statistical region for effort on the high seas). Fishing effort is represented in kilo-watt hours (kWh), which is obtained by multiplying the engine capacity of the vessel (kW) by the number of hours it spent fishing. This metric of fishing effort is used in order to better compare fishing effort across gear types. Hovering over each EEZ or FAO statistical region on the map also provides information on the sovereignty of that location, as well as the total number of vessels that identified as fishing in that region in 2018, the total fishing effort expended by those vessels (hours and kWh), and the number of unique flag states that those vessels represent.

It is difficult to discern the actual percentage of global fishing effort captured by this map, because there is great uncertainty regarding the total number of active fishing vessels in the world, let alone the total amount of fishing effort globally. As it only includes fishing vessels with AIS systems onboard, GFW does not capture all global fishing effort. The International Maritime Organization (IMO) requires all vessels greater than 300 tons traveling in international waters to have AIS, though certain countries also require smaller vessels to carry them as well. As previously mentioned, Kroodsma et al. (2018) estimated that in 2016 the number of vessels with AIS comprised approximately 56% of all vessels larger than 24 m, 9% of vessels 12-24 m, and only 0.2% of vessels under 12 m. They also estimated that vessels with AIS likely contributed between 26% - 34% of the global fishing effort (kWh expended) of all vessels in the world, with that value increasing to 50% - 70% for all vessels fishing more than 100 nautical miles from shore (halfway to the EEZ boundary).

The number of vessels with AIS has been increasing exponentially since 2016, so it likely that this map (2018) represents more than 34% of global fishing effort of all vessels in the world, and more than 70% of fishing effort for vessels fishing more than 100 nautical miles from shore. For this reason, we consider this map to represent the majority of industrial fishing worldwide, but assume that small-scale or artisanal fishing effort is not captured.

Reforming fisheries subsidies

The purpose of the second section is to allow users to think about the magnitude and distribution of possible effects of fisheries subsidies reforms.

Data sources

In addition to the data sources discussed in the previous section, this portion of the analysis also utilized data from the following sources:

- the Combined IUU Fishing Vessel List;
- the RAM Legacy stock assessment database (RAMLDB);
- the RAM Legacy stock boundary database created by Free et al. (2019);
- the stock status database created by Costello et al. (2016).

<u>*Combined IUU Fishing Vessel List*</u>

Most regional fisheries management organizations (RFMOs) maintain their own lists of vessels that have been found to carry out or support IUU fishing. The Combined IUU Fishing Vessel List was created by Trygg Mat Tracking (TMT), a Norwegian non-profit, to consolidate all of the different RFMO IUU lists into one. This dataset can be downloaded directly as an Excel file (https://iuu-vessels.org/Home/Download). The data used in this analysis was last downloaded on January 22, 2019.

RAM Legacy Stock Assessment Database (RAMLDB)

The RAM Legacy Stock Assessment Database (RAMLDB) is a compliation of stock assessment results for commercially exploited fish stocks around the world. These assessments come from Australia, New Zealand, Canada, the United States, Peru, South Africa, Russia, Argentina, Japan, the European Union (EU), and RFMOs covering multinational tuna and billfish stocks. The version of the databse used in this assessment is 4.44, released on December 22, 2018.

RAM Legacy Stock Boundary Database - Free et al. (2019)

Each of the fish stocks represented in the RAMLDB was delimited by the organization that performed the assessment, meaning that the spatial extents of these stocks vary. Chris Free created an accompanying database to the RAMLDB containing the spatial boundaries of each stock (Free et al., 2019).

Stock status database - Costello et al. (2016)

The majority of global fish stocks are not assessed with formal stock assessments, and are instead managed using a variety of data-limited methods or unassessed. No global database exists with the results of these data-limited methods of estimating the status of a fisheries for which formal stocks assessments have not been conducted. Costello et al. (2016) provide estimates of the status of 4,316 fisheries (defined by species-state-FAO region triples) not included in the RAM database.

Select a policy

This tab allows the user to select which disciplines should be included as part of the subsidy reform policy to be modeled. Selection of a subsidy refom proposal on this tab informs the results displayed on all subsequent tabs by defining the size and composition of the fleets for the bieconomic projection model. Once a policy is selected, the percentage of global industrial fishing effort (from GFW) that would likely to be targeted by that policy is identified. The user is able to select from subsidy disciplines based on the provisions included in the original nine proposals submitted to the WTO as well as new ideas that have come up over the course of the negotiations. Potential disciplines are grouped into four categories: subsidies contributing to IUU fishing, subsidies to fishing on overfished or unassessed stocks, subsidies contributing to overcapacity and overfishing, and total subsidy caps (based on a tiered system). Within each category, there may be alternative ways in which a discipline could be defined, changing the scope of which vessels would be likely to be targeted by the proposal. Therefore, there can be multiple disciplines listed within each category.

Illegal, unreported, and unregulated (IUU) fishing

Starting with subsidies contributing to IUU fishing, we include four possible subsidy disciplines:

> **IUU #1**: Subsidies for fishing shall be prohibited to any vessel currently listed as having engaged in IUU fishing activities by a RFMO or other international agreement.
>
> **IUU #2**: Subsidies for fishing shall be prohibited to any vessel currently listed as having engaged in IUU fishing activities by the coastal state.
>
> **IUU #3**: Subsidies for fishing shall be prohibited to any vessel currently listed as having engaged in IUU fishing activities by the flag state.
>
> **IUU #4**: Subsidies for fishing shall be prohibited to any vessel currently listed as having engaged in IUU fishing activities by the subsidizing Member state.

For the first discipline, there are nine RFMOs and Agreements that currently maintain IUU lists, though there is a great deal of overlap between these lists with many vessels appearing on multiple lists. Interpol can also issue Purple Notices to request or provide information regarding fishing vessels that are wanted for illegal activities. The Combined IUU Fishing Vessel List has consolidated these lists into one location that is updated regularly, so we manually matched vessel characteristics (vessel name, flag, length, tonnage, AIS identification number, call sign) from this list to GFW in order to identify which vessels would be likely to be targeted by this discipline.

For the second, third, and forth disciplines, no data currently exists on a global scale to identify vessels listed as having engaged in IUU fishing activities by a coastal state, flag state, or subsidizing Member state. Very few states maintain their own IUU lists (only the EU, United States, and Norway), and the very small number of vessels on these lists also appear on RFMO lists. Therefore, only selecting one of these three options will not returning any matching vessels at present.

Even though state IUU lists are extremely limited today, there is reason to believe that adoption of IUU disciplines by the WTO could incentivize more states to maintain and enforce such lists in the future. As a way of thinking about the effects that an IUU discipline could have if more coastal, flag, or subsidizing Member states started maintaining and enforcing their own IUU lists, we offer users the option of making their own assumption about the amount of IUU fishing currently occurring worldwide. This assumption is meant to simulate the % of fishing that could someday be identified and disciplined by state IUU lists.

If the user chooses to make an assumption about the percentage of total fishing effort that is IUU worldwide, we assume that the selected percentage of fishing effort from GFW for each flag state is IUU for the purposes of the bioeconomic projection model.

Vessels triggering IUU disciplines are assumed to lose all of their subsidies.

Overfished and unassessed stocks

For subsidies to fishing overfished or unassessed stocks, we include two possible subsidy disciplines:

> **OA #1**: Subsidies for fishing shall be prohibited if the fish stock is considered to be overfished (B/Bmsy < 0.8) as determined by the most recent stock assessment in the RAM Legacy Stock Assessment database.

OA #2: Subsidies for fishing shall be prohibited if the fish stock is considered to be overfished (B/Bmsy < 0.8) as determined by the data-limited assessment done by Costello et al. (2016).

For the first discipline, the RAMLDB includes status information on approximately 400 fisheries (representing approximately 30-40% of global catches). To identify vessels likely to be targeted by this discipline, we overlaid the spatial extent of each stock (from the RAM Legacy Stock Boundary database created by Christopher Free) with the fishing activity of each vessel in GFW.

For the second discipline, we used the stock status database created by Costello et al. (2016) to obtain an estimate of stock status for fisheries not included in the RAMLD. For each fishery (species-state-FAO region), we identified vessels in GFW from that state that fished in that region. The average status of all stocks for that state-FAO region pairing was determined, and if overfished, matching vessels were considered to be targeted by this discipline.

Vessels triggering overfished and unassessed stock disciplines are assumed to lose all of their subsidies.

Subsidies contributing to overcapacity and overfishing

For subsidies contributing to overcapacity and overfishing, we include seven possible subsidy disciplines based on the subsidy types used by Sumaila et al. (2016):

CE #1: Boat construction, renewal and modernization programs

CE #2: Fishery development projects and support services

CE #3: Fishing port construction and renovation programs

CE #4: Price and marketing support, processing and storage infrastructure programs

CE #5: Non-fuel tax exemptions

CE #6: Foreign access agreements

CE #7: Fuel subsidies

For each discipline, we identified vessels in GFW from flag states that provided the corresponding type of subsidy (based on Rashid Sumaila's fisheries subsidies estimates) to identify vessels that would likely to trigger the discipline.

Vessels triggering overcapacity and overfishing disciplines are assumed to only lose subsidies of the corresponding type.

Scope and special and differential treatment (S&DT)

Once the user has selected one or more disciplines from each of the above categories, they are also able to select the scope of and any special and differential treatment that should apply to those disciplines.

For the purpose of scope, we allow the user to apply the selected discipline(s) from each category to vessels flagged to all Members, or only those flagged to selected Members. For subsidies to fishing on overfished and unassessed stocks and subsidies contributing to overcapacity and overfishing, the user may instead choose to only applying the selected discipline(s) from each category only to Member-flagged vessels fishing in areas beyond national jurisdiction (“high seas”), only to Member-flagged vessels fishing in the EEZs of other coastal states, or both.

No clear definition exists regarding what constitutes a “high seas” vessel, so if the selected discipline(s) should only be applied to Member-flagged vessels fishing on the high seas, different assumptions about the minimum amount of time (expressed as a percentage of each vessel’s annual fishing effort) that a vessel would need to spend fishing on the high seas to qualify can be made.

For the purposes of special and differential treatment, the user can choose to exclude certain vessels from the selected discipline(s) based on the development status of the flag state. The WTO recognizes the 47 states that are designated as least developing countries (LDCs) by the UN Committee for Development (from this list: https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/ldc_list.pdf). However, in terms of “developing” versus “developed”, the WTO allows states to self-declare their development status for each agreement. The states assumed to self-declare as “developed” are given in Table 3 – all other states that do not qualify as an LDC as identified by the UN Committee for Development are assumed to self-declare as “developing”.

Table 3. WTO Member states assumed to self-declare development status as “developed” (2018).

State
Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Japan
Latvia
Lithuania
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Slovenia
Spain
Sweden
Switzerland

United Kingdom
United States

Subsidy caps with a tier system

Unlike the previously discussed categories of subsidy disciplines, the final category does not come from the original nine proposals submitted to the WTO, but rather from recent proposals that have been submitted during the course of negotiations. As opposed to prohibiting subsidies based on the characteristics of who is receiving the subsidy, the fish stock on which the fishing is occurring, or the type of subsidy being provided, a cap and tier system would limit the total amount of all subsidies that a Member state would be able to provide. This approach has been proposed as an additional constraint imposed on top of any IUU or overfished stock disciplines to further restrict fisheries subsidies. A subsidy cap would set a specific monetary limit on the total amount of fisheries subsidies each member is allowed to provide. Subsidies that exceed this cap would be prohibited. A tiered approach that accommodates the differential circumstances of members can be used. Under this approach, member groups are given different caps based on rule that separates them into tiers.

In this section, the user fist makes the choice about whether to include a cap and tier system for fisheries subsidies. If “yes”, the user then must select the number of tiers into which Members should be sorted, as well as the rationale by which they would be sorted.

Then the user must determine how the subsidy caps should be set for Members in each tier. Whichever cap rule is selected will be applied equally to all Members within that tier, however if the rule is based on a percentage, this will likely result in different monetary caps for each Member.

Which states would be affected

This tab contains a global map on which flag states are colored by the percentage of fisheries subsidies provided by that state which would likely be directly targeted by the policy selections made on the previous tab.

In order to make these determinations, total reported catches from the FAO (2017), as well as subsidies (by type) from Rashid Sumaila (2018 US$) were allocated to all vessels in GFW. Catches were summed for each state and FAO region, and then allocated across all vessels in GFW flagged to that state and fishing in that region. Catches were allocated based proportionally based on the amount of fishing effort (kWh) expended by that vessel as a percentage of the total for that flag state and region. Fisheries subsidies were summed by state and then allocated across all vessels in GFW flagged to that state. Subsidies were also allocated proportionally based on the amount of fishing effort (kWh) expended by that vessel as a percentage of the total for that flag state and region.

For the purposes of the bioeconomic analysis, the characteristics of the vessels that were identified as being affected (represented in terms of their flag states on this map) are aggregated into a single fleet (“targeted”). Fishing effort, catches, and subsidies are summed for the targeted fleet.

Where fishing would be affected

This tab contains a global map on which EEZs (and FAO regions on the high seas) are colored by the percentage of fishing effort in that location that would likely be directly targeted by the policy selections made on the previous tab. Hovering over each location on the map also provides information about the sovereignty of that location, as well as the total number of vessels in GFW that fished in that region in 2018, the total fishing effort (KWh), the number of flag states from which those vessels comes, and the percentage of that effort which would be likely to be directly targeted by the selected subsidy reforms.

F For the purposes of the bioeconomic analysis, the characteristics of the vessels that were identified as being affected (represented in terms of where they fish on this map) are aggregated into a single fleet (“targeted”). Fishing effort, catches, and subsidies are summed for the targeted fleet.

Consider indirect effects

If subsidy reform is not universal, it is possible that unaffected vessels may actually end up increasing effort as a result of biomass and/or price effects. These potential rebound effects could reduce the effectiveness of a subsidy reform policy (Figure 2). Such a rebound effect could occur in response to 1) increased biomass over time resulting from decreased effort (and therefore catches) by the targeted fleet, or 2) increased fish price resulting from decreased supply from the targeted fleet, or 3) some combination of both.

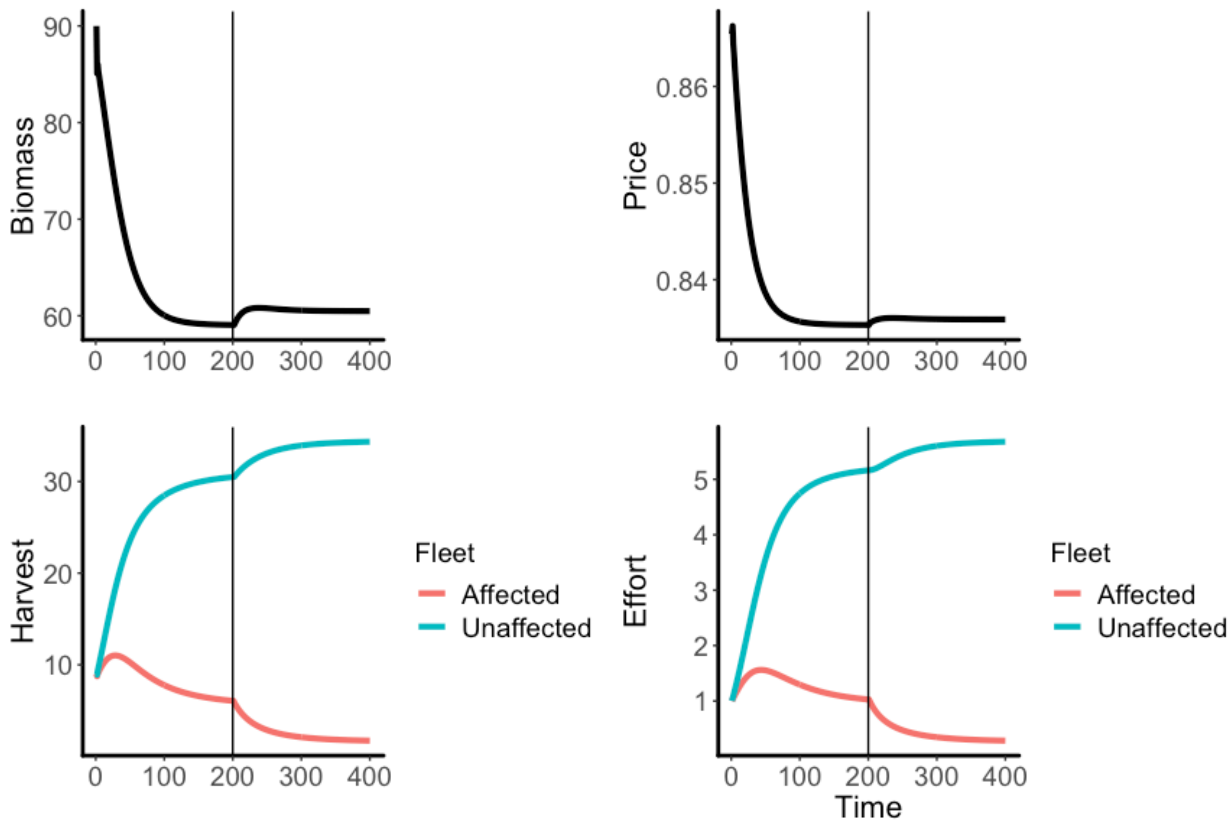

Figure 2. Hypothetical illustration of the rebound affect for a simple fishery with a single fish stock and two fleets.

On this tab, users are able to decide whether they would like to include these effects in the bioeconomic analysis. If rebound effects are allowed, users are asked to determine how this rebound fleet, capable of responding to changes biomass or price effects, would be identified. These relevant vessels could experience indirect effects of subsidy reform due to the fact that they share similar characteristics and/or geographical distributions as the affected vessels.

If similar characteristics is chosen as the method of identifying rebound vessels, we identified all vessels in GFW that weren't likely to be directly targeted by the selected reforms, but that were in the same engine power class, length class, gross tonnage class, or gear type as vessels in the targeted fleet. If geographic proximity is chosen as the method of identifying rebound vessels, we identified all vessels in GFW that weren't directly targeted, but that fished in the same EEZs (or FAO regions on the high seas) as the targeted fleet.

If rebound effects are turned on, the global fishing effort identified on this map is aggregated into a single fleet ("indirectly affected"). Fishing effort, catches, and subsidies are summed for the indirectly affected fleet.

Modeling future impacts

This tab alows the user to explore potential effects of the selected subsidy reform policy using a bioeconomic projection model. This model forecasts the trajectory of a global aggregate fishery: A simple biological model forecasts how the current global biomass will change based on how the selected subsidy reform policy would affect the current fishing mortality rate and then an economic model estimates profits based on the fish price resulting from total harvest each year.

Similar to the models used in Arnason (2007) and the "Sunken Billions" report (The World Bank & FAO, 2009) to estimate rents loss for the global marine fishery, our model assumes that global fisheries can be modeled as a single fish stock, represented by an aggregate growth function. Additionally, we assume that the global fishing industry can be represented by two discrete fishing "fleets", one affected by the subsidy reform policies ("targeted"), and the other not ("indirectly affected"). The relative sizes of the two fleets vary depending on the selected policy (see previous sections).

In its simplest form, the primary variables in the model are biomass, b, harvest, h, fishing effort, e, landing price p, costs, c, and profits, π. Global biomass is calculated based on a growth function (that depends on past biomass) and harvest:

$$b = G(b) - h$$

Harvest is calculated as a function of biomass and fishing effort:

$$h = Y(b, e)$$

Fish price is calculated as a function of harvest:

$$p = D(h)$$

Fishing costs are calculated as a function of fishing effort:

$$c = C(e)$$

Fishery profits are calculated as a function of fish price, harvest, and costs:

$$\pi = P(p, h, c)$$

Within this model, there are five main functions: the biomass growth function, $G(b)$, the harvest function, $Y(b, e)$, the demand function, $D(h)$, the cost function, $C(e)$, and the profit function, $P(p, h, c)$.

Biomass growth: For our biomass growth function, $G(b)$, we use a form of the basic logistic surplus production model commonly referred to as the Pella-Tomlinson Model. With discrete units of time (hereafter years for the purposes of our model), biomass in the next year, b_{t+1}, is given by:

$$b_{t+1} = b_t + \frac{\phi + 1}{\phi} r b_t (1 - (\frac{b_t}{K})^{\phi}) - h_t$$

where ϕ is the Pella-Tomlinson parameter that allows for asymmetry in the production curve, r characterizes the intrinsic growth rate of the global stock, K is the carrying capacity (maximum population size for growth to be positive), and h_t is the total harvest in that year across all fleets.

Harvest: Our harvest function, $Y(b, e)$, is really the sum of the individual harvest functions for our two fleets. For both the fleets affected and unaffected by the subsidy reform policies, harvest for fleet j in a given year, $h_{j,t}$, is represented by:

$$h_{j,t} = q_j b_t e_{j,t}$$

where q_j is a fleet specific catchability parameter, and $e_{j,t}$ is the fishing effort expended by that fleet that year. We estimate catchability directly for both fleets based on 2018 data by calculating q_j as follows:

$$q_j = \frac{h_{j,2018}}{b_{2018} * e_{j,2018}}$$

The total harvest is therefore the sum of harvests across both fleets:

$$h_t = \sum_{i=1}^{j} h_{j,t}$$

Global fish demand: In order to allow the price of fish to change as a function of harvest, we introduce a demand function, $D(h)$, for fish, and we assume it is downward-sloping. Total harvest in a given year, h_t, gives rise to fish price, p_t, through the constant elasticity of demand function:

$$p_t = (\frac{1}{\delta})^{1/\epsilon} h_t^{1/\epsilon}$$

where ϵ is the constant elasticity of demand, and δ is a constant. We calculate the parameter δ using data from 2012 as follows:

$$\delta = \frac{h_{2012}}{(p_{2012})^{\epsilon}}$$

Costs: Our cost function, $C(e)$, assumes that each fleet's total costs ($c_{j,t}$) are a function of fishing effort in that time step ($e_{j,t}$) and a fleet-specific cost coefficient (α_j):

$$c_{j,t} = \alpha_j e_{j,t}^{\beta}$$

where β is a scalar cost parameter that determines the shape of the cost curve (i.e. how non-linear costs are). The cost coefficient α_j for each fleet is a function of how much each unit of effort is being subsidized for that fleet $s_{j,t}$. Assuming that global fishery profits are equal to 0, we estimate the costs for each fleet directly based on 2018 data by calculating α_j as follows:

$$\alpha_j = \frac{p_{2018} h_{j,2018} + s_{j,2018} * e_{j,2018}}{(e_{j,2018})^{\beta}}$$

Profits: Fisheries profits are calculated as revenue less costs plus subsidies for each fleet, where revenue is the fish price p_t times harvest $h_{j,t}$ and costs are calculated as above. Profits for each fleet in each year, $\pi_{j,t}$, are therefore equal to:

$$\pi_{j,t} = p_t h_{j,t} - c_{j,t} + s_{j,t} e_{j,t}$$

where $s_{j,t}$ is the rate of subsidization (i.e. how much each unit of effort is being subsidized) for fleet j.

Effort in the next year, $e_{j,t+1}$, adjusts in response to profits:

$$e_{j,t+1} = \eta\pi_{j,t} + e_{j,t}$$

where η is a parameter that regulates the speed at which effort enters and exits the fishery.

Model parameterization: Many model parameters are consistant regardless of the selected subsidy reform policy, summarized in Table 1. The source and/or method of deriving each input will be discussed in more detail later. The sensitivity of our model outputs to uncertainty and alternate assumptions for certain input parameters is currently in progress and will be included in the final product.

Table 4. Bioeconomic model parameters (consistent) used in SubsidyExplorer.

Parameter	Description	Value	Units	Source(s)
Biomass				
ϕ	Pella-Tomlinson shape parameter	0.188	-	Thorson et al., 2012
r	Global biomass growth rate	0.1039	-	Costello et al., 2016
K	Global biomass carrying capacity	1.84	billion mt	Costello et al., 2016
Price				
ϵ	Price flexibility or elasticity of demand	-1.15	-	Costello et al., 2016
δ	Price coefficient	353.15e9	-	See calculation above under “Global fish demand”
Costs				
β	Cost linearity parameter	1.3	-	Costello et al., 2016
η	Effort dampening parameter	0.1	-	Costello et al., 2016

Other parameters depend on the relative sizes of the “targeted” and “indirectly affected” fleets, and therefore vary based on the selected subsidy reform policy. These parameters, summarized in Table 2, are re-estimated or calculated before each model run.

Table 5. Bioeconomic model parameters (input dependent) used in SubsidyExplorer.

Parameter	Description	Method
Biomass		
b_{2018}	Biomass in the base year	K is scaled by the percent of global effort represented by the two fleets
Harvest		
$e_{a,2018}$	Fishing effort in the base year (affected fleet)	Effort from GFW is summed for all vessels in the affected fleet
$h_{a,2018}$	Harvest in the base year (affected fleet)	Catches from FAO allocated across all vessels in GFW based on flag and relative fishing energy, summed for all vessels in the affected fleet
q_a	Catchability (affected fleet)	See calculation above under “Harvest”
$e_{u,2018}$	Fishing effort in the base year (unaffected fleet)	Effort from GFW is summed for all vessels in the unaffected fleet

$h_{a,2018}$	Harvest in the base year (unaffected fleet)	Catches from FAO allocated across all vessels in GFW based on flag and relative fishing energy, summed for all vessels in the unaffected fleet
q_u	Catchability (affected fleet)	See calculation above under "Harvest"
Costs		
α_u	Cost coefficient (affected fleet)	See calculation above under "Costs"
α_a	Cost coefficient (unaffected fleet)	See calculation above under "Costs"

Model results shown on this tab represent the percent change in stock biomass, fish catches, and fishery revenue relative to a "business as usual" scenario in which fisheries subsidies remain the same. The end year of the simulation is set at 2100 by default, but can be changed by the user.

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