Contributions of marine capture fisheries to the domestic livelihoods and seafood consumption of Brazil Chile and Peru

Draft report prepared for Oceana

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Project Goal and Objectives

- Determine the contribution of specific fisheries to domestic fish consumption and domestic livelihoods throughout Brazil, Chile, and Peru.
- Critical analysis highlighting important capture fisheries for domestic food security, in the context of vulnerable populations and regions.
- Determine most important capture fisheries for food provision, and domestic seafood consumption patterns through time and space.
- Determine most important capture fisheries and fisheries sectors for regional employment and income.
- Determine most important capture fisheries and fisheries sectors for domestic catch and landed value.

Executive Summary

Latin America is a highly diverse and dynamic region and there are many contexts to seafood production, as reflected in the countries included in this report, Brazil, Chile, and Peru. Nevertheless, there are several cross-cutting themes in these countries, and very likely throughout the Latin American region. Actions to address current issues in seafood production and food security include improved clarity in marine resource policies, transparency in data sharing and collection strategies, institutional accountability, and recognition and meaningful inclusion of all stakeholders. These actions, aside from necessary support for operational aspects of resource management, are vital for establishing ecologically sustainable and socially equitable seafood production systems that meet food security needs and provide economic and social benefits at local and national scales.

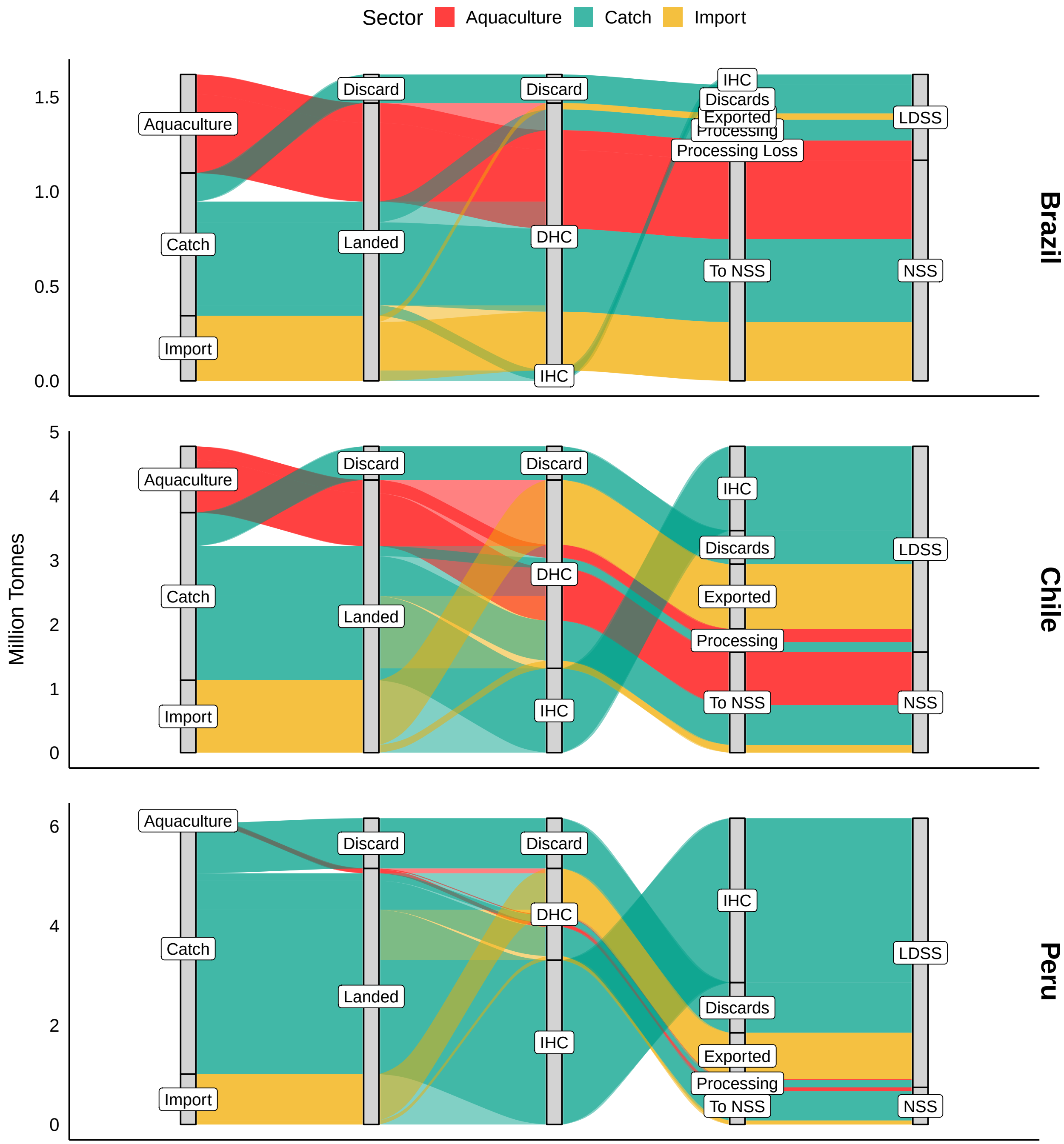
Chile is one of the largest producers of seafood in the world and is currently a net exporter of seafood. Available data reflects a clear distinction between seafood production for domestic consumption (e.g., squids, hakes) sourced largely from the artisanal sector, and production of high-value exports through aquaculture and the industrial sector (e.g., salmons, mussels, mackerels). There is also a high consumption of canned tuna in the country, though this is mainly sourced from imports. As is common throughout Latin America, the industrial fishing sector in Chile is very important in a few key regions where processing plants are based, but artisanal fisheries are more widespread throughout the country and generate more employment, almost 90 thousand jobs compared with 3,500 in the industrial sector. Resource management and monitoring programs in Chile are relatively advanced compared with other countries in the region, though the complexity of seafood production and trade in Chile require much more coordination and standardization between various institutions to facilitate nationwide analyses.

Peru is clearly ahead of the curve when it comes to seafood production data collection and dissemination, with detailed information available on production, trade, and value chains. Without diminishing these advances in national fisheries and aquaculture data collection systems, it must be noted that transparency in methods of said collection must be improved to increase the reliability and usability of such data in support of sustainable management of fisheries and aquaculture. Peruvian anchoveta is one of the largest and most well-known fisheries in the world, though it is overwhelmingly reduced and exported as fish meal and oil. Hence, the most important fisheries for domestic food security in Peru are mackerels and hake. Available data suggests there are over 217 thousand total seafood-related jobs in the Peruvian economy, particularly artisanal fishers (67 thousand) and in the processing sector (136 thousand), contributing 4% to Peru's GDP.

Brazil is a particularly challenging nation regarding research into seafood production dynamics, notably due to a lack of nation-wide fisheries data collection since 2008. Nevertheless, data do exist and an extensive review revealed overarching trends in seafood production and consumption, highlighting the importance of the artisanal fishing sector for generating between 500 thousand and 1 million direct jobs throughout the country and furthermore contributing over half of all landings for domestic food consumption. Sardines are important for food security in Brazil, though hundreds of largely-unmonitored species make up artisanal catches that are vital for regional food security, particularly in the northern marine coastal regions, and in the Amazon basin where per capita seafood consumption is among the highest in the world (>160 kg/year). Sardines, and lobster and croakers are particularly important as a source of income for industrial and artisanal fisheries, respectively. Despite observed declines in catch throughout the country, fish consumption has traditionally been important in the north and northeast of Brazil and other regions have recently increased their demand for seafood, incentivizing marine and freshwater aquaculture production (e.g., tilapia, tambaqui); Brazil has furthermore become a net importer of seafood (e.g., salmons, Alaska pollock). Aside from a clear and urgent need for local and nationwide monitoring and data collection, a key next step for Brazil would be the creation of a new fisheries law to clarify institutional duties, establish seafood production policies, and recognize priority issues and sectors.

Data by itself cannot adequately portray the diversity and complex social and ecological dynamics of seafood production and consumption, particularly given the rich and sometimes fraught histories of Latin American countries. Artisanal and industrial fisheries, aquaculture, trade, and traditions of seafood consumption in Brazil, Chile, and Peru, have evolved and prevailed through colonial and post-colonial times, dictatorships, globalization, and continuing environmental pressures and climate change. This report offers a critical

analysis of available information regarding the production and consumption of seafood in these three countries. Developing strategies to address specific challenges and to leverage opportunities for actions will require further collection and assessment of data, and most importantly a deep understanding of local and national social contexts.



Production flow of seafood in Brazil, Chile, and Peru. NSS = Net Seafood Supply, seafood produced in the country or imported and consumed domestically. LDSS = Losses to Domestic Seafood Supply, seafood produced in the country and lost to discards and processing, exported or not for human consumption. Average (2010-2016). Dataset: FAO.

Resumen Ejecutivo

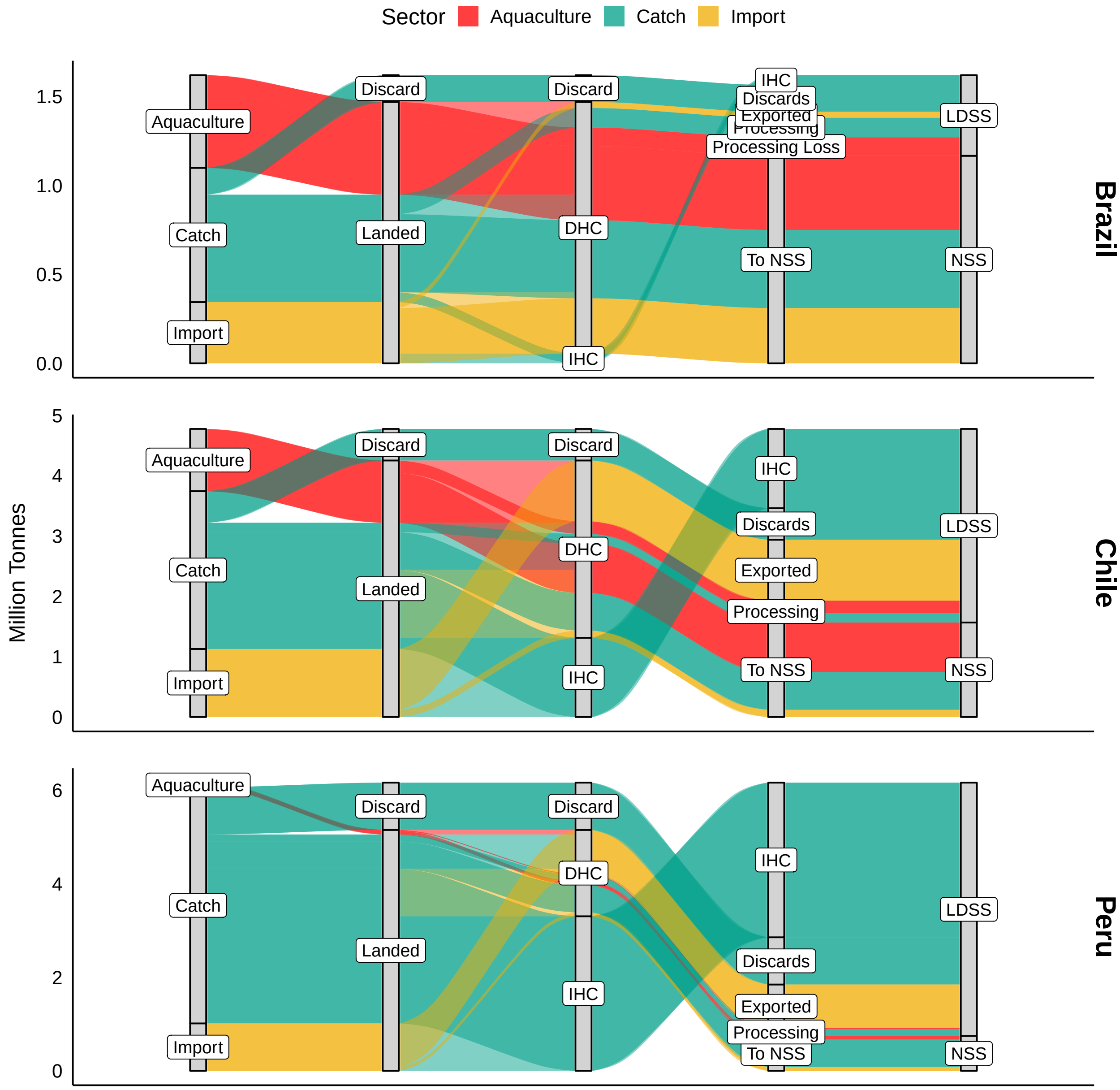
América Latina es una región altamente diversa y dinámica y existen muchos contextos en torno a la producción de mariscos, lo cuál se ve reflejado en los países incluidos en este reporte, Brasil, Chile y Perú. Sin embargo, hay varios temas compartidos en estos países, y muy probablemente a lo largo de la región Latinoamericana. Las acciones para abordar algunos temas actuales en la producción de mariscos y seguridad alimentaria incluyen mejor claridad en las políticas de recursos marinos, transparencia en las estrategias de recolección y diseminación de datos, responsabilidad institucional, y reconocimiento e inclusión adecuada de todos los involucrados en la actividad. Estas acciones, además de la necesidad de apoyo a los aspectos operativos del manejo de recursos, son esenciales para establecer sistemas de producción de mariscos que sean ecológicamente sostenibles y socialmente equitativos y que pueden aportar a las necesidades de seguridad alimentaria y proveer beneficios económicos y sociales a escalas locales y nacionales.

Chile es uno de los productores más grandes de mariscos en el mundo y actualmente es un exportador neto. Los datos disponibles reflejan una clara distinción entre la producción de mariscos para consumo doméstico (e.g., calamares, merluzas) provenientes en su mayoría del sector artesanal, y producción de exportaciones de alto valor mediante la acuacultura y pesca industrial (e.g., salmones, mejillones, macarelas). También hay un alto consumo nacional de atún enlatado, aunque ello proviene principalmente de importaciones. Como es común en Latinoamérica, la pesca industrial en Chile es muy importante en algunas regiones clave donde están situadas las plantas procesadoras, pero la pesca artesanal está distribuida más ampliamente en el país y genera más empleo, unas 90 mil personas comparado con 3,500 en el sector industrial. Los programas de manejo de recursos y monitoreo en Chile son relativamente avanzados comparados con otros países en la región, aunque la complejidad de la producción y comercialización de mariscos en Chile requiere de más coordinación y estandarización entre instituciones para facilitar los análisis a nivel nacional.

Perú claramente lleva la delantera en cuanto a recopilación y diseminación de información acerca de la producción de mariscos, con datos detallados disponibles acerca de la producción, comercialización y cadenas de valor. Sin hacer menos estos avances en los sistemas de recopilación de datos de pesca y acuacultura, cabe mencionarse que debe mejorarse la transparencia en los métodos de dicha recopilación para incrementar la certidumbre y utilidad de estos datos para apoyar al manejo sostenible de la pesca y acuacultura. La anchoveta en Perú es una de las pesquerías más grandes y mejor conocidas del mundo, aunque en su gran mayoría se reduce para exportarse como aceite y harina de pescado. Luego entonces, las pesquerías más importantes para la seguridad alimentaria en Perú son las macarelas y merluzas. Los datos disponibles indican que hay más de 217 mil empleos relacionados con la producción de mariscos en la economía Peruana, particularmente pescadores artesanales (67 mil) y en el sector de procesamiento (136 mil), contribuyendo un 4% del PIB de Perú.

Brasil representa un reto particular en cuanto a la investigación de las dinámicas de producción de mariscos, notablemente debido a la falta de recopilación de datos nacionales de pesca desde el 2008. Sin embargo, existen datos y una revisión extensa reveló tendencias generales en la producción y consumo de mariscos, resaltando la importancia del sector pesquero artesanal al generar entre 500 mil y 1 millón de empleos directos a lo largo del país, además de contribuir más de la mitad de toda la producción pesquera para consumo doméstico. Las sardinas son importantes para la seguridad alimentaria en Brasil, aunque hay cientos de especies en su mayoría no monitoreadas las que conforman la captura artesanal que es esencial para la seguridad alimentaria regional, particularmente en las regiones marinas costeras del norte, y en la cuenca del Amazonas donde el consumo de mariscos per capita es de los más altos del mundo (>160 kg/año). Las sardinas, y la langosta y curvinas son particularmente importantes como fuente de ingresos para las pesca industrial y artesanal, respectivamente. A pesar de la disminución observada en capturas a lo largo del país, hay una importante tradición de consumo de mariscos en las regiones norte y noreste de Brasil y otras regiones han venido incrementando su demanda de mariscos, incentivando la producción acuícola marina y de agua dulce (e.g., tilapia y tambaqui); Brasil además se ha convertido en importador neto de mariscos. Además de una clara y urgente necesidad de monitoreo y recopilación de datos a nivel local y nacional, un paso clave para Brasil sería la creación de una nueva ley nacional para aclarar responsabilidades institucionales, establecer políticas de producción de mariscos y reconocer retos y sectores prioritarios.

Los datos por si mismos no pueden reflejar adecuadamente a la diversidad y complejas dinámicas sociales y ecológicas de la producción y consumo de mariscos, particularmente dadas las ricas y a veces difíciles historias de los países de América Latina. La pesca artesanal e industrial, acuacultura, comercialización y tradiciones de consumo de mariscos en Brasil, Chile y Perú han evolucionado y se han mantenido durante tiempos coloniales y poscoloniales, dictaduras, globalización, presiones ambientales continuas y cambio climático. Este reporte ofrece un análisis crítico de la información disponible respecto a la producción y consumo de mariscos en estos tres países. El desarrollo de estrategias para abordar retos específicos y aprovechar oportunidades para tomar acciones requiere de más recopilación y evaluación de datos, pero sobre todo de un conocimiento profundo de los contextos sociales locales y nacionales.



Flujo de producción de mariscos en Brasil, Chile y Perú. NSS = Aporte Nacional de Mariscos, los mariscos producidos en el país o importados para su consumo local. LDSS = Pérdidas al consumo doméstico de mariscos, mariscos producidos en el país y perdidos en procesamiento, exportados o no destinados a consumo humano. Promedio de 2010-2016. Datos: FAO.

Background

Latin American nations include some of the world's most important producers of seafood from capture fisheries and aquaculture and, with a high (51%) proportion of net seafood production traded locally (FAO 2018), domestic fisheries remain highly important for national food security across the region. The UN Food and Agriculture Organization (FAO) estimates that Latin American countries consumed around 6.2 million tonnes of fish in 2015, averaging a per capita food fish consumption of 9.8 kg/year (FAO 2018). The contribution of fisheries to food security and livelihoods is particularly pertinent given the adoption of the UN Sustainable Development Goals (SDGs) (United Nations 2018), where adequate management of marine fisheries can be directly linked to the achievement of goals related to decreasing hunger and poverty throughout the world (Singh et al. 2017). There has been a further increase in attention to global capture fisheries due to the ongoing World Trade Organization (WTO) negotiations on fishery subsidies disciplines (WTO 2018), as these are partially intended to avoid trade and operational distortions that may threaten local food security in maritime nations.

In 2016, total fish landings in Chile and Peru, two of the world's top fishing nations, averaged 8 million tonnes per year (FAO 2016b). In Peru, the seafood sector generates over US 1.7 billion per year, supporting over 200 thousand jobs. Moreover, Chile's aquaculture production is among the largest of the world1 and fish meal and salmon exports generate over US$2.2 billion per year. Despite comparatively lower catches, Brazil's fisheries sustain thousands of local families in coastal areas 5-6, and inland captures along riverine systems including the Amazon basin are among the largest in the world. Aside from seafood production volumes, fisheries in Latin America are extremely important as a source of employment and livelihoods along coastal regions, and further inland through value chains. Around 90% of all motorized fishing vessels in Latin America are part of the small-scale fisheries sector (SSF) and are under 12m length. Despite supporting 120 million people (FAO 2015), this sector is among the most marginalized groups in the region 7, despite it being critical to achieving sustainable development goals (United Nations 2018), as highlighted by the recent FAO small scale fisheries guidelines that explicitly link the sector with food security, poverty eradication, and social (FAO 2016b; FAO 2015).

Given the increasing pressures on vulnerable populations, including climate change but also rapid national and international policy and market shifts, it is imperative to highlight the critical importance of particular capture fisheries for meeting domestic seafood supply. This knowledge can help guide future policies to ensure economic development does not jeopardize health and livelihoods, either in fishing communities or at the national scale.

Methods

The objective of this project is to determine the most important species for domestic seafood consumption (regionally, as possible) produced by wild capture fisheries in Brazil, Chile, and Peru, and their relationship with local employment. Given that seafood is a widely traded commodity and that aquaculture has steadily increased market supply, meeting this objective involved using species-specific data on domestic catches, aquaculture, and seafood imports and exports to highlight the most important species and fisheries that contribute to local and national food security and livelihoods.

Analytical framework

Given the nature of fisheries data and governance systems, each of the nations considered presented unique analytic challenges (see 'Data sources'), but a consistent methodological framework (Figure 1) was used to maintain consistency in methods and comparability of results across nations.

Based on the best available data in each country, total seafood supply was estimated as the sum of per-species production of domestic catch and aquaculture (minus exports), plus the sum of species net imports. Catch statistics were separated by sectors whenever possible, including artisanal, industrial, and subsistence catches.

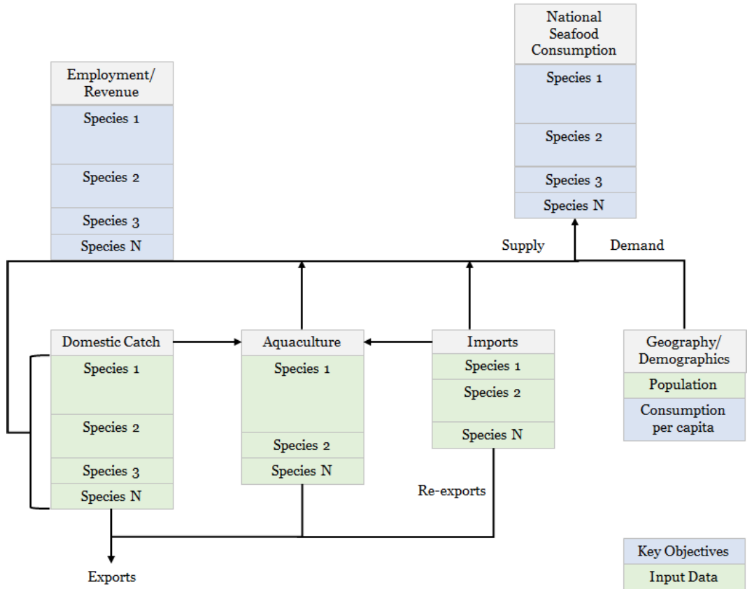


Figure 1: Methodological framework to estimate national food consumption, employment, and revenue from fisheries.

In the case of domestic catch, inputs to aquaculture are subtracted from production (similar to exports); this is particularly relevant for large industrialized fisheries for small pelagics that are almost entirely reduced into fish feeds. The distribution of consumption (demand) of this seafood supply was based on regional (as available) estimates of seafood consumption per capita and regional populations. An important additional aspect for the critical analysis portion of the project was the linking of fisheries landings with available regional socioeconomic and governance indicators, providing a basis for discussing relative vulnerabilities to potential changes in seafood supply.

The framework proposed in Figure 1 is similar to that proposed by FAO (FAO 2017), which has also been adapted and applied to specific national fisheries (Sumaila et al. 2007). We further incorporate species-specific accounting in our approach, which is challenging due to the differences in aggregation in data reporting, for example when landings are reported by species (e.g., “Whiteleg shrimp”) and trade statistics by product name (e.g., “Shrimp frozen,” “Shrimp fresh”). However, this modification is critical for identifying specific species or species groups that are important for national food security.

The following sections provide detailed methods for estimating i) net seafood supply and ii) revenues for key species in each country. This focuses on production from capture fisheries, but also includes aquaculture and trade supply. This analysis was applied across all countries using different datasets. Results will vary within countries according to the dataset (source) used.

Estimating National Seafood Supply

We followed the framework described above (Figure 1) to estimate total seafood supply. The model included fish production from for wild (marine) domestic catch, farmed fish, and trade. (Unless otherwise noted, ‘fish’ is used here to refer to all marine organisms.) In addition, estimations accounted for discards at sea and biomass losses due to processing (Table 1).

The model first estimated the total domestic catch of fish supply per species (i) from wild captures and aquaculture as follows:

Table 1: Description of variables used to estimate the national seaffod supply.

Symbol	Description
C	Fish catch, i.e., wild capture production.
A	Aquaculture production.
I	Fish imports.
E	Fish exports.
D	Rate of losses () from discards (D) at sea.
O	Rate of losses from other uses (O), i.e., not for human consumption.
P	Rate of losses from processing (P), i.e., during canning, filleting, etc.
L	Landings from wild capture production (catch minus discards).
TDFS	Total domestic fish supply. Total amount of fish produced in the country.
NDFS	Net domestic fish supply. Total amount of fish produced in the country, minus exports and discards.
TFS	Total fish supply. Total amount of fish in the country (NDFS plus imports).
NSS	Net seafood supply. Effective amount of fish for human consumption in the country (TFS for human consumption, minus processing waste).

$$TDFS_i = C_i + A_i \tag{1}$$

Note that, to avoid double-counting fish production, domestic catch that is fed to farmed fish was subtracted from overall production. This was done as possible given available country information and context (i.e., this may be more of an issue for some countries than others). Then, net domestic fish supply was estimated from fish landed (catch minus discards), aquaculture and exports as:

$$NDFS_i = L_i + A_i + E_i \tag{2}$$

$$L_i = C_i - (C_i * D_i) \tag{3}$$

where the second term in Equation 3 allows for a calculation of total discards in each country. In Equations 4 and 5, we assume that all imported seafood (we do not include imports not for human consumption, e.g., fish meal) is ready to be consumed and thus do not include losses from processing. We also assume that all aquaculture production is for human consumption and that none of this production is discarded, though processing losses do occur as in production from capture fisheries (e.g., farmed and wild caught shrimps would receive similar processing).

$$TFS_i = NDFS_i + I_i \tag{4}$$

$$NSS_i = [L_i - (L_i * O_i + A_i)] * P_i - E_i + I_i \tag{5}$$

Estimating National Economic Participation

Fishing revenue integrates the different ex-vessel price that fish landings can have depending on the final destination, i.e., for direct human consumption (DHC) and indirect human consumption (IHC). Therefore, total revenue (R) is estimated in the SAU database as follows:

Table 2: Description of variables used to estimate the national economic participation.

Symbol	Description
b	Ex-vessel price for catch landed for direct human consumption
a	Ex-vessel price for catch landed for indirect human consumption
I	Imports. Economic value of imported fish
RI	Re-Imports. Economic value of fish products re imported in the country
E	Exports. Economic value of exported fish
FR	Fishing Revenue. The total revenue for that species provided by the fishing activity
NT	Net trade. Economic value of fish traded considering both exports and imports

Fishing revenue integrates the different ex-vessel price that landings have, depending on the final destination: direct human consumption (DHC) and indirect human consumption (IHC). Therefore, total revenue (R) is estimated in the SAU database as follows:

$$FR = \sum_{i=1}^{n} (L_i * b_i) * b * P_i + (L_i * a_i) * a * P_i \tag{6}$$

Activities after landing fish are an important contributor to national economies, and these indirect and induced economic impacts were estimated based on economic multipliers for each country included in *Dyck et al (2010)* in their estimation of fishery contributions to national GDPs (Dyck and Sumaila 2010).

In addition to landings data, we used FAO statistics (FAO 2018) database to determine the value ($USD) of fish and crustaceans, mollusks and other aquatic invertebrates imported and exported by Brazil, Chile and Peru. We estimate the net trade (NT) as follows:

$$NT = (E - I) - RI \tag{7}$$

Data descriptions

This section outlines the sources, types, and limitations of available input data for the models described above. Data searches and analyses were undertaken at two levels. The first collated intergovernmental and global (e.g., FAO, SAU) datasets that were comparable across countries but involved various uncertainties. The second involved in-country data searches and validation and, though data quality varied across countries, results represent estimates using the best available information for each country.

Intergovernmental Analysis

The first approach using intergovernmental data is a somewhat broad analysis when one considers the uncertainties associated with global fisheries data (Zeller et al. 2016). Nevertheless, these are the best available official data and provide general and readily comparable trends across nations. This also provides a good starting point for highlighting key areas and species of interest that can then be addressed during in-country searches. The intergovernmental analysis used three main datasets:

1. *FAO* - The United Nations Fish and Agriculture Organization through the FishStatJ platform,[1] provides landings by country, year, and species (or species groups); imports, exports, and re-exports (i.e., exports of imported fish after processing) by country, year, and product name; and aquaculture production by species. All datasets report in tonnes, and trade information includes both weight and $USD values.

[1] UN-FAO FishStatJ, available at http://www.fao.org/fishery/statistics/software/fishstatj/en.

Landings data are available from 1950 to 2016, and other data from the early 1970s; all data are provided to FAO by member nations, either through fisheries ministries or in-country consultants.

2. *SAU* - The Sea Around Us project maintains a global dataset of "reconstructed" fisheries catches for every country from 1950 to 2014[2]. The dataset for each country was estimated using the FAO data as a baseline, on top of which estimated unreported catches and discards are added based on available literature and expert consultation (Zeller et al. 2016). Catches are furthermore divided by sector (industrial, artisanal, recreational, subsistence) and, as possible, split into specific species when FAO reports species groups. Data furthermore include yearly ex-vessel prices by species (Tai et al. 2017).
3. *Fish reduction data* - A recent study estimated the proportion of fish landings used for human direct consumption and fish meal and fish oil, by species and country (Zeller et al. 2017). These estimates were based on the SAU database and available country-specific information.

Data extracted from SAU for Chile included the Juan Fernandez Islands, Easter Island, and Desventuradas Islands. For Brazil, landings data included Fernando de Noronha Island, St Paul and St.Peter Archipelagos, and Trindade & Martim Vaz Islands.

For this level of analysis we used the FAO database to estimate the total landings (tonnes) of Chile, Brazil, and Peru averaging the values from 2012 to 2014, the last year with data available for all databases, including all fishing sectors (Industrial, Subsistence, Artisanal, Recreational) and various taxa.

Country-specific data, Brazil

Brazil has over 7 thousand kilometers of coastline including most of its states and one of the largest river networks in the world, with the Amazon River alone covering over 7 million km^2 . Fisheries resources in Brazil are extremely important for income and food security of millions of people throughout the country. Despite enormous social and economic importance, many fish stock are overexploited and in risk of collapse. According to a study conducted by the Ministry of Environment, 80% of fish stocks are over exploited or fully exploited. This signals the urgency for sustainable management of fisheries in order to guarantee the livelihoods of fishers, improve food security in the country, and conserve marine biodiversity.

There has been no official national collection of fisheries statistics in Brazil since 2008, a serious issue which was highlighted throughout our interviews with researchers and managers in the country, and which posed a great challenge to this study. Information such as how much the country produces, how much it consumes or even the number of fishers in the country is very sparse. In an interview with one of the most renowned fisheries scientists in Brazil, Dr. Fabio Hazin, he pointed out that there are between 400 thousand and one million fishers in the country. Additionally, he pointed out that data from FAO on Brazilian fisheries is mostly a copy of production reported in previous years. Therefore, our analysis for Brazil required an extensive interview effort and contacting of people from all fisheries sectors to find out what data is available. We gathered six different databases representing various fisheries sectors and further conducted an extensive literature research. We also identified other potential sources of information that we were not able to obtain in time for this study.

1. *SIGSIF* - Data obtained from the sanitary inspection services of the Brazilian Ministry of Agriculture. This database includes all seafood processed by fishing industries with a federal inspection certificate required to commercialize seafood products to different states of Brazil and for export and import. It is a rigorous inspection program, where one of the requirements is to report all seafood (by species) that enters each company, whether from imports or domestic production, for a total of 47 companies. It includes both aquaculture and wild caught products from both freshwater and the oceanic species (2016-2017).
2. *CEAGESP* - The largest wholesale open seafood market in Latin America is located in the city of São Paulo and is run by a state-owned company where sellers and buyers from all over the country gather

[2] The Sea Around Us, available at www.seaaroundus.org

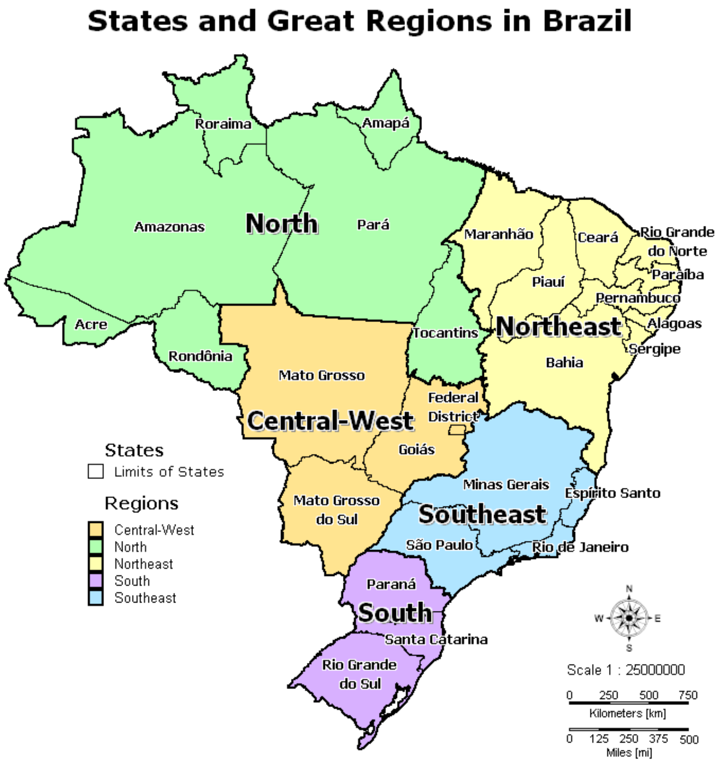


Figure 2: Regional distribution of Brazil. Map available at http://gps.wikia.com

to trade seafood and seafood products. We obtained information on all the seafood products traded in the market by species and price, for 2016-2017.

3. *MDIC* - Import and Export data from the Ministry of Development, Industry and Foreign Trade. This database contains all seafood imported and exported in Brazil, available to us for 2014-2017.

4. *State fisheries landings* - Fisheries landings data from three states of Brazil where there is continuous data collection and data are publicly available. These three states (São Paulo, Parana and Santa Catarina) are located in Southern Brazil and have a continuous data collection program sponsored by Petrobras in partnership with local universities. Petrobras is required to collect landings information for insurance purposes and has made some of its data publicly available for research projects. For São Paulo, data is available since 1998, for Santa Catarina since 2000, and for Parana since 2016. In addition to these detailed datasets, we were able to obtain total production data from the state of Amazon from 2009 to 2017.

5. *IBGE* - Brazilian Institute of Geography and Statistics. This federal institute is responsible for surveying the country to provide basic information on all social aspects of Brazil. We gathered two pieces of information to inform our analysis: household food consumption (last survey dates from 2009 and 2010) and income by region of Brazil (2017).

6. *Fishing Permits* - Two sources of data: 1) Total number of registered fishers in the country from the extinct Ministry of Fisheries and Aquaculture (2003 - 2013). 2) Number of registered fishers by state from a study conducted during an investigation of fraud in the fishers' insurance system (Ministério da Transparência, Fiscalização e Controladoria-Geral da União - CGU, 2017)[3].

[3]Ministry of Transparency, Supervision and Controllership of the Union, http://www.cgu.gov.br/

Country-specific data, Chile

1. *SERNAPESCA* -SERNAPESCA - The Chilean National Service of Fisheries is the main entity in charge of keeping track of landings and other fisheries and aquaculture related data in Chile. Most of their data is available on their website but we also obtained additional databases upon request[Cˆ1]. We accessed their databases on landings from wild-caught and farmed fisheries, first transaction prices (ex-vessel price) for artisanal fisheries, and landings used in different types of sea products. These databases provided information at the species and regional level. We also downloaded their data on the geographical distribution of production facilities and the types of sea products they produce. We issued data requests on SERNAPESCA's portal to obtain more detailed information. Via this method, they provided us the national record of artisanal fishers (RPA), which lists current registered fishers and boats, and the national record of industrial vessels (RPI), which lists current registered industrial vessels. The RPA informs the region, gender and age for each artisanal fisher as well as the species-specific permits they hold. Together the RPA and RPI provide information on artisanal and industrial vessels, including length and storing capacity. SERNAPESCA also provided the number of employees of each gender per processing facility.

2. *Aduanas Chile (Chilean Customs).* is the main entity in charge of keeping records of imported and exported goods in the country. We accessed their exports and imports data by product and region via their website. Each product in the original exports and imports datasets is identified through an ID number that matches the name of the product in a code known as the Arancel Aduanero. Most products provided details on the species or groups of species involved.

3. *IFOP* - The Fisheries Development Institute is a private entity that advises fisheries management based on permanent biological, environmental and economic monitoring, and scientific reasoning. Although most of the data collected by IFOP pertains to stock assessments and biological indicators, they also generate economically relevant statistics. We reviewed their most recent annual report on the economic monitoring of Chilean fisheries for 2015. It includes databases and estimates for employment. We also extracted data from their monthly reports on exports of fisheries products, which are based on ADUANAS's data.

4. *CCB* - The Chilean Central Bank (*Banco Central de Chile*) is the entity in charge of establishing the Chilean currency. To fulfill its function it monitors the main economic indicators per economic sector. We accessed their data on sectorial GDP (including fisheries) for each region.

5. We reviewed several reports from other national agencies like the Undersecretary of Fisheries (SUBPESCA), NGOs and scientific publications to complement our analysis.

Country-specific data, Peru

Data from the following governmental institutions were used to characterize Peruvian capture and aquaculture production, internal and international trade of seafood products, apparent seafood consumption and the contribution of seafood to the national economy. The following governmental institutions provided data for this study (or include it on their official webpages):

1. *PRODUCE* - The Peruvian Ministry of Production (Ministerio de la Producción del Perú), reports fisheries landings by species and line of production (e.g., canning, curing, freezing, etc.) on annual statistical reports available on their webpage[4]. They also report aquaculture production, yields by line of production, internal trade, and apparent seafood consumption[5].

2. *IMARPE* - The Peruvian Marine Research Institute (Instituto del Mar del Perú; IMARPE), reports ex-vessel prices on a daily basis by species and landing site. This database was provided by Juan Carlos Riveros (Oceana Peru), and can be found at IMARPE's website.[6] Moreover, IMARPE has published

[4]Peruvian Ministry of Production (Ministerio de la Producción del Perú; PRODUCE), Available at http://www.produce.gob.pe
[5]Statistic Landings Yearbooks 2012; 2013; 2015a; 2015b: 2016; 2017. See References folder.
[6]Peruvian Marine Research Institute (Instituto del Mar del Perú; IMARPE) Available at http://www.infomar.imarpe.gob.pe

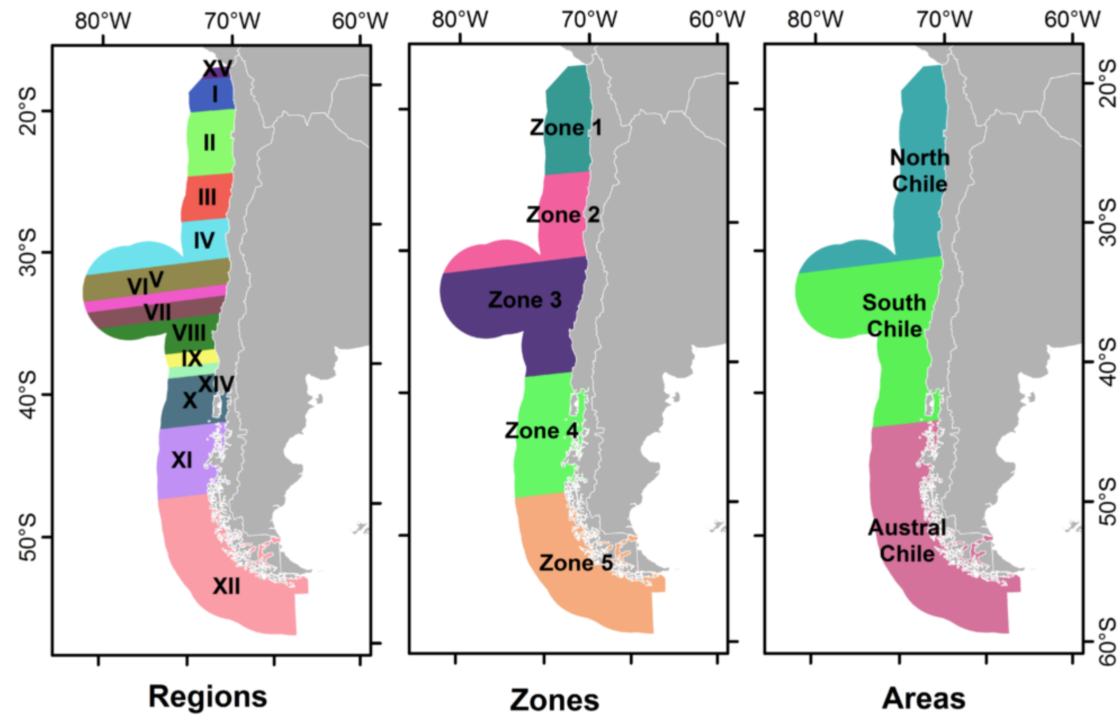


Figure 3: Regional distribution of Chile. Image from Bórquez, A.S. and Hernández A.J. 2009

the results of several national surveys of small-scale fishermen by fishing gear (Carrasco et al. 2017). These include information on the number of fishers by gear.

3. *SUNAT* - The Peruvian Customs Agency (Superintendencia Nacional de Aduanas y de Administración Tributaria), reports seafood imports and exports by 'custom code', which group together products by type and sometimes species.

4. *INEI* - The Peruvian Institute of Statistics and Informatics (Instituto Nacional de Estadística e Informática). Reports the results of the annual household survey (ENAHO – Encuesta Nacional de Hogares). These include information regarding per capita seafood consumption by species, product type and region.

Figure 4: Regional distribution of Peru. Image available at https://commons.wikimedia.org/wiki

Results

The results section is divided in two main subsections representing analyses using intergovernmental datasets (*Intergovernmental results*) and national datasets (*Brazil, Chile, Peru*). The results for each subsection follow the same structure and include a general overview, estimates of seafood supply and consumption, and contributions to employment and income.

Regional Overview

Fisheries Context

Wild Caught Fish

Results from the intergovernmental data show a clear dominance in total fisheries landings by Chile and Peru over Brazil, even though Brazil captures more different species than the former. However, Brazil is a main exporter of seafood, importing more than double that of Chile and Peru (Table 3).

Figure 5: Fishing effort within Brazil, Chile and Peru's Economic Exclusive Zones. Logarithmic scale. Dataet: SAU.

The FAO database on fish landings (wild caught) present different trends between and within countries (Figure 5). In Brazil, the highest average catch for any one species between 2012 and 2016 was Brazilian sardinella (*Sardinella brasiliensis*), representing 8.9% of the country's average landings. Sardinella is a very

Table 3: Summary of results from 2012-2016. Database SOFIA-FAO. Thousand tonnes.

Sector	Total	Mean	s.d.
Brazil			
Aquaculture	2,679	536	52
Capture	3,804	761	52
Exports	208	42	6
Imports	1,918	384	36
Chile			
Aquaculture	5,456	1,091	77
Capture	11,852	2,370	451
Exports	6,235	1,247	57
Imports	889	178	22
Peru			
Aquaculture	504	101	21
Capture	22,979	4,596	918
Exports	7,290	1,458	400
Imports	536	107	26

popular fish in Brazil and supports a big industry (see Brazil's section below); while catches are variable, they remain relatively high and the FAO data is most likely under-reporting this species' landings. For both Chile and Peru, the species with highest landings was anchoveta (*Engraulis ringens*) with a 28.7% and 76.5% of total national landings, respectively. Anchoveta is mainly used for fish meal and fish oil, with only a small proportion used for human consumption; therefore, both Chile and Peru's biggest fisheries in terms of landings are most likely not major contributors to national food security.

Fish landed as part of subsistence fisheries are all destined to direct human consumption and therefore represent an important source of protein for coastal communities and fishers themselves in Brazil, Chile and Peru. While FAO's data does not differentiate between sectors, we can use the SAU dataset (as recently as 2014) to get a sense of subsistence landings in all three countries (Figure 7). It is worth noting that our comprenhension of this sector is highly limited, as data describing it is limted, highly uncertain and mostly incomplete. As a result, subsistence fisheries' capture production is highly under reported and its relevance to national food security is highly underappreciated by government authorities.

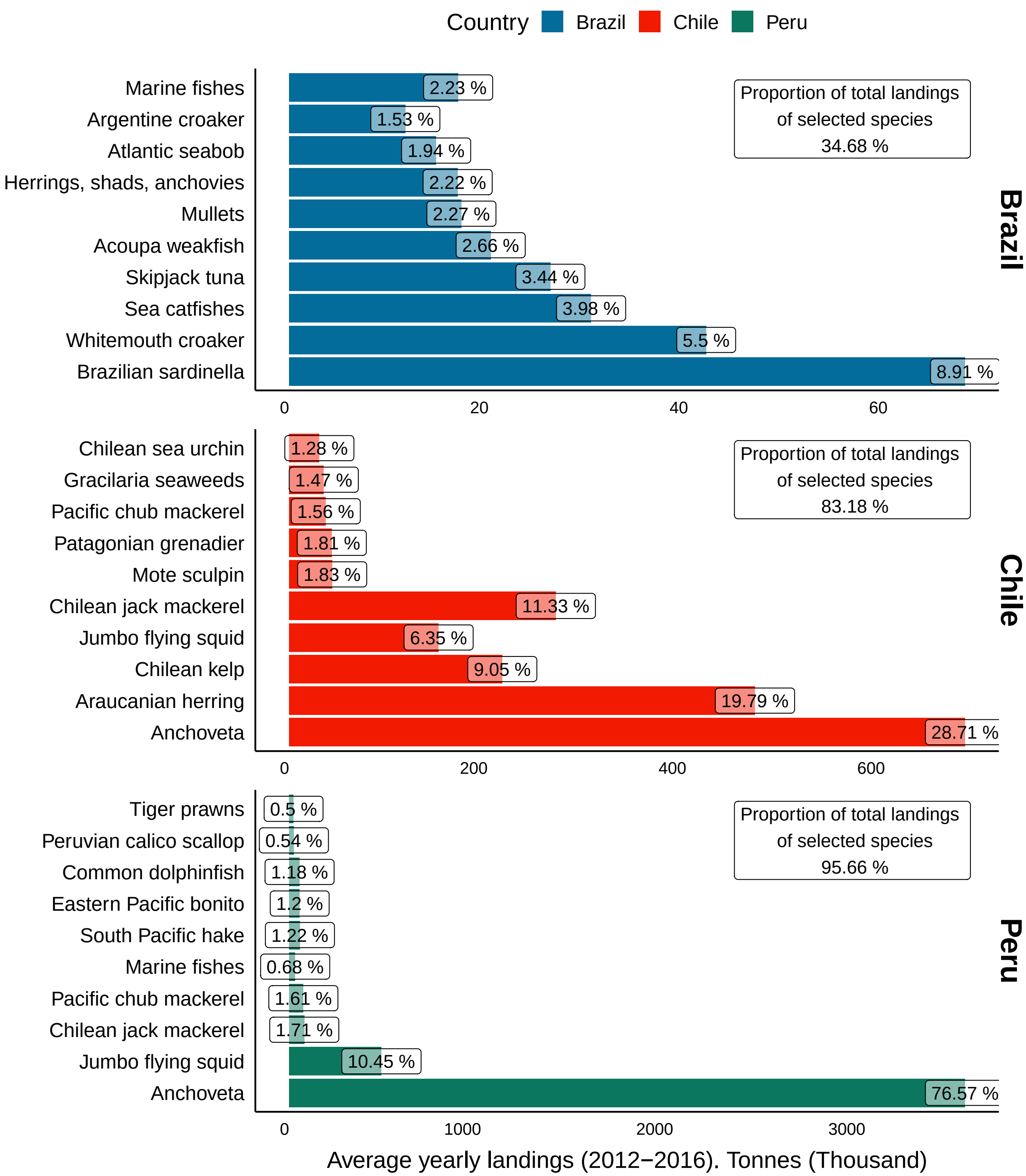


Figure 6: Proportion of total landings by species from the FAO dataset for Brazil (top), Chile (middle), and Peru (bottom). Values average from 2012-2016

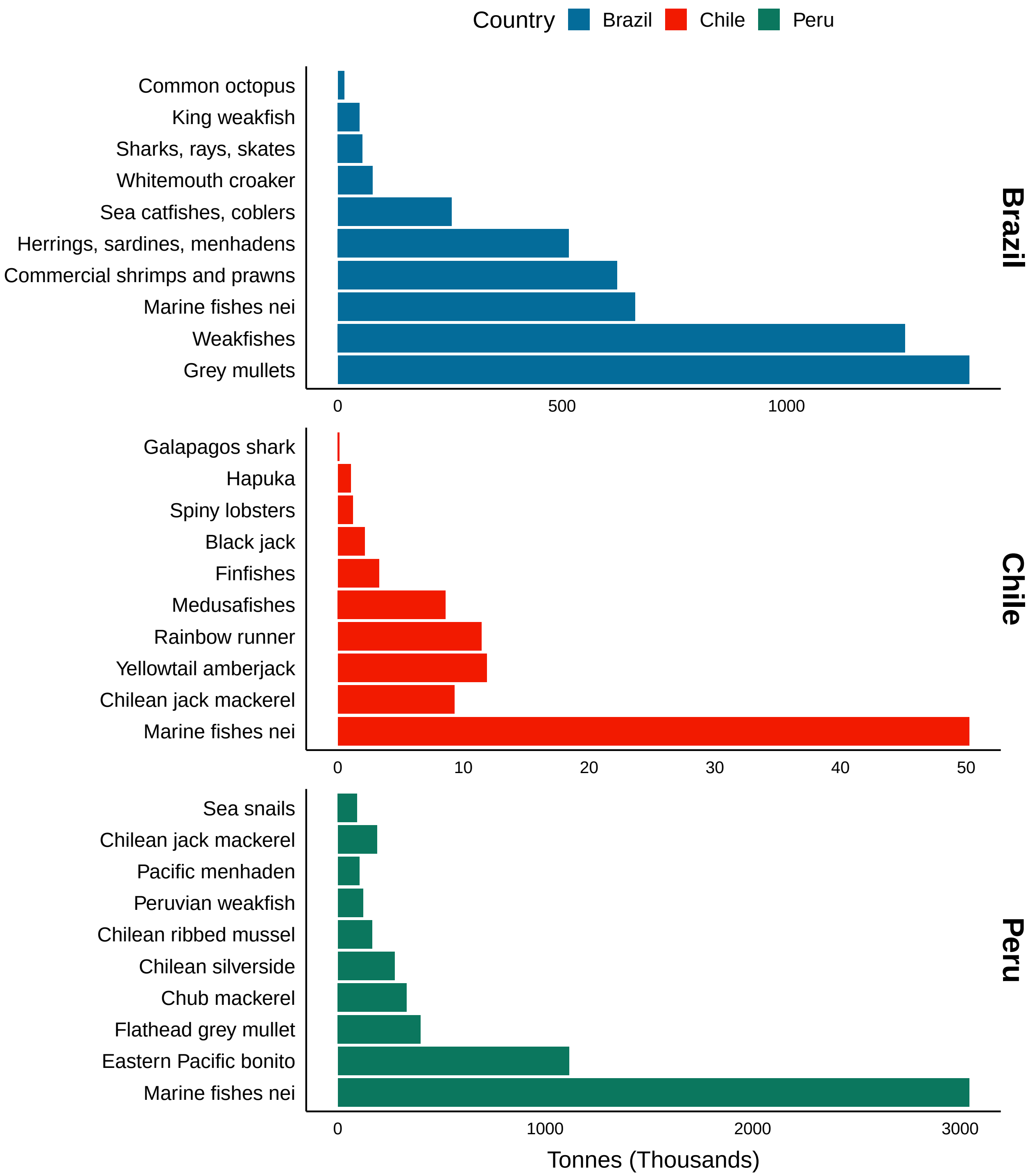


Figure 7: Mean top 10 subsistence species by landings in 2014 from the SAU dataset.

According to SAU data, subsistence fisheries are more important in Peru and Brazil, although their numbers are quite low. In the case of Chile, subsistence fisheries are relatively limited as most fishing communitites have the option to sell and/or eat their catch. For Peru, marine subsistence fisheries are not that important for food security at the national scale. However, that is not the case for freshwater subsitance fisheries (see Peru critical analysis). The low subsistence landings volume in the data can also be product of the high uncertainty around these fisheries. The category "Marine fishes not identified" reflects this, as it represents most of the subsistence landings for Chile and Peru, and are very important to Brazil. In the case of Brazil, the fact that mullets (genus *Mugil*, *Tainha* in portuguese) are the main species group in subsistence data is not surprising as this group is known to represent an important source of protein for fishing villages and is common in local dishes.

Finally, it is worth mentioning that only three species (Chilean jack mackerel, eastern pacific bonito, and whitemouth croaker) are found in both the top landed species in FAO data and in subsistence captures in SAU data. This comparison highlights potentially important differences between commercial and food importance of species at local scales, thought it should be taken with care as both datasets could differ in the species-specific level of detail (e.g., taxa vs broader groups).

Fish Trade

In addition to the internal fish production, Brazil, Chile and Peru all import and export fish (Table 4). Brazil leads all three countries in terms of fish imports with Atlantic salmon and Alaskan pollock in the top of the list in terms of net trade (Imports-Exports). The only seafood imports of Chile and Peru equitable to Brazil's are tunas, Chilean jack mackerel, and Pacific chub mackerel (in the case of Peru), all other products are substantially lower than Brazil's products.

Estimating National Seafood Supply

Because seafood can be supplied by different sectors, we combine the multiple datasets collected for this study to include aquaculture, wild capture, and international trade. Names in the FAO trade data were standardized as possible to match the taxa and species groups in the catch and consumption data. Results suggest that the main fish group destined for food in Brazil is tilapia, salmon in Chile and anchoveta in Peru (Table 4). However, as discussed below (see each country's section) these results might not represent the main food sources as regional dynamics (e.g.subsistence fishing, fishers interactions) might not be captured by international data sources by country. These differences might result from regional and local dynamics (e.g.subsistence fishing, fishers interactions) not being accuaretely captured by international data sources. The latter might also be subject to bias driven by methodological assumptions included for catch reconstructions, or to error from data manipulation and incorrect data sharing between national government fisheries institutions and FAO. Finally, because FAO trade data is arranged by product (e.g.American and European Lobsters Homarus.spp, whole, frozen) it is very challenging to match such products with the actual species or species group.

The different international data suggest that Brazil is the only country where most seafood supply (including aquaculture, fisheries and trade) are destined for domestic human consumption (Figure 1). However, in terms of quantity (tonnes) Chile is the country that has the most seafood supply for national consumption, and Peru is the least.

In terms of sectors, all three countries are dominated by wild fisheries, specially Peru. However, most of Peru's wild catch comes from Anchovy (*Engraulis ringens*) where only a very small part is destined to direct human consumption driving the flow away from NSS (Figure 8). Brazil's wild fisheries participation is somehow misleading as the country lacks fisheries statistics, however, as stated below (See Brazil's section) there are some states with important fisheries. Aquaculture production seems to be proportionally higher in Brazil followed by Chile and almost non-existent in Peru. Chile is known to export most of its salmon (*Salmon salar*) aquaculture while Brazil heavily relies in aquaculture for seafood supply. Finally, in terms of fish trade, Brazil is the only country where seafood import represents an important contribution to national seafood supply (Figure 8).

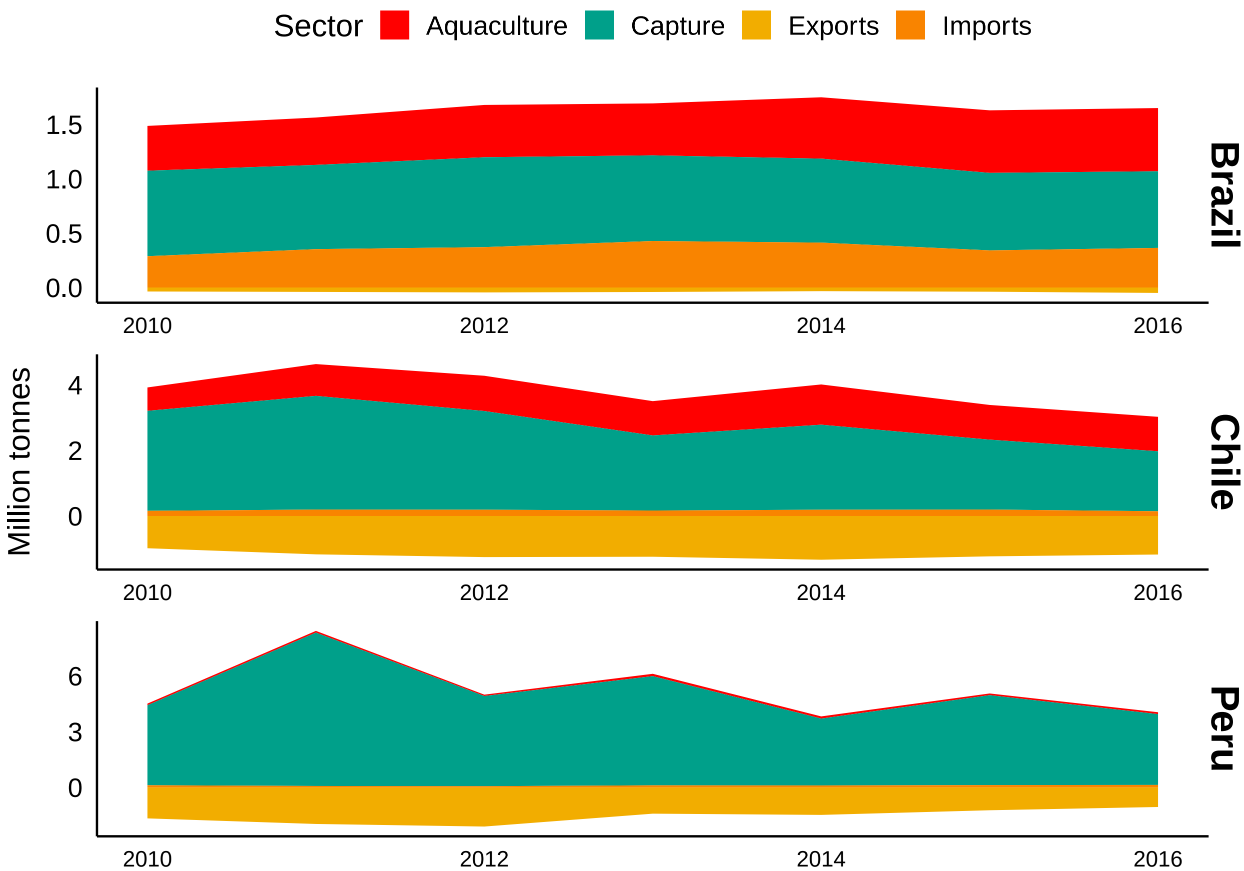


Figure 8: Seafood production by sector and species group for each country over time. Dataset FAO.

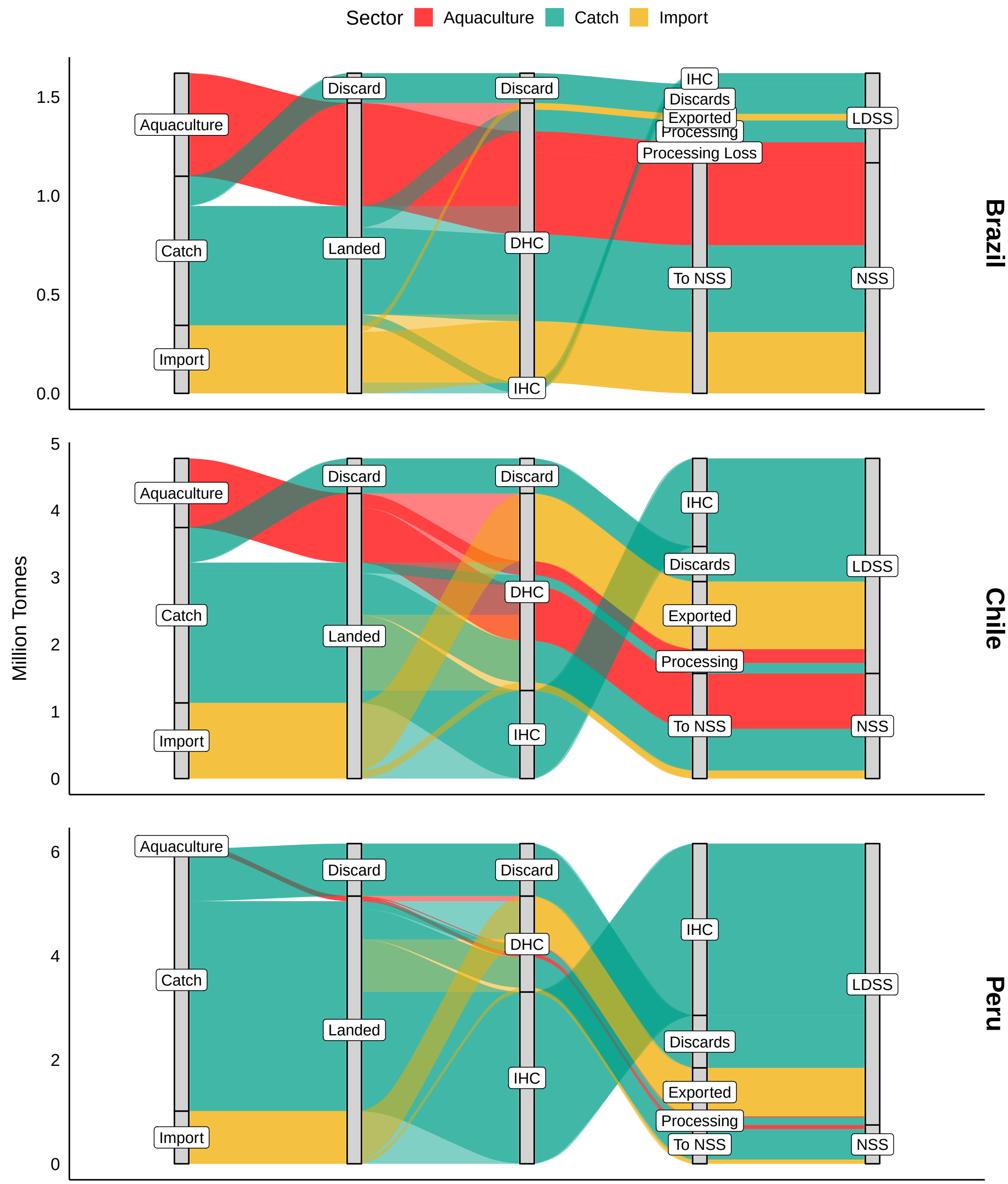


Figure 9: Production flow of seafood in Brazil, Chile, and Peru. NSS = Net Seafood Supply, seafood produced in the country or imported and consumed domestically. LDSS = Losses to Domestic Seafood Supply, seafood produced in the country and lost to discards and processing, exported or not for human consumption. Average (2010-2016). Dataset: FAO.

At the species (or species group) level, Brazil's seafood supply comes mainly from aquaculture of tilapia, cachama (*Colossoma macropomum*), and shrimp, wild capture of miscellaneous fish (not identified in the database), and imports of Atlantic salmon (*Salmon salar*), Alaska pollock, and herrings, sardines, and anchovies. In the case of Chile, the main sources of seafood come from aquaculture with species such as Atlantic salmon, Chilean mussel and rainbow trout, in addition to wild captures of jumbo flying squid (*Dosidicus gigas*) and mote sculpin. Finally the data shows a clear dominance by wild captures of anchovies (*Engraulis ringens*) in Peru, followed by jumbo flying squid, and mackerels.

As previously mentioned, matching FAO trade data with captures can be quite challenging and the model becomes somewhat sensitive to it. In the case of Peru, for example, Chilean jack mackerel is positioned in third place concidering only catch data. However, as previously shown (Table 5) Peru imported on average 27.5 thousand tonnes of jacks and horse mackerels between 2012 and 2016, of which a substantial portion may have been Chilean jack mackerel. While this is still not enough to exceed the Peruvian anchoveta, it represents an important increase in NSS of Chilean jack mackerel. Despite this discrepancy in quantities, the categories presented here are very similar to the results obtained using country-level data (see below). In addition, international data are not allways capable of capturing details at the country level. For example, Chilean kelp shows up as a main contributor to seafood supply however, FAO data does not account for the water loss in the landings (see supplementary material, Chile), resulting in an overestimation of the actual NSS.

Table 4: Top 10 species (or species groups) contributing to the National Seafood Supply of Brazil, Chile and Peru. Thousand Tonnes. Dataset: FAO and SAU

Specie	Landings Food Supply	Aquaculutre Food Supply	Net Imports	National Seafood Supply
Brazil				
Tilapias	5.8	152.3	0.0	158.1
Cachama	2.5	82.8	0.0	85.3
Whiteleg shrimp	0.0	53.2	0.0	53.2
Atlantic salmon	0.0	0.0	50.0	50.0
Marine fishes	11.3	0.0	35.7	47.1
Alaska pollock	0.0	0.0	42.1	42.1
Herrings, sardines, anchovies	0.2	0.0	37.3	37.5
Whitemouth croaker	26.7	0.0	0.0	26.7
Tambacu.hybrid	0.0	25.6	0.0	25.6
Freshwater.siluroids.nei	11.4	10.3	0.0	21.8
Chile				
Atlantic salmon	0.0	350.3	-132.0	218.3
Chilean mussel	0.5	199.3	0.0	199.8
Chilean kelp	137.6	0.0	0.0	137.6
Rainbow trout	0.0	134.0	0.0	134.0
Coho salmon	0.0	112.7	0.0	112.7
Jumbo flying squid	76.4	0.0	0.0	76.4
Mote sculpin	39.0	0.0	0.0	39.0
Gracilaria seaweeds	23.9	9.5	0.0	33.4
Pacific chub mackerel	28.0	0.0	0.0	28.0
Chilean jack mackerel	27.1	0.0	0.0	27.1
Peru				
Anchoveta	146.8	0.0	0.0	146.8
Jumbo flying squid	82.5	0.0	0.0	82.5
Chilean jack mackerel	64.4	0.0	0.0	64.4
Peruvian calico scallop	25.5	34.5	0.0	60.0
Pacific chub mackerel	40.0	0.0	0.0	40.0
Common dolphinfish	33.7	0.0	0.0	33.7
South Pacific hake	32.8	0.0	0.0	32.8
Eastern Pacific bonito	27.7	0.0	0.0	27.7
Rainbow trout	0.2	25.2	0.0	25.4
Tiger prawns	15.1	0.0	0.0	15.1

Estimating National Economic Participation

Fisheries are important to local and national economies of most Latin American countries. Of the case study countries, the fishing sector (counting only landed values) has the highest GDP contribution in Peru (2.3%) and lowest in Brazil (<1%). By using a multiplier developed by Dyck and Sumaila (Dyck and Sumaila 2010) we can estimate the total impact of the fisheries industry (supply chain) in the country's GDP. Such multiplier (2.05 for Latin american countries) boosts the GDP contribution to 2.6% in Chile and 4.7% in Peru (Brazil maintains under 1%) (Table 5).

Table 5: Fisheries contributions to Gross Domestic Product (GDP). Total economic impact includes indirect and induced effects of the fisheries sector. Data based on economic impact multipliers reported in Dyck and Sumaila (2010) for each country. All values in USD billions.

Country	Landed value	Total Economic Impact	Household Income	% of GDP
Brazil	2.32	4.75	1.30	0.002
Chile	2.83	5.79	1.58	2.355
Peru	3.82	7.83	2.14	4.492

In terms of economic contribution of specific fish landings, Brazil's most valuable fishery between 2012 and 2014 was *Umbrina canosai*, a croaker fished in the southern part of the country. For Chile, the most valuable fishery was anchoveta (*Engraulis ringens*). Peru's most valuable fishery in 2014 was the Peruvian scallop (*Argopecten purpuratus*) (Figure 10). International databases describing ex-vessel prices are also subject to error and biased estimates, as was the case for capture production (FAO) and reconstructed catch (SAU). Thus, the most valuable fisheries per country might also differ when estimates use national and international datasets (see Peru - National Economic Participation).

Trade is an important component of fisheries. Of the countries analyzed Brazil was the only country to have an overall net import of fish. Brazil spends more money importing fish than what it makes from producing it and exporting that production. Conversely, both Chile and Peru have a trade surplus from their fisheries, with Peru the most "profitable" country (Figure 11 and Table 6).

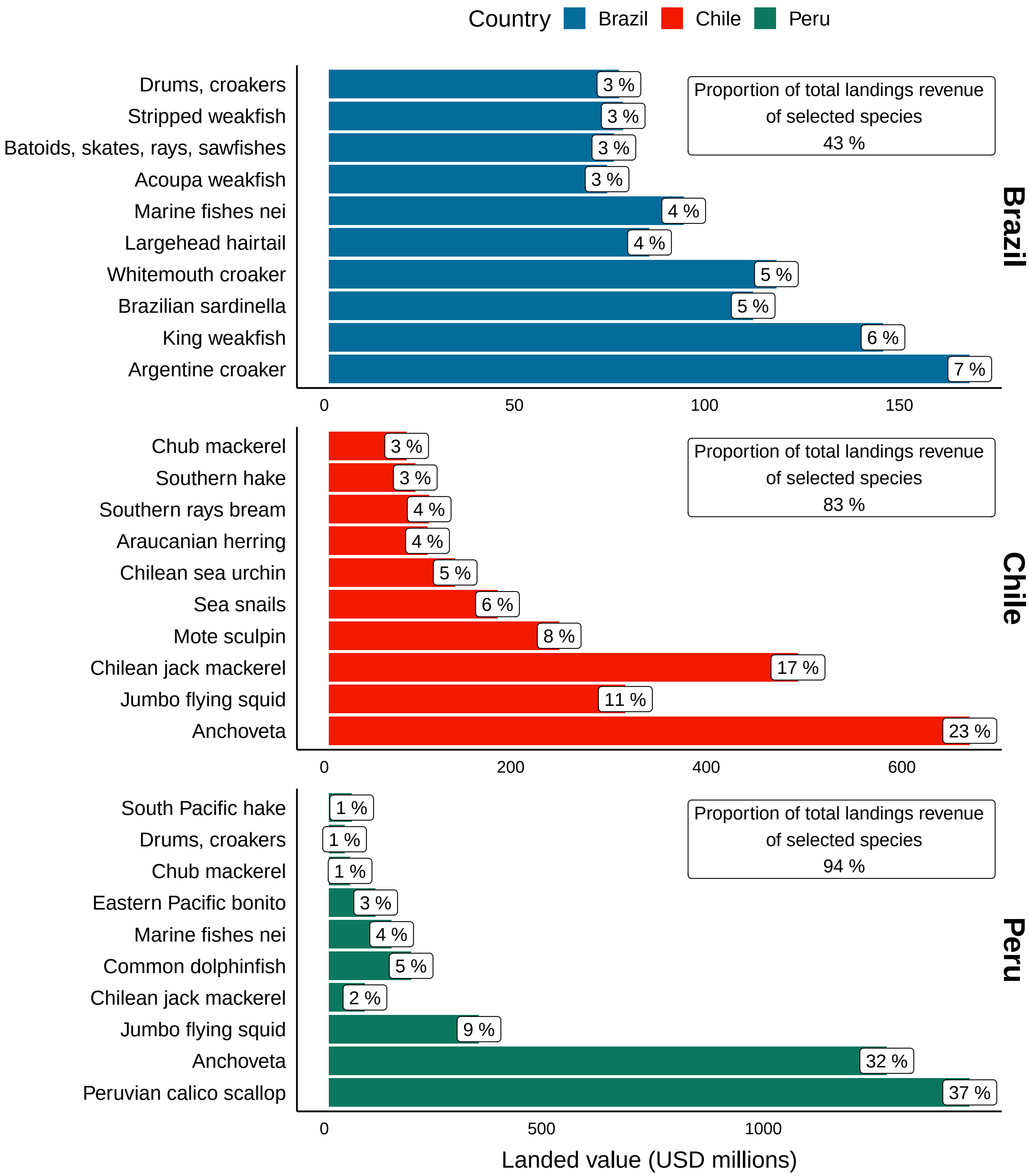


Figure 10: Top 10 species by landed value from the SAU dataset. White boxes represent the contribution of species in each figure to the total country value, 2012-2014

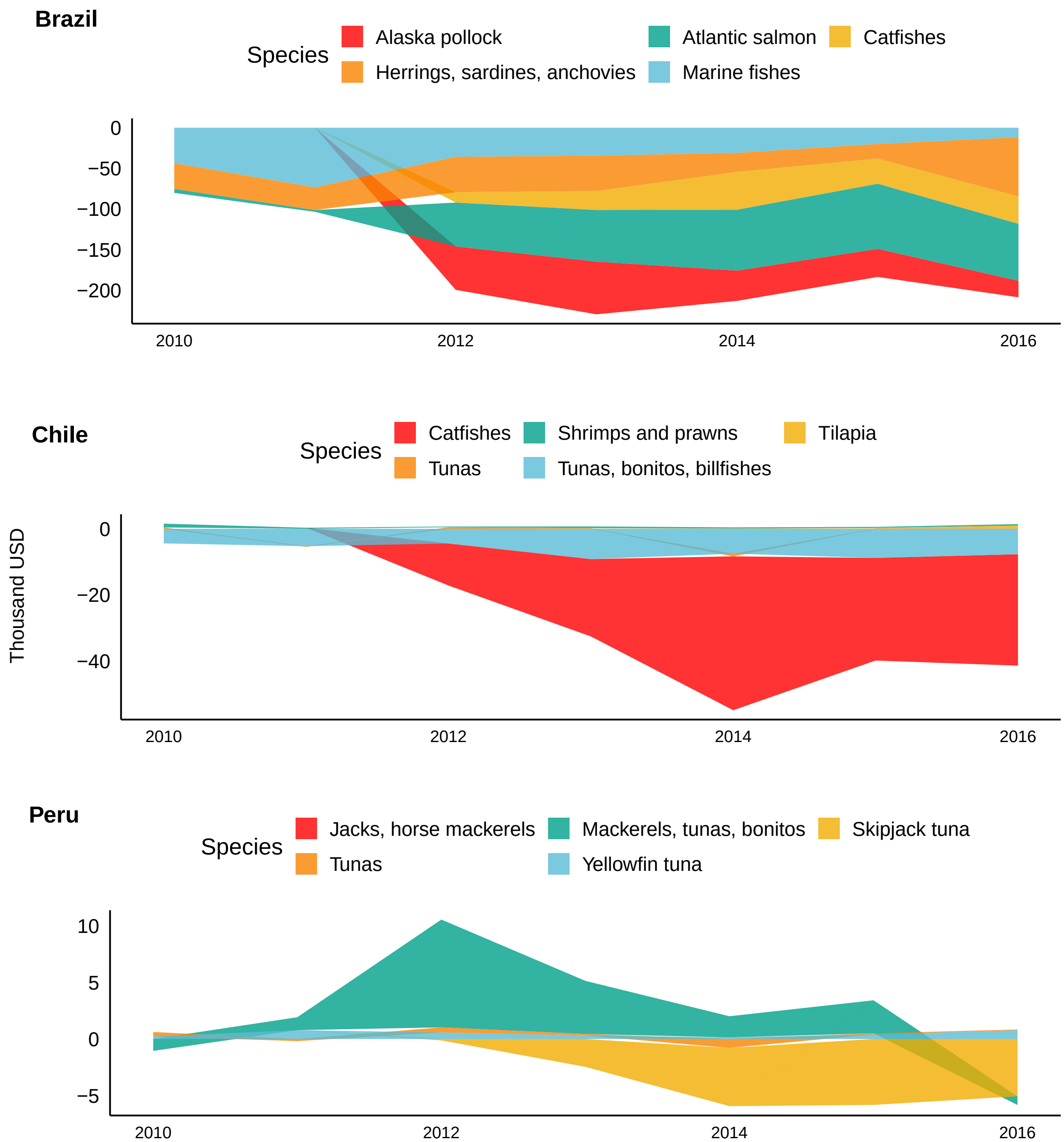


Figure 11: Net trade (Exports - Imports) of the most valuable traded species of Brazil, Chile, and Peru. Thousand USD. Dataset: FAO

Table 6: Top ten traded seafood fish products trade between Brazil, Chile and Peru. Dataset SOFIA-FAO. Net trade = Exports-Imports in thousand USD

Product	Exports	Imports	Net Trade
Brazil			
Snappers	3,170	5	3,165
Mackerels, tunas, bonitos	8,119	5,498	2,621
Crabs, lobsters, shrimps	1,790	1	1,789
Swordfish	1,067	6	1,061
Angler	1,043	0	1,043
Stingrays, skates	971	0	971
Drums, croakers	2,289	1,358	931
Weakfishes	538	29	509
Shrimps and prawns	472	2	470
Yellowfin tuna	464	6	458
All products	39,158	353,693	-314,535
Chile			
All products	1,073,502	166,686	906,815
Atlantic salmon	132,010	44	131,966
Marine fishes	167,802	61,769	106,034
Salmons, trouts	100,784	13	100,771
Trouts	98,620	74	98,546
Jacks, horse mackerels	92,664	10,424	82,240
Salmonids	74,392	110	74,283
Squids	56,206	190	56,016
Seaweeds	18,992	1,355	17,637
Marine molluscs	12,560	177	12,383
Grenadiers	10,332	45	10,287
Peru			
All products	1,537,192	102,425	1,434,767
Marine fishes	594,261	14,948	579,313
Cuttlefishes	173,357	1,598	171,759
Cuttlefishes, bobtail squids	29,197	43	29,154
Marine crabs, shrimps, lobsters	13,020	222	12,798
Marine molluscs	9,942	24	9,917
Anchovies	9,815	1,677	8,138
Seaweeds	6,975	3	6,972
Shrimps and prawns	7,426	775	6,650
Hakes	6,665	216	6,449
Scallops	4,778	2	4,776

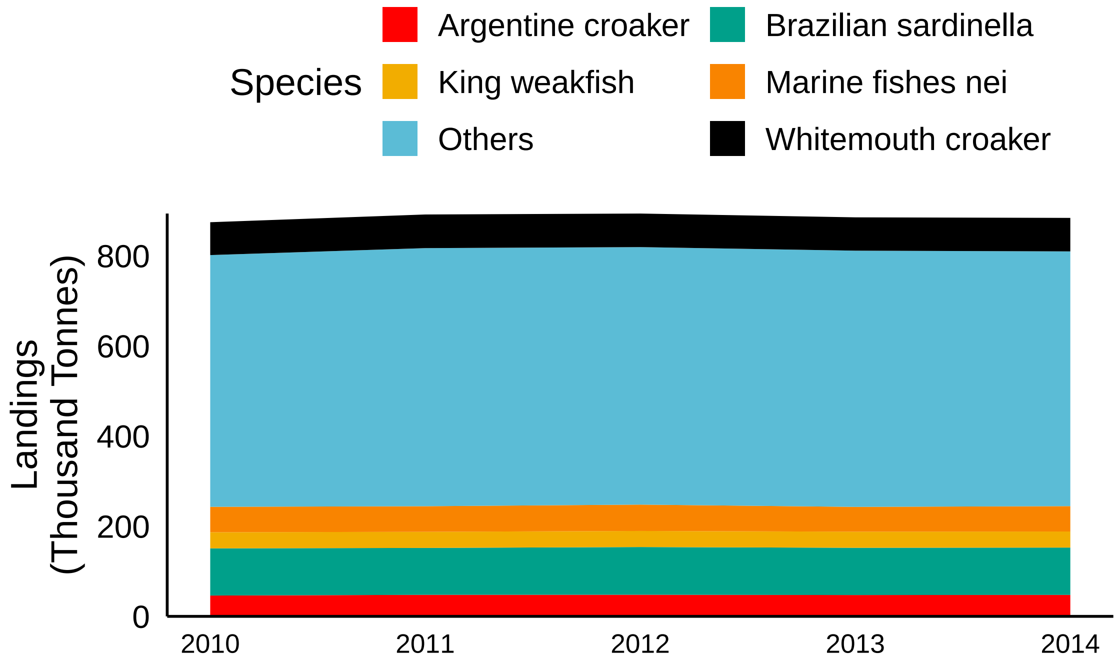


Figure 12: Main landed groups in Brazil. Dataset SAU

Results: Brazil

Fisheries Context

Wild Caught Fish

Global Databases (FAO and SAU)

As previously mentioned, there are no national-level fisheries statistics data in Brazil since 2008. Therefore, the country-wide assessment was only possible using the SAU and FAO datasets. While these datasets provide information regarding landings by species, it is worth mentioning that they are far from realistic. In our meeting with Dr.Fabio Hazin, he pointed out that data from FAO on Brazilian fisheries is mostly extrapolated as-is from production in previous years, when reliability was already questionable. The figure showing the top 5 species fished in the country gives a clear picture of such extrapolation (Figure 12)

According to the SAU database Whitemouth croaker (*Micropogonias furnieri*), Sardine (*Sardinella brasiliensis*), argentine croaker (*Umbrina canosai*) are the most landed fish between 2010 and 2014 (Figure 12). However, these are a small proportion compared to other fish. It is very likely that these four fish species are consumed in the country representing an important source of food.

The SAU database accounts for unreported catches in Brazil (Meirelles Felizola Freire et al. 2014) and estimates around 50 thousand tonnes more captures than reported in FAO. These captures are important since they are mainly caught by the artisanal sector, hence contributing directly to food security (Meirelles Felizola Freire et al. 2014) (Table 7).

Table 7: Summary of results for Brazil. Database used: SOFIA-FAO and SAU. Exploited species in quantity, other variables represent thousand tones

Year	Exploited Species	Aquaculture	Capture	SAU Capture	Exports	Imports
2014	248	564	772	884	33	413
2015	235	575	713	NA	39	342
2016	240	581	705	NA	50	364

Regional Databases - State Fisheries Landings

Parana

Fisheries production in Parana state is mainly artisanal and totaled around one thousand tonnes in 2017. The main species caught in the state is shrimp, followed by crab and crayfish (Table 8).

Table 8: Main species caught in the Parana state, Brazil. Dataset Fundepag. Tonnes

Species	2016	2017	2018	Mean	s.d	Total
Shrimp	821	17,553	12,346	10,240	8,563	30,720
Seabob shrimp	74	1,228	506	603	583	1,808
Crab	24	1,016	82	374	557	1,122
Cockle	NA	182	175	179	5	357
Mullet	7	88	108	68	53	203
Crayfish	NA	30	101	65	50	131
Brazilian sardinella	3	109	73	62	54	185
Weakfish	20	88	51	53	34	160
Oyster	10	113	32	52	54	155
Wahoo	7	79	5	30	42	90

Santa Catarina

The state of Santa Catarina is one of the main fisheries producers in the country. This state is home to the largest fisheries port in the country, Itajai Port, concentrating most of Brazil's industrial fleet (Table 9). Landings data from this state are available since 2000, although from 2014-2016 catches are underreported due to lack of funding (Figure 13). Historic production from Santa Catarina has been over 100 thousand tonnes until 2013 and corresponds to about 18% of the total estimated landing from capture fisheries in Brazil (about 760 thousand tonnes). The main species caught in the state across all years are sardines, herring, croaker and skipjack tuna (Figure 13). Historical records of the main species caught show a clear declining trend in catch of sardines, a key fish for consumption regionally and nationaly (Figure 13).

São Paulo

The state of São Paulo has a continuous data collection program dating back to 1998 (Table 10). Although this state is not the main fisheries producer in the country, landings average about 35 thousand tonnes per year (about 5% of the total estimated landing from capture fisheries in Brazil). 2017 was the year in which the data collection program covered all regions in the state, which explains “increased” catches during this period. The main species caught in the state across all years were shrimps, crayfish and crabs (Figure 14). The fishing fleet from this state is mainly artisanal, with few industrial boats.

Aquaculture Production

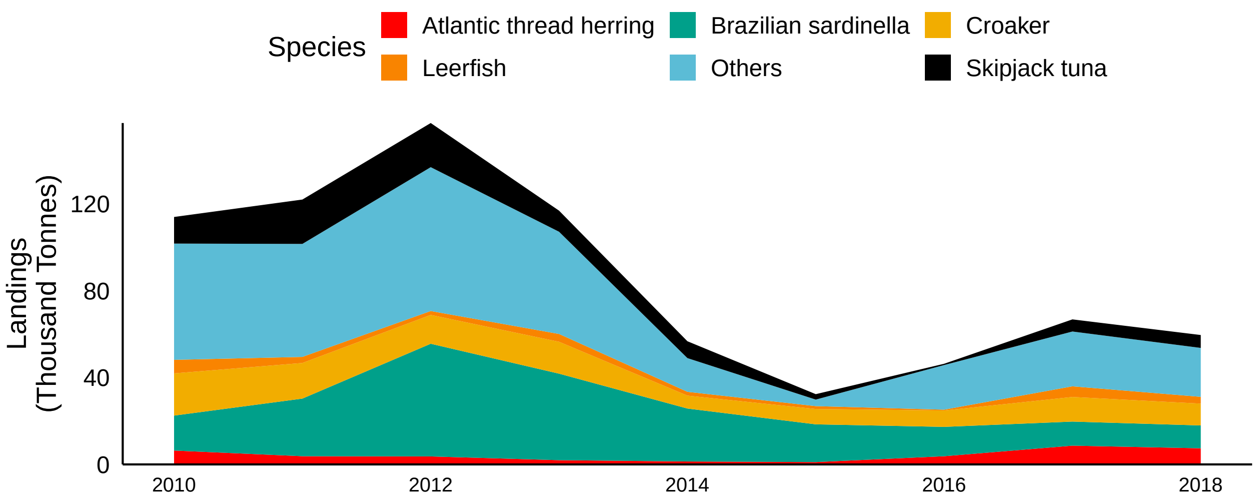


Figure 13: Main landed species in Santa Catarina state from 2000 to 2018. Dataset UNIVALI

Table 9: Main species caught in the state of Santa Catarina, Brazil from 2010 to 2018. Dataset: Univali. Thousand Tonnes. Mean represents the average of 2014-2018

Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean	s.d	Total
Brazilian sardinella	16.1	26.5	51.9	39.8	24.4	17.4	13.5	11.1	10.5	23.5	14.1	211.2
Croaker	19.5	16.4	13.3	14.7	6.0	7.1	7.5	11.3	10.1	11.8	4.6	105.8
Skipjack tuna	12.2	20.4	20.3	9.7	7.8	2.5	0.6	5.6	5.9	9.5	7.1	85.1
Others	30.4	33.4	48.5	32.6	9.4	0.8	10.1	13.4	10.7	8.9	4.8	44.3
Atlantic thread herring	6.4	3.8	3.7	1.9	1.3	1.1	3.8	8.6	7.4	4.2	2.7	38.0
Argentine croaker	6.8	6.4	5.4	4.9	1.5	0.2	3.6	3.0	2.0	3.8	2.3	33.8
Shrimp	5.5	3.8	5.2	3.4	1.4	NA	3.6	2.8	1.6	3.4	1.5	27.3
Leerfish	6.2	2.8	1.8	3.6	1.7	1.3	0.4	4.9	3.1	2.9	1.8	25.9
East Atlantic Red Gurnard	4.8	3.4	3.6	2.8	0.8	0.0	1.7	2.8	2.3	2.5	1.5	22.1
Mullet	3.3	3.0	1.6	1.2	1.2	2.0	0.8	0.6	3.1	1.9	1.1	16.9
Other fish	2.7	2.0	1.9	2.2	1.3	0.0	0.8	2.8	2.8	1.8	1.0	16.4

Table 10: Main species caught in the state of São Paulo, Brazil from 2010 to 2018. Dataset: Univali. Thousand Tonnes. Mean represents the average of 2014-2018

Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean	s.d	Total
Brazilian sardinella	4.4	4.9	7.2	15.2	8.3	6.6	4.7	0.5	0.2	5.8	4.5	51.8
Shrimp	3.3	3.2	4.1	2.1	2.6	2.7	1.9	28.3	2.2	5.6	8.5	50.6
Crab	0.2	0.2	0.2	0.2	4.2	0.2	19.1	4.4	0.1	3.2	6.2	28.7
Others	6.6	6.6	8.0	6.7	5.5	6.4	5.2	5.1	2.6	5.0	1.4	24.8
Crayfish	0.0	0.0	0.0	0.0	1.0	0.0	3.0	12.7	7.5	2.7	4.5	24.2
Bashaw	2.8	2.4	2.3	2.4	2.3	2.3	2.0	2.0	0.5	2.1	0.7	19.2
Weakfish	1.0	0.9	1.3	1.2	1.2	0.8	0.9	0.7	0.5	0.9	0.3	8.5
Jamaica weakfish	1.2	1.2	1.0	1.0	1.2	1.1	0.7	0.5	0.2	0.9	0.4	8.1
Mullet	0.6	0.5	0.5	0.5	0.5	0.7	0.8	0.9	1.9	0.8	0.5	6.9
Mistura	1.0	0.9	1.0	1.0	0.8	0.7	0.6	0.4	0.2	0.7	0.3	6.6
anchovy	1.2	0.7	0.7	0.8	0.4	1.0	0.5	0.5	0.2	0.6	0.3	5.8

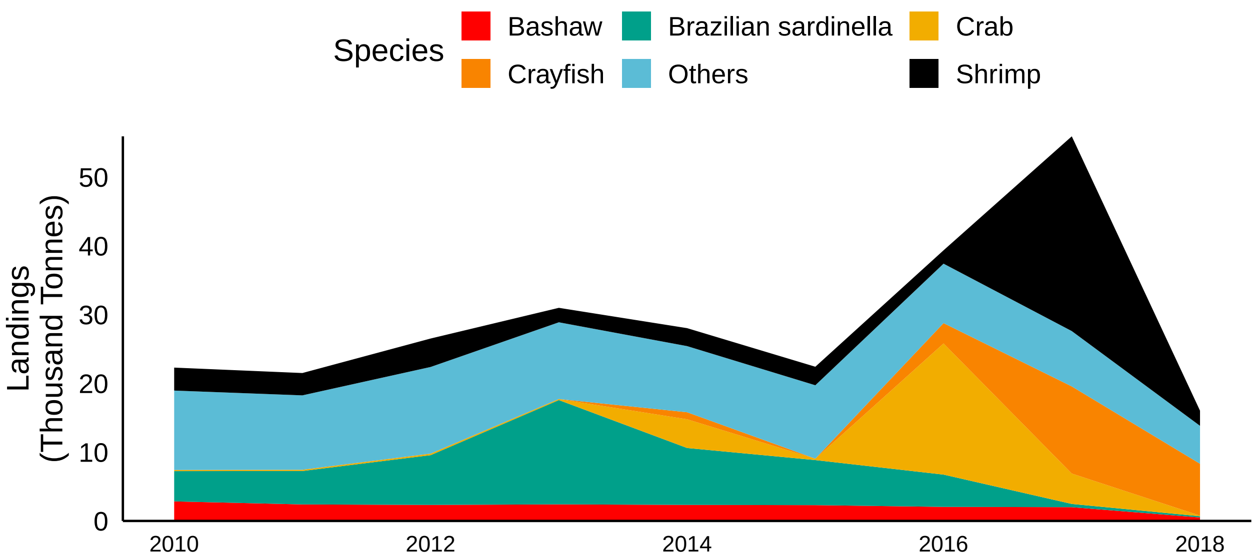


Figure 14: Main landed species in São Paulo state from 2014 to 2018. Dataset UNIVALI. Bashaw is also known as croaker

Table 11: Aquaculture production in Brazil by group of species in 2017. Dataset PeixeBR

Species group	Production (Thousand tonnes)	Percent (%)
Tilapia	357.64	46.3
Native fish	302.24	39.2
Shrimp	80.00	10.3
Others	31.82	4.1

According to the Brazilian fish farming association (PeixeBR), the aquaculture industry is the fastest growing food production sector in the country (PeixeBR 2018). Brazil has some the largest potential for aquaculture in the world and will become a significant producer of fish in the next years. Fish farming has been growing around 8% per year in recent years, with a large increase in farming of native fish, especially in the north and middle-west regions. Additionally, Brazil is the fourth largest producer of tilapia in the world, with rapidly growing industries in the south and northeast regions. Another important aquaculture industry in the country is shrimp farming in the northeast region, although it has not been growing the production in recent years (Table 11). According to PeixeBR, there was a total production of about 690 thousand tonnes of fish in 2017 (plus about 80 thousand of shrimp, which totals about 771 thousand tones). Thus, aquaculture products are already an important source of food for Brazil and has the perspective to grow rapidly in the future.

Fish Trade

Despite a large potential for seafood production from both capture fisheries and aquaculture, Brazil imports large quantities of seafood for domestic consumption. In 2017, Brazil imported more than 380 thousand tonnes of fish and seafood products, while exporting less than 10% of that value (Figure 15). Local production is clearly insufficient for meeting national seafood demand, and fish stock recoveries and increased aquaculture production are required to support national food supply.

Fish and seafood import data show that the main imported species in the last four years were salmon, followed by sardines, catfish (*Pangasius*) and hake (Table 12). There was a major increase in the import of sardines in the last two years, from 17 thousand tonnes imported in 2015 to 90 thousand tonnes in 2017. This increase is

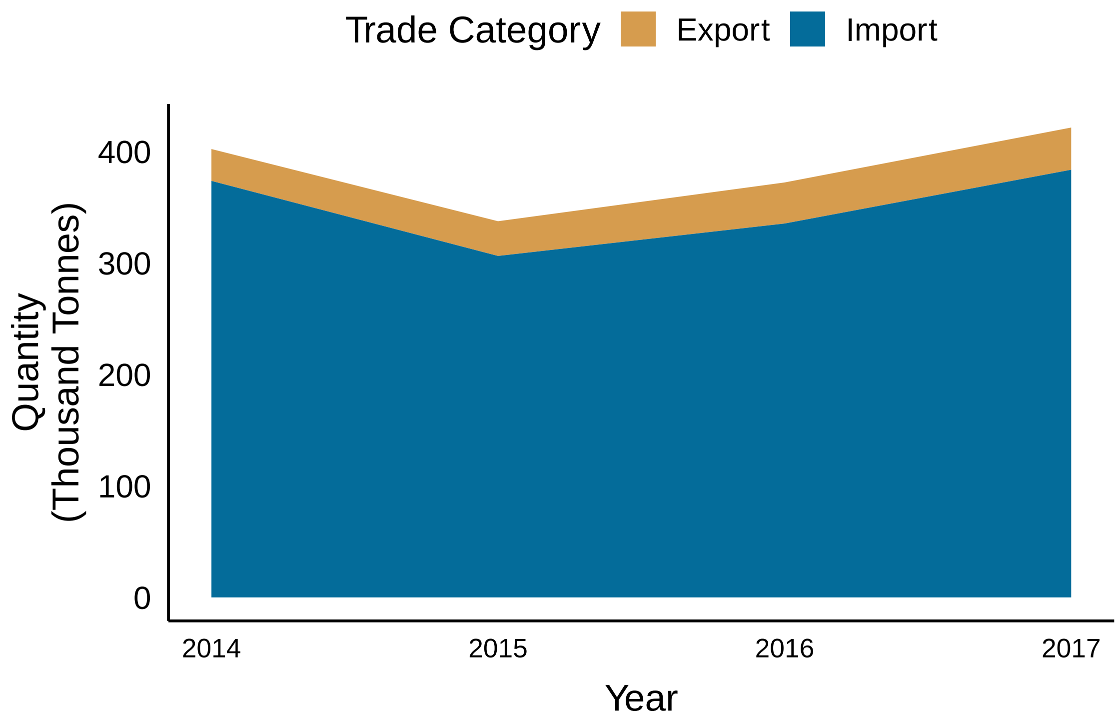


Figure 15: Seafood and fish imports and exports from Brazil between 2014 to 2017. Source: MDIC.

mainly result of the decline in sardine catches from the industrial fleet (Figure above for Santa Catarina).

According to information from research developed about this fishery, about 100 thousand tonnes of sardine was landed in 2014 followed by a decline to about 20 thousand tonnes in 2017 (Pincinato and Asche (2018)). According to the authors, this decline is mainly because of environmental variability in the south of Brazil and “El Niño” events that occurred during that period. Thus, Brazilian sardine and imports form a fully integrated market, which maintains a steady supply of sardines to canary industries year-round.

Fresh Water Fish in the Amazon

Fisheries production in Amazon state is exclusively from riverine systems and artisanal fisheries. According to estimates from the state government, production has remained stable over the last decade, totaling around 200 thousand tonnes per year (Figure 16). From the estimated production, about 40% of the catch is for subsistence of riverine communities.

Table 12: Main species imported from 2014 to 2017 in Brazil. Dataset MDIC. Thousand Tonnes.

Product	2014	2015	2016	2017	Mean	s.d	Total
All Other Categories	294.3	247.0	279.1	327.4	287.0	33.4	1147.8
Atlantic and danube salmon, chilled	72.4	75.8	65.0	71.8	71.2	4.5	284.9
Sardines	23.1	17.9	73.0	93.1	51.8	37.1	207.1
Catfishes	45.7	30.7	33.7	43.0	38.3	7.2	153.1
Hake and abrotea fillets	30.5	24.2	24.3	34.1	28.3	4.9	113.0
Alaskan hake fillets	37.0	34.1	19.4	20.1	27.7	9.2	110.6
Misc. Fish salted (excl. herrings, cod, anchovies)	14.1	12.3	17.1	23.8	16.8	5.0	67.4
Misc. fish frozen	27.7	18.7	14.4	5.2	16.5	9.4	66.1
Dogfish and other sharks	17.4	12.8	15.9	19.5	16.4	2.8	65.6
Atlantic, Pacific, and danube salmon, frozen	15.2	12.3	8.4	6.7	10.6	3.8	42.6
Other fish	11.2	8.1	7.9	10.2	9.3	1.6	37.4

* the category Other fish is from the MDIC dataset while all other categories represents the aggregate of the categories not shown in the table.

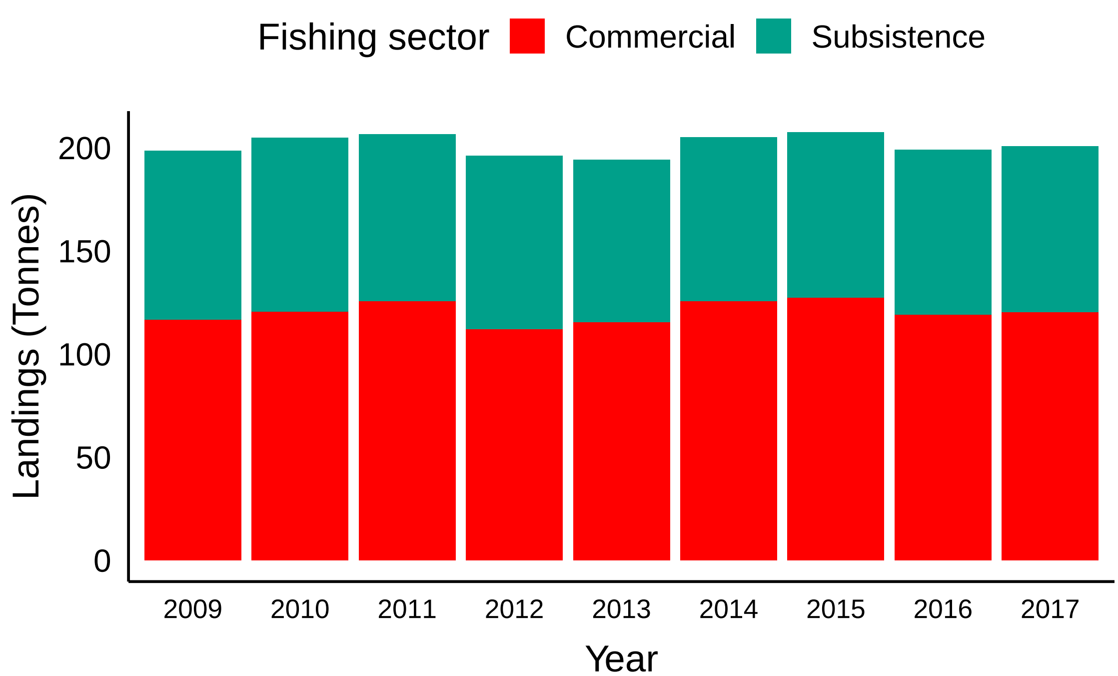


Figure 16: Fresh water fish landings in the Amazon state from 2009 to 2017. Dataset:: Amazon state government

National Seafood Supply

Using data from FAO and quantity imported and exported, it is possible to estimate the amount of seafood that is consumed in Brazil per year. The estimated consumption of seafood in Brazil is based on 760 thousand tonnes from capture fisheries plus 750 thousand tonnes from aquaculture and 380 thousand tonnes from imports, minus 37 thousand tonnes for exports. This results in an estimated 1.86 million tonnes of seafood consumed in Brazil. Assuming equal consumption per capita for the total population of 200 million, this would suggest a yearly consumption of about 9.3 kg per capita.

Domestic consumption of fish and seafood in Brazil is estimated to be around 10 kilograms per capita per year (FAO (2018)). Per capita consumption in Brazil is low relative to other countries (average of 18 kg in the world) and the World Health Organization recommendation of 12 kg per capita. However, fish and seafood consumption has been steadily increasing from 4.6 kg per capita in 1961 to about 10 kg per capita in 2014 (FAO). Because of Brazil's large population (about 200 million people), this sums up to large amounts of seafood being consumed in the country, although consumption significantly varies across regions of the country. Additionally, estimates from FAO do not account for subsistence consumption of fish, that in some regions of the Amazon can be as high as 169 kg/capita/year (Isaac, Almeida, and Giarrizzo (2015)). According to estimates from the fisheries department of Amazon state, about 80 thousand tonnes of fish are caught for subsistence by riverine communities (Figure 16).

Data from CEAGESP market suggests that the main species consumed in Brazil in 2017 was sardine, followed by tilapia, croaker, salmon, sharks and weakfishes (Table 13), supporting results from intergovernmental data analysis (see Figure 6). Of these species, tilapia and salmon are produced through aquaculture and the remaining are from fisheries. In São Paulo market alone, 4.2 thousand tonnes of tilapia were traded, with a total for all fish and seafood products of 42 thousand tonnes in 2016 and 37 thousand tonnes in 2017.

Table 13: Main species commercialized in CEAGESP market, Sao Paulo, Brazil in 2017. Thousand Tonnes. Dataset: CEAGESP.

Species	Quantity	Percent
Sardine	6.1	16.4
Tilapia	4.2	11.5
Croaker	3.7	10.0
Salmon	2.4	6.6
Shark	2.4	6.4
Maria mole weakfish	2.1	5.8
Triggerfish	2.0	5.5
Goete weakfish	1.6	4.4
Brazilian codling	1.6	4.2

Data from SIGSIF shows that the main species processed in the country in 2017 was tilapia, followed by tambaqui or cachama (*Colossoma macropomum*), sardine, croaker, salmon, tambatinga (hybrid aquaculture species from the Amazon), catfish, and tuna (Table 14). From the top 10 species processed in the country, 5 are from aquaculture production and 5 are from wild caught fisheries. A total of 360 thousand tonnes of fish and seafood products were commercialized by 472 processing and distribution companies. This volume corresponded to about 20% of all estimated seafood consumed in the country (1.8b tonnes).

Table 14: Main species comercialized by seafood industries with SIGSIF certificate in Brazil. Thousand Tonnes. Dataset:: Ministry of Agriculture.

Species	Percent	Production
Tilapia	11.5	41.5
Cachama	7.6	27.4
Sardine	7.4	26.8
Croaker	6.0	21.6
Salmon	5.9	21.3
Tambatinga	5.2	18.7
Catfish	4.4	16.0
Tuna	4.0	14.3
False herring	3.6	13.0

Figure 17 shows the regional patterns of the data from seafood processing industries (SIGSIF). The map on the left (producers) shows the quantity of fish and seafood products that entered industries directly from producers (fisheries and aquaculture). This map provides insights on the main producing states and location of seafood industries. According to this map, the Rio de Janeiro state has the largest density of seafood industries in the country. The map on the right (commerce) shows the quantity of fish and seafood products received from other seafood industries. In other words, the map shows the exchange of products between seafood industries. Because the map shows the receiving sates, it provides important insights on the consumption of seafood products per region. It is important to highlight that Santa Catarina state shows high quantity of fish and seafood products received, but not necessarily means there is high consumption. This happens because Santa Catarina State is where most of the sardine and tuna canaries are located. Such canned products are produced in these states and then distributed and consumed all over the country.

Consumption of fish and seafood products in Brazil increases significantly during religious dates. Data from CEAGESP suggests that seafood consumption increases during Easter, when other types of meat are not consumed in respect of Catholic tradition. For this reason, there is a significant peak in fish and seafood consumption during Easter week (Figure 18).

Fish and seafood consumption in Brazil has distinct patterns according to the region of the country. As shown in IBGE data, the top consumers of fish and seafood products in the country are from the north and northeast regions (Figure 19-A). These regions are the poorest of the country (Figure 19-B) and have the greatest number of registered fishers (Isaac and Almeida 2011), especially from the small-scale sector.

Since most of the artisanal production is consumed locally, these regions have greater availability of fish and seafood products relative to capitals far from fishing activities. In addition to greater availability of fish and seafood products, the North and Northeast regions of Brazil have, in general, greater tradition of consuming seafood products. Because of extensive areas of coastline, the northeast region has tradition of eating seafood in restaurants close to the ocean, especially in the summer. Similarly, the North region has extensive areas of rivers and coast, being part of the culture to eat fish and seafood products. In other parts of the country, people traditionally eat other types of protein. Brazil has historically been a agriculture and livestock production country, with large tradition of eating barbecue and bovine meat. In many places there are cultural barriers for regularly consuming fish and seafood products. However, with increased aquaculture production, many of these states are now producing more fish and as consequence are starting to eat more fish. In addition, people are increasingly aware of the health benefits derived from eating fish and seafood products. In summary, the north and northeast regions are the greatest consumers of fish and seafood in the country because of the availability and tradition of consuming fish and seafood products. Because these regions are the poorest of the country, fish and seafood products are crucial for food security, especially in coastal and riverine areas.

In the North and Northeast regions, where consumption of seafood is highest, it is important to distinguish

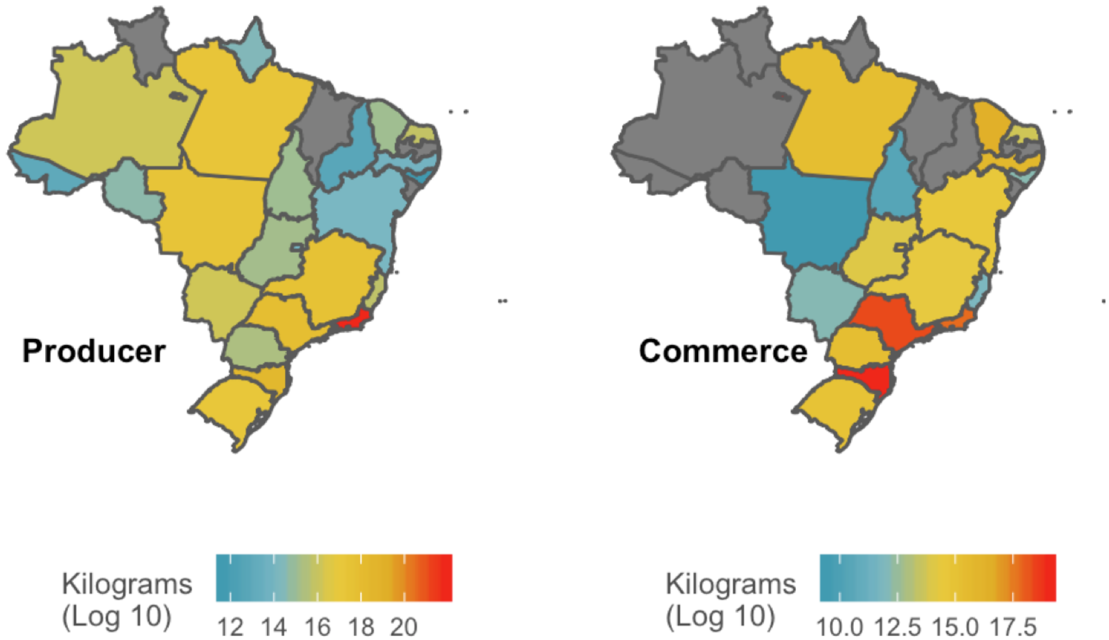


Figure 17: Regional patterns seafood processing industries in Brazil. Producers: quantity of fish and seafood products that entered industries directly from producers. Commerce: quantity of fish and seafood products received from other seafood industries. Logarithmic scale. Dataset CIGIF

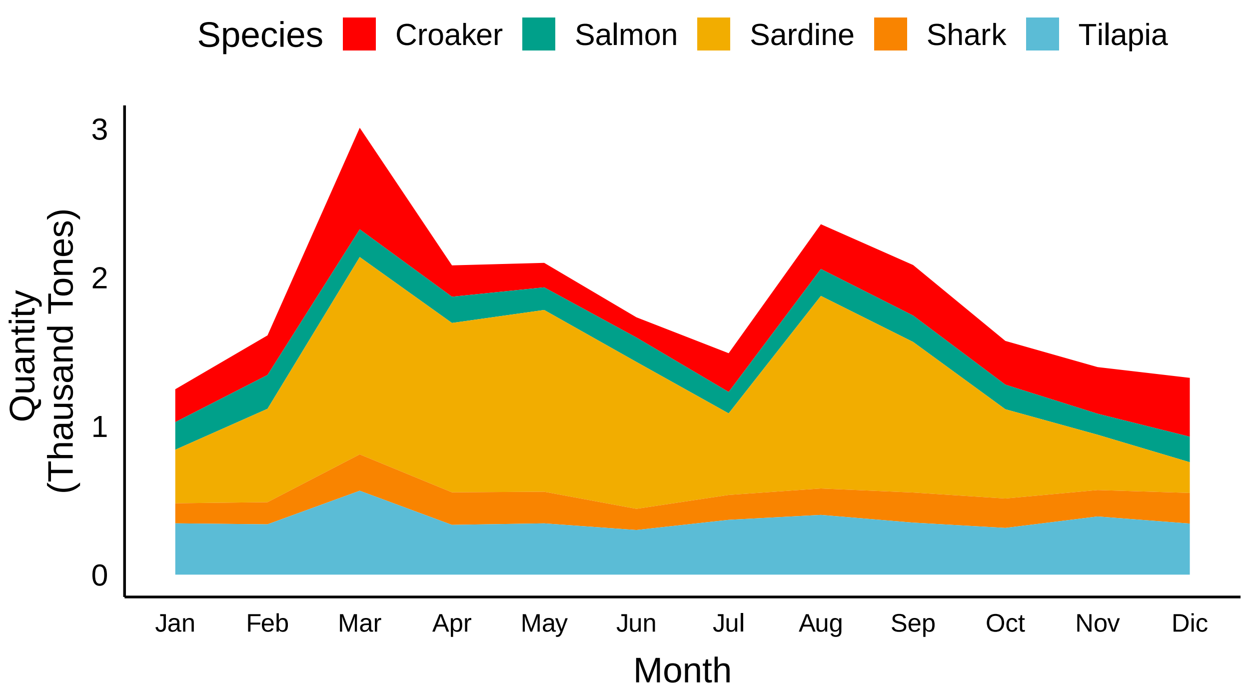


Figure 18: Quantity of seafood products commercialized per month in 2017 at CEAGESP market. Dataset CEAGESP

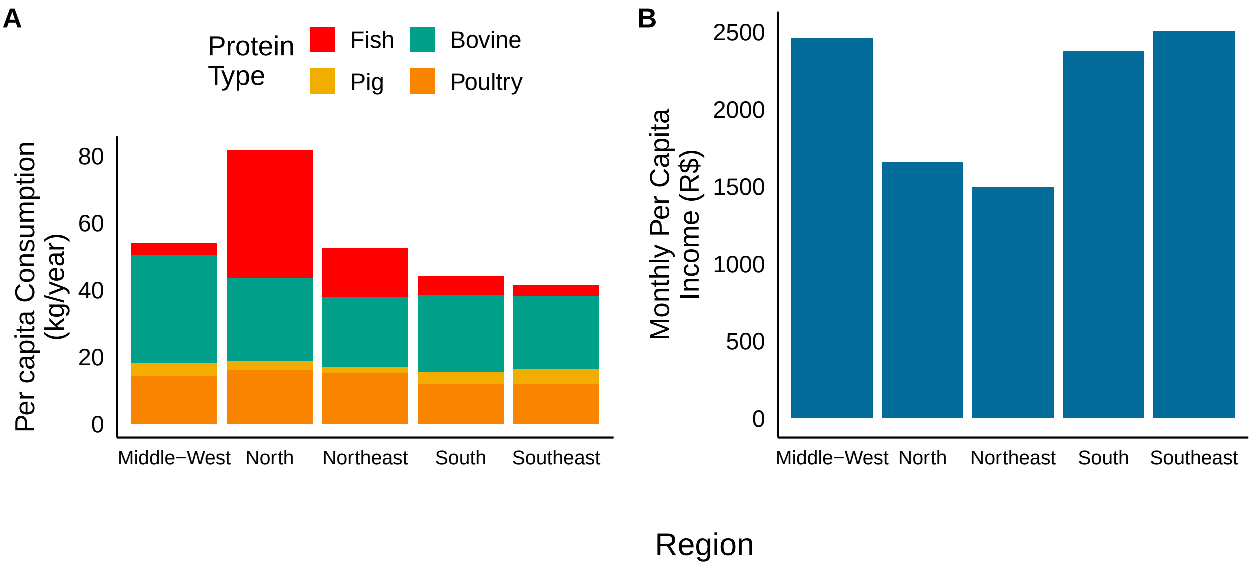


Figure 19: (A) Per capita consumption of protein types and (B) monthly per capita income per region in Brazil. Dataset IBGE

resources that are important for food security in coastal and riverine areas. Generally, while the most valuable species are usually sold for profit, smaller and less valuable fish are consumed by fishers and their families. Hundreds of species are consumed in these regions, with very little information on the most important species for food security.

For those people not involved directly in fishing activity, consumption of fish and seafood products is expensive relative to other protein types (Figure 19-B). Fish and seafood products (R 32, \$US ~9) are on average three times more expensive than poultry (R 10, \$US ~3), twice the price of pig meat (R 15, \$US ~ 4) and 25% more expensive than cow meat (R 23.18, \$US ~6).[7] Such difference in price ca explain in part the low consumption of fish and seafood products in Brazil, especially during an economic crisis. In many cases, consumption of fish and seafood products are mostly in restaurants as a "fancy" dinner and not a meat for the day-to-day life.

In addition to elevated prices, frozen seafood products available in supermarkets are many times unreliable and with poor quality. According to the Ministry of Agriculture, seafood fraud was detected in 21% of the fish sold in supermarkets. In addition, a preeminent newspaper article pointed out that 70% of frozen fillets sold in supermarkets had excess water, reaching up to one third of the total weight of the fish. This practice makes the product even more expensive and discourages people from buying seafood products (Folha de SP, 2008). Therefore, for the average consumer, seafood products are expensive and unreliable relative to other protein options. This explains in part low seafood consumption levels in many parts of the country.

Data on the main species consumed in Brazil suggests that consumers are mostly driven by price, although there are some exceptions. From the top 10 seafood products sold in CEAGESP, 6 where below the 0.5 percentile of prices (Table 15). This indicates that the primary driver of domestic consumption is affordability. However, there are some exceptions, such as salmon, shark and shrimps. Consumption of these species are mainly driven by desirability, supplying high-end markets and restaurants. Species such as salmon and shrimp have high demand because of their distinct flavor and color. Other species, especially white fish can be more easily substituted by other similar fish.

The aquaculture industry in Brazil has been growing rapidly. In the North region, farmed fish is already affecting the market and reducing prices. Today, a large portion of the fish consumed in the region is produced by aquaculture. Tilapia is already the second most commercialized species in the CEAGESP market in São Paulo and the top species processed by seafood companies in the country. Cachuma (or Tambaqui) is a native

[7] Institute for Agricultural Economics, http://www.iae-bg.com/en/

Table 15: Price (RS/Kg) and quantity (Thousand Tonnes) of main species commercialized in CEAGESP market, Sao Paulo, Brazil in 2017.

Species	Quantity	Price	Pirce (Percentile)
Sardine	9.7	3.6	0.2
Tilapia	4.4	5.8	0.5
Croaker	3.6	4.1	0.3
Maria mole weakfish	2.9	3.8	0.3
Shark	2.2	8.2	0.6
Salmon	2.1	30.9	1.0
Triggerfish	1.9	3.5	0.2
Shrimp	1.8	25.2	1.0
Goete weakfish	1.5	3.4	0.2

[*] 1Brazilian Real (RS) = 0.26 US Dollar

species farmed in the north and mid-west regions and is the second most processed fish by seafood industries in Brazil. Therefore, with the expansion of the aquaculture industry in the country, the domestic supply of seafood will increase thus increasing accessibility of fish and seafood product for Brazil's population.

National Economic Participation

Because there is no reliable national-level landings data in Brazil since 2008, it is challenging to determine the top fisheries by income generated in the country. Data available are mainly from the industrial sector, where sardines, croaker and tuna are the main species caught. However, information from the SIGSIF (Table 15) and Santa Catarina state landings does not have any information on price.

A report by Nielsen analytic (Nielsen, 2018) shows that the canned sardine market in Brazil is valued at about 1.4 billion Brazilian Reais (approx. US$ 380 million) and the canned tuna market is worth about 145 million Brazilian Reais (approx. US$ 39 million). Additionally, according to the Brazilian seafood industry association, seafood industries have an aggregate revenue of 8 billion Brazilian Reais (approx. US$2.2 billion) per year. These numbers demonstrate the strength of the seafood market (especially canned market) in Brazil and the importance of sardines for income and food security in the country.

Data from CEAGESP market have important information on the value of seafood in the country. This database contains quantity and price information for all seafood products. Products sold in the market are both from industrial and artisanal sectors. Table 17 shows the main species ranked by value sold in the CEAGESP market in 2017. The most valuable species in this year were sardines followed by sharks, croaker, tuna and acoupa weakfish (Table 16).

Sharks are not distinguished by species and are both imported an captured by both artisanal and industrial fleets. Sardines, croakers and tunas are caught mainly by the industrial fleet, while the acoupa weakfish is mainly caught by artisanal fisheries from the north and northeast regions of Brazil. Snook is also one of the top 10 species sold in the market and mainly captured by the artisanal sector. It is one of the species with highest price in the market.

Table 16: Value of main species comercialized (million Reais) in 2017 at CEAGESP fishmarket, Sao Paulo, Brazil (Source: CEAGESP)

Species	Value (RS)	Percent
Sardine	26.3	14
Shark	19.4	11
Croaker	16.6	9
Tuna	14.8	8
Acoupa weakfish	11.9	6
Maria mole weakfish	8.9	5
Squid	8.2	4
Triggerfish	7.0	4
Brazilian codling	6.4	3
Goete weakfish	6.1	3

* 1 Brazilian Real (RS) = 0.26 US Dollar

Many important small-scale resources are not sold in the CEAGESP market but are important sources of income through sale in local markets. Resources such as crabs, lobsters, mullets, shrimp, snappers and groupers are very important sources of income for small-scale fishers. Only from our databases there are over 500 different species reported. For example, in São Paulo state most of the production is from small-scale fisheries sector. In this state, total fisheries value has increased in latest years, fluctuating at around one million reais per year (Figure 20). If we divide total value (1 million) by the number of registered fishers in the state (26 thousand), there is an annual income of about 37 thousand per fisher. In this state, shrimps, crab and crayfish are the most important species in terms of value (Table 17).

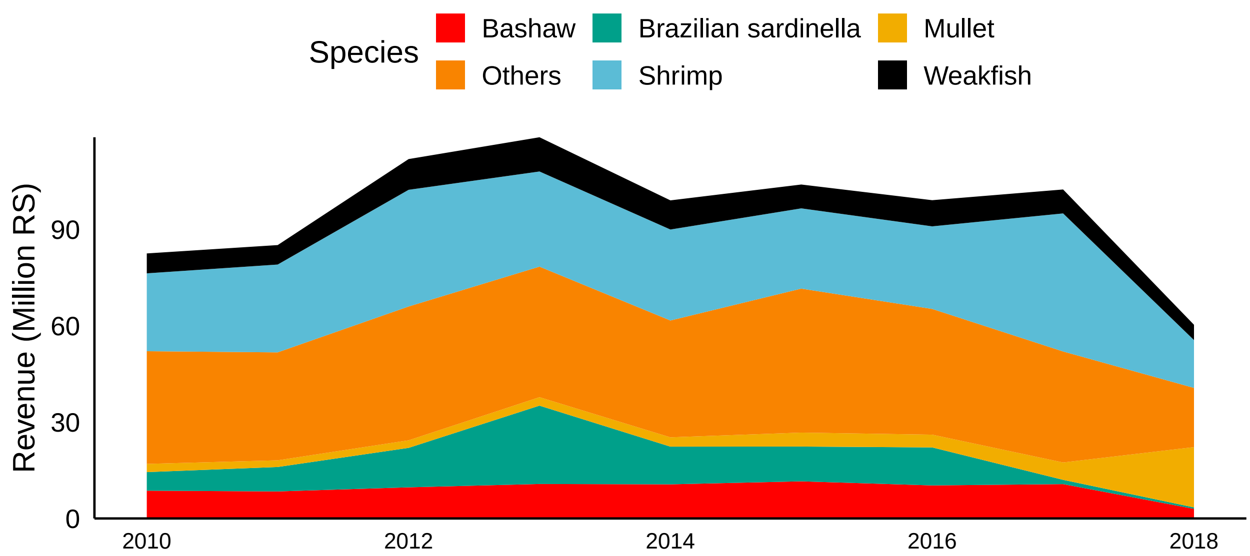


Figure 20: Main species in terms of fishing revenue in São Paulo state from 2014 to 2018. Dataset UNIVALI. Bashaw = is also known as Croaker. 1 RS = 0.26 USD

Table 17: Landing value of main species caught in São Paulo state, Brazil from 2010 - 2018 (Source: Univali). Mean and s.d of 2014-2018. Million Reais (R)

Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean	s.d	Total
Shrimp	24.2	27.3	36.3	29.6	28.3	25.0	25.7	43.0	14.9	17.2	12.8	361.2
Brazilian sardinella	5.8	7.6	12.3	24.4	11.7	10.8	11.8	1.3	0.4	8.1	7.8	169.1
Bashaw	8.6	8.4	9.7	10.7	10.6	11.6	10.3	10.7	3.0	6.4	4.2	135.4
Octopus	5.2	5.3	9.3	10.8	7.2	10.9	11.1	3.3	2.3	5.6	4.3	116.6
Weakfish	6.2	6.1	9.6	10.7	9.1	7.4	8.1	7.5	4.8	5.0	3.3	105.3
Mullet	2.6	2.1	2.4	2.6	2.9	4.4	4.0	5.4	18.8	2.8	4.0	58.1
Jamaica weakfish	2.8	2.7	2.2	2.3	4.0	3.8	2.4	2.1	0.7	2.1	1.6	44.5
anchovy	3.0	2.1	1.8	3.2	2.0	3.8	1.9	2.6	1.0	1.7	1.0	36.7
Carolina Whiting	1.6	1.5	1.2	1.5	1.4	1.6	1.6	1.2	0.4	1.1	0.7	23.3
Mistura	1.4	1.3	1.4	1.5	1.3	1.0	1.0	0.8	0.3	0.9	0.6	19.3

Another important piece of information regarding income generated are the main species exported in Brazil. Data from the Ministry of Development, Industry and Foreign Trade (MDIC) show that the main species exported are lobsters, followed by other fish, swim bladders and pelagic fish (tunas and swordfish) (Table 18). The main species exported, lobsters, are caught exclusively by the artisanal sector, with resources threatened by over exploitation (according to the Ministry of Environment). Because of the high value, the lobster fishery is profitable even when the resource is depleted. Exports of lobsters in Brazil reached a staggering US$ 73 million in 2017, with no reported landings of the species in the country.

Table 18: Main species imported from 2014 to 2017, Brazil. Million USD. Dataset: MDIC.

Product	2014	2015	2016	2017	Mean	s.d.	Total
Rock lobster and other sea crawfish	65.2	65.5	59.9	73.9	3.11	3.32	264.48
Other fish, excluding livers and roes	44.3	48.3	63.1	66.6	0.59	0.78	222.24
Heads, tails, and swim bladders of fish	19.6	19.6	19.1	15.6	1.54	0.38	73.86
Frozen skipjack or stripe-bellied bonito	11.2	13.0	10.4	11.5	1.15	0.75	46.06
Freshwater ornamental fish	13.5	9.0	6.2	6.0	0.72	0.41	34.68
Miscellaneous fish	2.4	5.6	15.1	10.2	0.70	0.52	33.37
Shrimps and prawns	8.5	7.3	7.2	3.0	0.46	0.31	25.96
Fish livers and roes	5.8	7.1	6.8	NA	0.73	0.76	19.70
Swordfish (Xiphias gladius	2.6	4.2	6.1	6.4	0.40	0.21	19.18
Bigeye tunas Thunnus obesus	2.5	4.9	5.4	5.4	0.38	0.22	18.23

Employment in Wild Capture Fisheries

As pointed out in the introduction, Brazil has no reliable data on the number of fishers in the country. To respond this question we put together several pieces of information from different sources to have an estimate of the importance of fisheries for employment in Brazil.

Data from IBGE (2013) suggests that Brazil had about 500 thousand fishers throughout the country, with 90% from the small-scale sector and 10% from the industrial sector (Campos and Chaves 2016). However, data from the extinct Ministry of Fisheries and Aquaculture (MPA) suggests there are many more fishers in Brazil (Figure 21). According to these data, there were about one million registered fishers in 2013 throughout the country, with about 95% of the registered fishers from the small-scale sector (MPA). There is a large discrepancy between these two sources, which reiterates the uncertainty around estimates of the number of

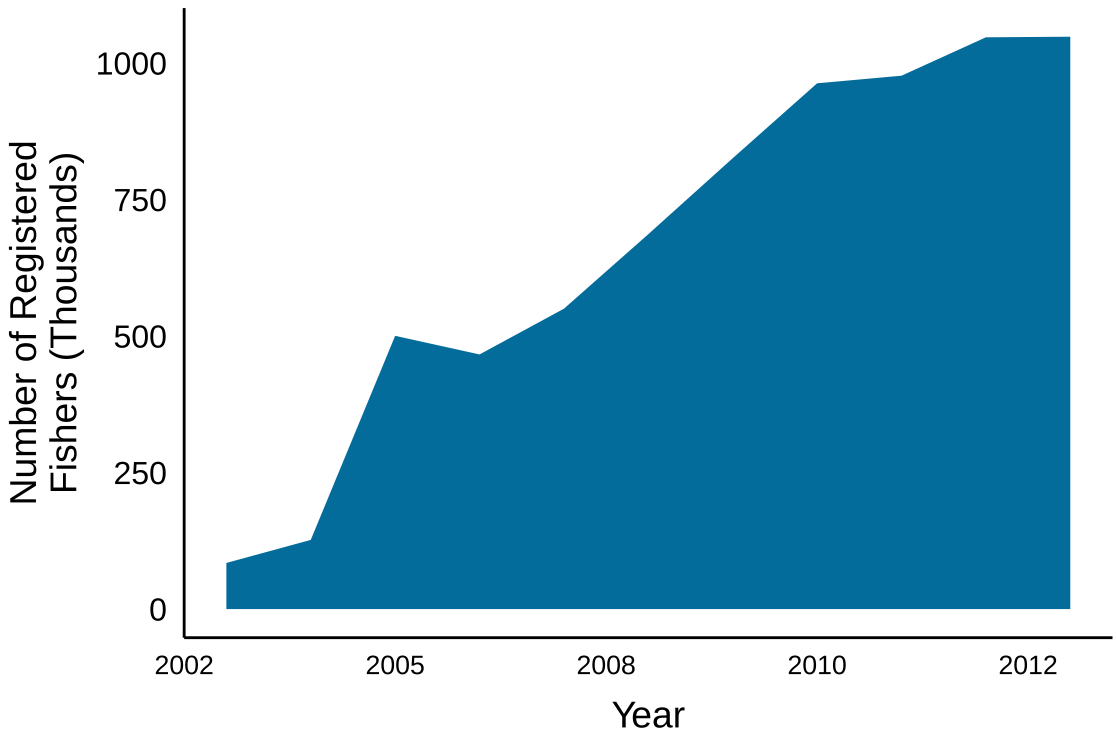


Figure 21: Number of registered fishers in Brazil from 2003 to 2010. Dataset: Ministry of Fisheries and Aquaculture

fishers in the country. Nonetheless, these numbers highlight the huge importance of the fisheries sector for employment in Brazil.

Artisanal sector

Assuming that the number of fishers are between 500 thousand and 1 million, and that about 90% of them are from the small-scale sector, the most important fisheries for employment in the country are those from the artisanal sector. The artisanal sector is where we have the least amount of data on the production and species harvested. There is an estimate from the extinct MPA that 50-70% of the catch from the entire country comes from the artisanal sector (MPA, 2013). Small-scale fisheries in Brazil target hundreds of species and there is no reliable information on the most important species for this sector.

Most of the registered fishers in Brazil are from the North (37% of total registered fishers) and Northeast regions (52% of total registered fishers) (Figure 22). In these regions, freshwater resources from the Amazon and estuarine fisheries are very important. From the Amazonas state, the top commercialized fish are: curimatã (*Prochilodus nigricans*), jaraqui (*Semaprochilodus spp.*), matrinchã (*Brycon amazonicus*), pacu *(Mylossoma duriventre*), tambaqui (*Colossoma macropomum*) and tucunaré (*Cichla monoculus*) (data from the secretary of fisheries in the Amazon state - (SEPOR 2017)). In estuaries, there are many important resources such as the mangrove crabs, shrimps, bivalves, weakfish and snook (information gathered though literature review and interviews). Besides these fisheries, small-scale fishers target all ecosystems and resources, such as pelagic, reefs, demersal and coastal. In the Northeast region for example, reef fisheries are very important, capturing some highly valued species such as snappers, groupers and lobsters. In the south, the mullet fishery is very important, with the first quota system for Brazil implemented in 2018 to manage this fishery (Mcdermott 2018). Therefore, the artisanal sector is a multi-species fishery, with the main species depending on the region and ecosystem.

Employment along the supply chain varies according to the region, fisheries and species commercialized. In

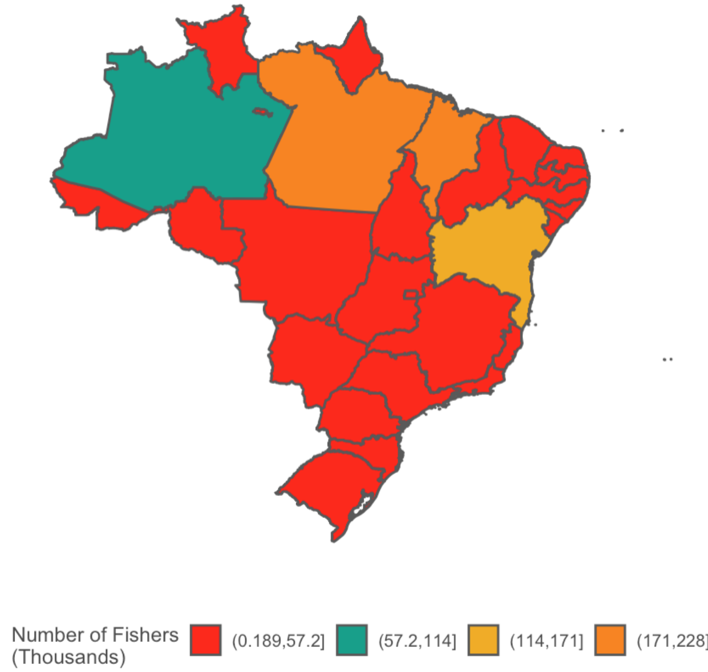


Figure 22: Number of registered fishers per state in Brazil. Dataset SIGIF

the artisanal sector, most of the catch is consumed regionally, or in nearby capitals. However, some valuable fish and seafood are also commercialized in the main capitals - São Paulo and Rio de Janeiro. These fish are sold through middlemen and larger seafood industries to large capitals, thus involving a larger number of people in the supply chain. However, there is no reliable estimate on the total number of people employed in the supply chain of artisanal fisheries. The extinct Ministry of Fisheries and Aquaculture estimates that there are about two million people involved in these fisheries (MAPA 2013).

Industrial sector

Industrial fisheries in Brazil employ only about 5% of fishers and is responsible for about 30-50% of the fisheries production. The industrial sector in Brazil is mainly concentrated in the south of the country, especially in Santa Catarina state where the main industrial fisheries port is located Itajai port. Landings data from Santa Catarina state indicate that sardines are the most important species, followed by corvina and skipjack tuna (Table 19). Another important industrial fisheries fleet is located in the mouth of the Amazon river, in the north of Brazil. The main resource captured in the region is the catfish piramutaba (*Brachyplatystoma vaillantii*), although there is no data available from this fleet. Therefore, the top fisheries by employment in the industrial sector are represented in the landings data from the Santa Catarina state and the piramutaba fishery in the north.

In the industrial sector, the majority of the catch is processed by large companies to be distributed in supermarkets and restaurants all over the country. According to data published by the Seafood Industry Association (ABIPESCA), the seafood industry employs about 8 thousand direct employments and 30 thousand indirect employments. Data from the seafood companies (SIGSIF) indicates that the most important industrial fisheries are sardines, croacker, tuna and piramutaba catfish (Table 20). Thus, the industrial sector employs relatively less people per tonne of captured fish compared to the artisanal sector.

Table 19: Main species commercialized (thousand tonnes) by seafood industries with SIF certificate in Brazil (Source: Ministry of Agriculture)

Species	Quantity	Percent
Sardine	26.8	11.5
Croaker	21.6	9.3
Tuna	14.2	6.1
False herring	13.0	5.6
Piramutaba catfish	11.9	5.1
Weakfish	10.8	4.6
Argentine croaker	9.8	4.2
Hake	8.8	3.8
Zabaleta anchovy	8.5	3.7
Skipjack tuna	8.0	3.4

Results Chile

Fisheries Context

There are three subsectors that supply seafood in Chile for domestic and international consumption; aquaculture, and industrial and artisanal fisheries, which are mostly commercial. Despite being recognized as a major producer of salmon, Peruvian anchoveta and Araucarian herring, Chile presents a high diversity of species that are used in the seafood industry. Important fisheries range from valuable endemic invertebrates like the loco (*Concholepas concholepas*) to large migratory pelagics like giant jumbo squid. This biological diversity together with the heterogeneity of the sectors involved must be considered when addressing the relevance of fisheries and aquaculture for national food and economic security.

The composition of catch and harvest varies between subsectors as well as the supply chains that their raw material enters. These differences could highly impact the quantity and quality of seafood that different socio-economic groups can access. Thus, identifying what are the different species being harvested in each subsector, and where and how are they processed and commercialized is the first step to define cost-effective strategies to improve access to seafood and employment. In this report, we used available information to characterize and analyze the role of different sectors in national food security and Chilean economy as a first step to identify main actors and species.

Wild-caught fish

According to landing records from SERNAPESCA over the last five years, the artisanal sector lands on average 1.6 ± 0.58 million annual tonnes of marine species while the industrial sector lands around 0.9 ± 0.16 million tonnes per year. Is worth noting that large part of the artisanal landings are of algae and benthic species that are not targeted by the industrial sector. Both sectors have among their most landed species the Peruvian anchoveta (*Engraulis ringens*) and the Araucanian herring (*Strangomera bentincki*), two species that are mostly used as inputs for fish meal and oil (Figure 23). Other important species in artisanal landings are the Giant grey kelp (*Lessonia nigrescens*), exported mostly as dried algae, and the jumbo squid (*Dosidicus gigas*), mostly commercialized fresh or frozen for human consumption (HC). The Chilean jack mackerel (*Trachurus murphyi*) is also an important fishery in terms of volume for the industrial sector, which is also mostly used in the production of fish meal and oil and to a lesser extent for direct HC.

Over the last years the catch composition of the artisanal sector has presented no major changes (the abrupt increase in artisanal landings for 2015 was identified as a data error in SERNAPESCA's records (See Appendix Chile Methods 1). In the case of the industrial sector, composition of the main species is also stable over the last years. Yet, the landings of Peruvian anchoveta (*Engraulis ringens*) started declining in 2014 relative to previous years, increasing the relevance of the Chilean jack mackerel (*Trachurus murphyi*) (Table 20).

SAU and FAO databases also identify Peruvian anchoveta (*Engraulis ringens*), the Araucarian herring (*Strangomera bentincki*) and the Chilean jack mackerel (*Trachurus murphyi*) as the main landed species in Chile.

Regional Diferences in volumes of wild-caught fisheries

Landings varies widely along the coast of Chile for both artisanal and industrial sectors. Figure 24 shows the mean total landing per sector and region. The color of the bars represents the most landed species in 2017. We observe that the VIII region is by far the region with most landings from both sectors. However, the industrial sector, also concentrates landings in the north of the country. Artisanals are spread throughout the country. The most landed species vary geographically but tend to be the same over the years (Appendix Results Chile 1 and 2).

Aquaculture production

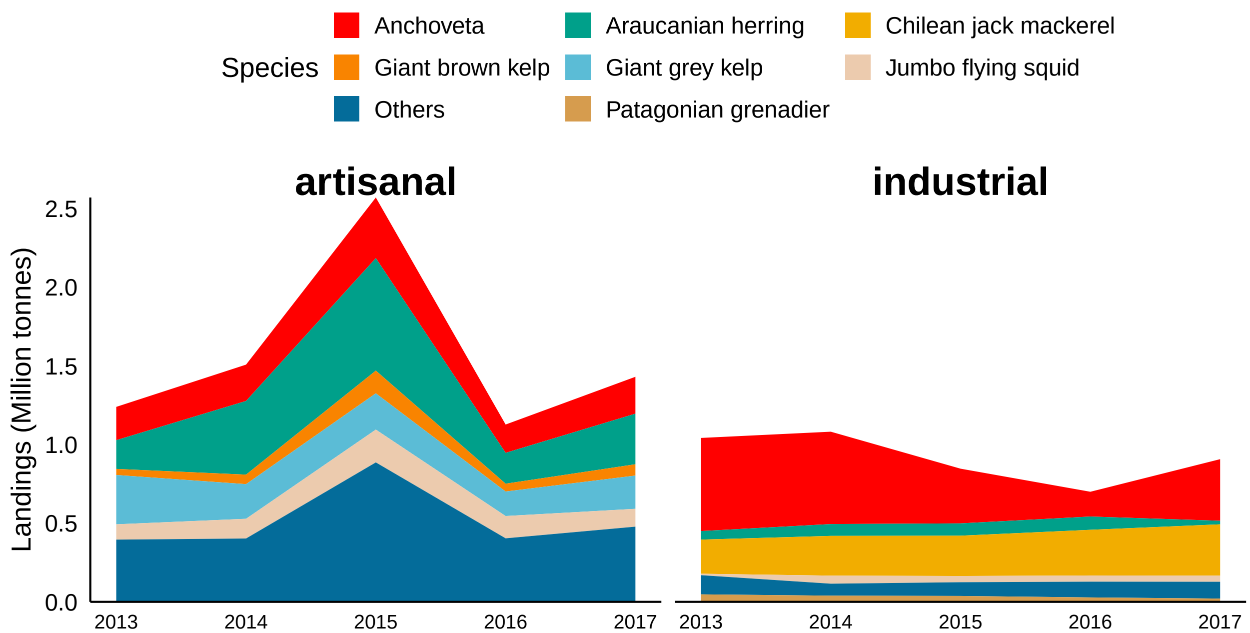


Figure 23: Main species landed in Chile by the artisanal and industrial sector between 2013 and 2017. Data SERNAPESCA, 2018.

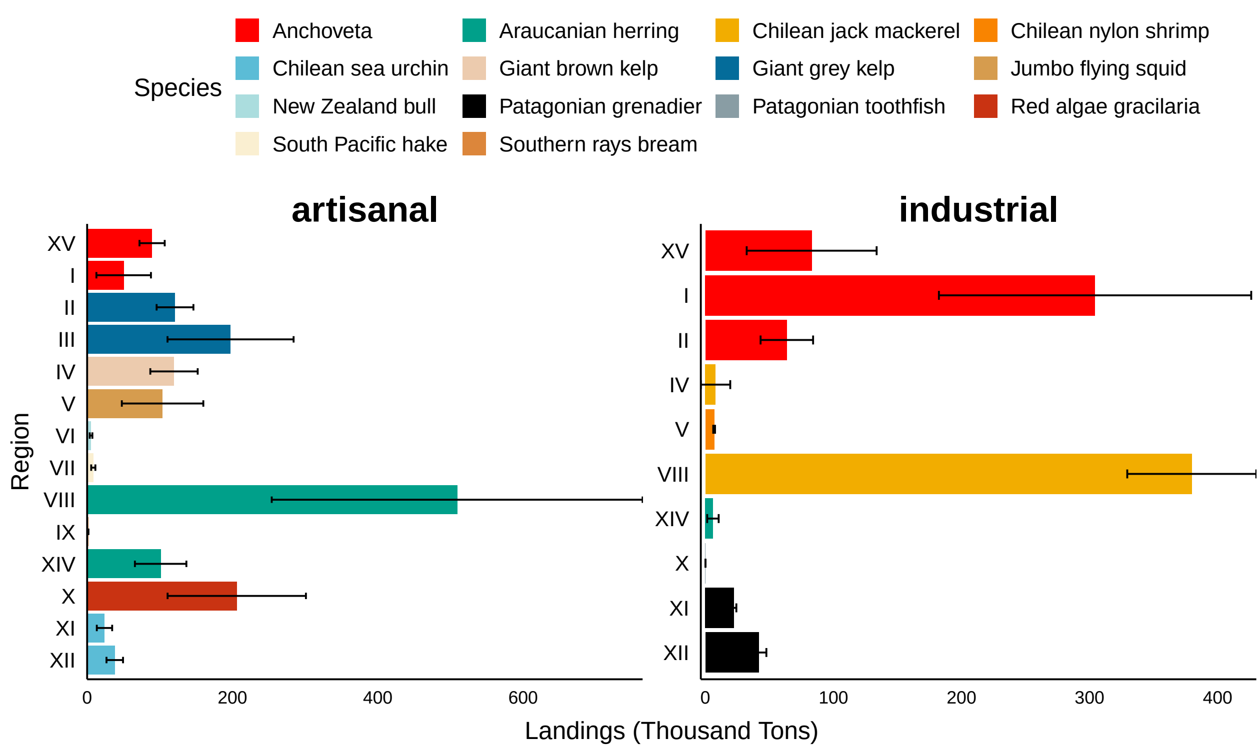


Figure 24: Mean annual total landings per region for the artisanal (left pannel) and industrial sector (right pannel) between 2013 and 2017. The color represents the most landed species in 2017 and regions are ordered from north to south. Error bars represent one standard deviation. Note that scales are different between pannels. Data Landing records from SERNAPESCA, 2018.

Table 20: Main landed (tonnes) species by sector in Chile from 2013-2017.

Species	2013	2014	2015	2016	2017	Mean	s.d.	Total
Artisanal								
Araucanian herring	183	468	715	196	322	377	221	1,883
Anchoveta	212	231	385	180	234	248	79	1,242
Giant grey kelp	313	220	231	156	211	226	57	1,131
Jumbo flying squid	97	125	208	142	113	137	43	686
Giant brown kelp	39	61	144	50	72	73	42	365
Red algae gracilaria	46	32	91	26	48	49	25	243
Mote sculpin	39	48	52	20	60	44	15	219
Black algae luga	34	35	82	31	21	41	24	203
Chilean sea urchin	30	32	62	29	30	37	14	184
Giant kelp	31	26	57	32	30	35	13	175
Industrial								
Anchoveta	592	587	348	157	391	415	182	2,075
Chilean jack mackerel	217	252	256	290	326	268	41	1,342
Araucanian herring	54	75	78	84	23	63	25	315
Jumbo flying squid	9	51	39	39	39	36	16	178
Patagonian grenadier	48	39	37	28	21	35	10	173
Chub mackerel	23	16	20	32	44	27	11	136
South Pacific hake	24	11	12	13	14	15	5	73
Southern blue whiting	15	11	9	8	8	10	3	52
Southern hake	14	7	9	10	11	10	2	51
Red squat lobster	8	8	5	4	4	6	2	29

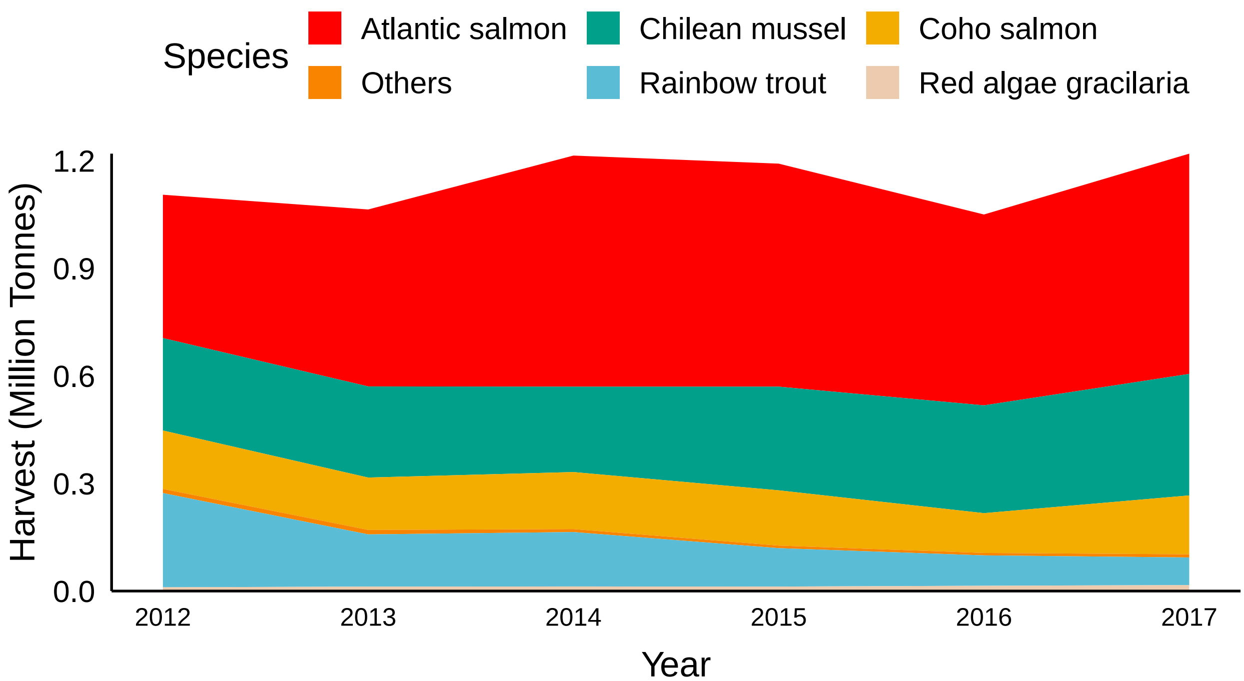


Figure 25: Top 5 species farmed in Chile between 2013 and 2017. Data : Harvest records from SERNAPESCA, 2018.

Main farmed fisheries in terms of volume

The main species harvested from aquaculture centers in the last 5 years have been the Atlantic salmon (*Salmo salar*), the Chilean mussels (*Mytilus chilensis*), the Coho salmon (*Oncorhynchus kisutch*), and the Red algae gracilaria (*Gracilaria spp.*) in descending order (Figure 25). These species predominate total aquaculture production. Overall, the composition of the most farmed species and its volumes have been stable over the last 5 years. However, rainbow trout (*Oncorhynchus mykiss*) production is slightly declining.

Regional diferences in farmed fisheries

Aquaculture production is highly concentrated in the South of the country, between regions X and XII (Figure 26), dominated by the production of salmons and trouts, especially Atlantic salmon (*Salmo salar*). In this area, there is also centers growing algaes and mussels (*Mytilus chilensis*). In the north, from region I to region IV, the most farmed resources are algaes and scallops (*Argopecten purpuratus*) (Appendix Results Chile 3). The red abalone (*Haliotis rufescens*) became the most farmed in 2013 in region V, replacing the turbot (*Scophtalmus maximus*).

Fish Trade

Around 72% of the landings from fisheries and aquaculture are exported outside the country (IFOP 2015). In Chile, exported volumes of marine products are larger than imported volumes. The main group of species being exported is salmon, which is exclussively produced in aquaculture, followed by far by jack mackerel (Figure 27). Tunas lead the import activities followed, by jack mackerels. If we consider net trade, by substracting Chilean exported volumes of similar species, tuna is still the main group of imported species with a net trade of ~ 25 $\pm$ 4 thousand tonnes per year (Table 21). When considering net trade, the second most imported group is no longer jack mackerels but shrimp. These results are in line with those done using international databases, which estimate tunas net trade to be ~ 22,000 tonnes per year and also identify jack mackerel and shrimp as groups with high net trade in Chile.

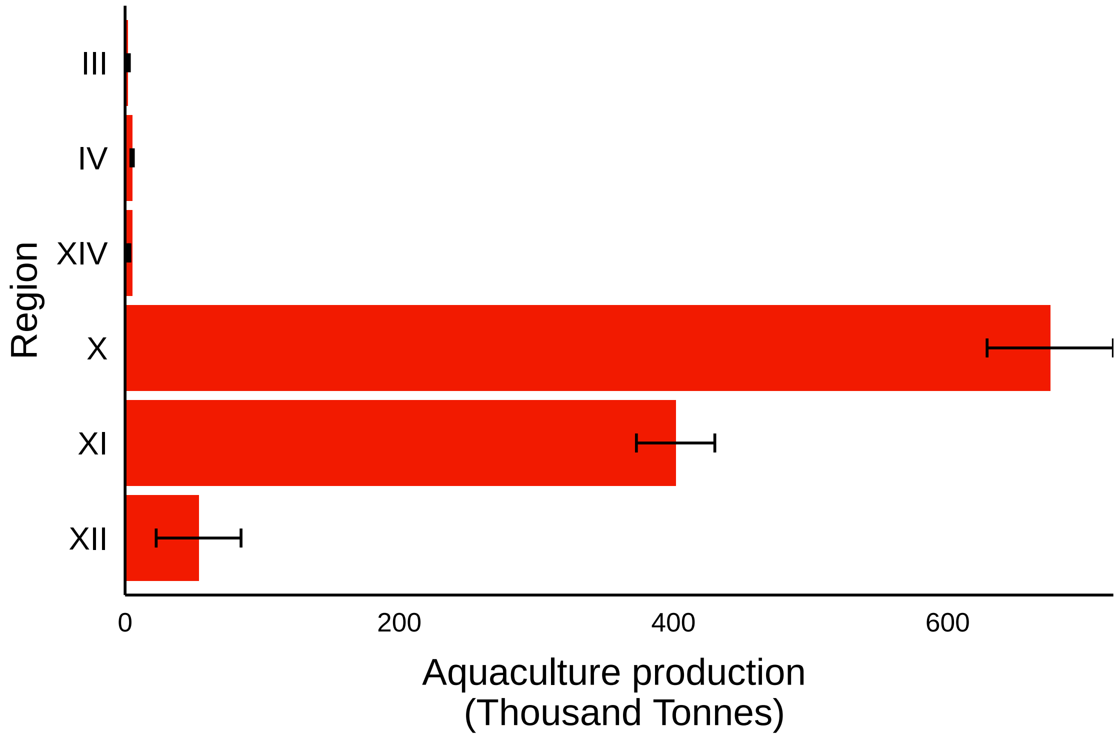


Figure 26: Mean annual harvest per region from aquaculture centers between 2012 and 2017. Error bars represent one standard deviation. Only showing regions with production. Database SERNAPESCA

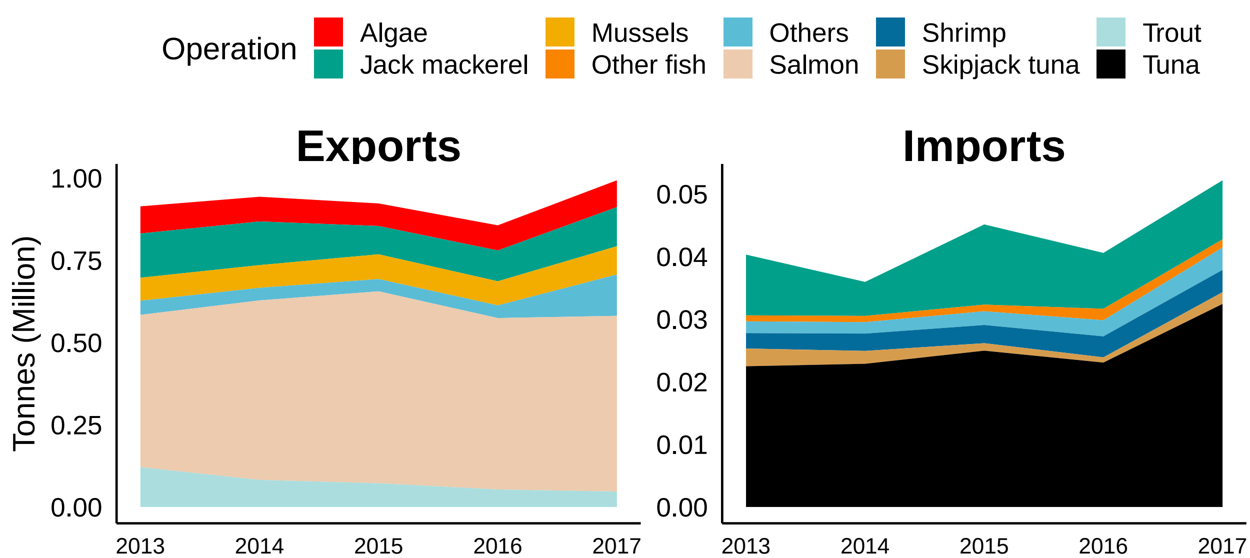


Figure 27: Main species exported and imported in Chile between 2013 and 2017. Note that the scales differ. Thousand Tonnes

Table 21: Export and Import value, and net trade (Import - Exports) for the most imported species in Chile

species	2013	2014	2015	2016	2017	Total	Mean	s.d.
Exports								
Others	686,731.6	726,770.3	746,297.0	672,771.1	763,181.9	3,595,751.8	719,150.4	38,522.1
Jack mackerel	134,526.8	132,665.3	86,039.9	93,724.1	119,011.2	565,967.4	113,193.5	22,273.8
Mussels	69,987.0	68,918.3	75,203.9	73,284.8	86,025.1	373,419.1	74,683.8	6,821.9
Hake	22,075.6	13,949.2	14,160.7	15,115.3	21,680.3	86,981.1	17,396.2	4,117.1
Mackerel	38.2	212.2	465.6	432.4	2,557.1	3,705.5	741.1	1,029.9
Shrimp	505.8	485.6	460.9	520.8	584.9	2,557.9	511.6	46.7
Tuna	39.5	103.6	61.6	441.6	24.2	670.4	134.1	174.5
Sardines	56.8	29.1	64.7	2.7	3.1	156.5	31.3	29.1
Other fish	0.0	2.1	0.0	1.8	103.6	107.5	21.5	45.9
Skipjack tuna	0.0	0.0	0.0	0.0	0.7	0.7	0.1	0.3
Imports								
Tuna	22,472.8	22,869.1	24,961.1	23,062.7	32,424.0	125,789.7	25,157.9	4,173.5
Jack mackerel	9,703.5	5,431.3	12,810.4	8,919.2	9,436.3	46,300.8	9,260.2	2,627.2
Shrimp	2,460.8	2,771.6	2,909.0	3,356.6	3,558.0	15,055.9	3,011.2	444.2
Skipjack tuna	2,834.5	2,054.5	1,196.2	833.6	1,885.2	8,804.1	1,760.8	779.9
Other fish	956.6	992.4	1,062.5	1,832.2	1,295.2	6,138.9	1,227.8	362.7
Mackerel	174.6	245.7	776.6	1,502.9	2,133.1	4,832.9	966.6	841.3
Sardines	745.7	586.1	418.8	274.8	375.9	2,401.3	480.3	186.1
Mussels	460.8	406.5	386.2	243.1	421.2	1,917.7	383.5	83.2
Hake	259.4	374.8	293.9	224.5	310.5	1,463.2	292.6	56.6
Others	237.1	214.2	312.6	328.2	337.7	1,429.8	286.0	56.4
Net Trade								
Tuna	22,433.3	22,765.5	24,899.5	22,621.1	32,399.9	125,119.3	25,023.9	4,242.8
Shrimp	1,955.0	2,286.0	2,448.1	2,835.9	2,973.1	12,498.0	2,499.6	413.0
Skipjack tuna	2,834.5	2,054.5	1,196.2	833.6	1,884.5	8,803.4	1,760.7	779.9
Other fish	956.5	990.3	1,062.5	1,830.4	1,191.7	6,031.4	1,206.3	360.4
Sardines	689.0	557.0	354.0	272.0	372.8	2,244.8	449.0	169.9
Mackerel	136.4	33.5	311.0	1,070.5	-424.0	1,127.3	225.5	545.0
Hake	-21,816.2	-13,574.4	-13,866.8	-14,890.8	-21,369.8	-85,517.9	-17,103.6	4,130.3
Mussels	-69,526.1	-68,511.8	-74,817.7	-73,041.7	-85,603.9	-371,501.3	-74,300.3	6,817.7
Jack mackerel	-124,823.3	-127,234.0	-73,229.5	-84,804.8	-109,575.0	-519,666.6	-103,933.3	24,082.0
Others	-686,494.5	-726,556.1	-745,984.4	-672,442.8	-762,844.2	-3,594,322.0	-718,864.4	38,508.6

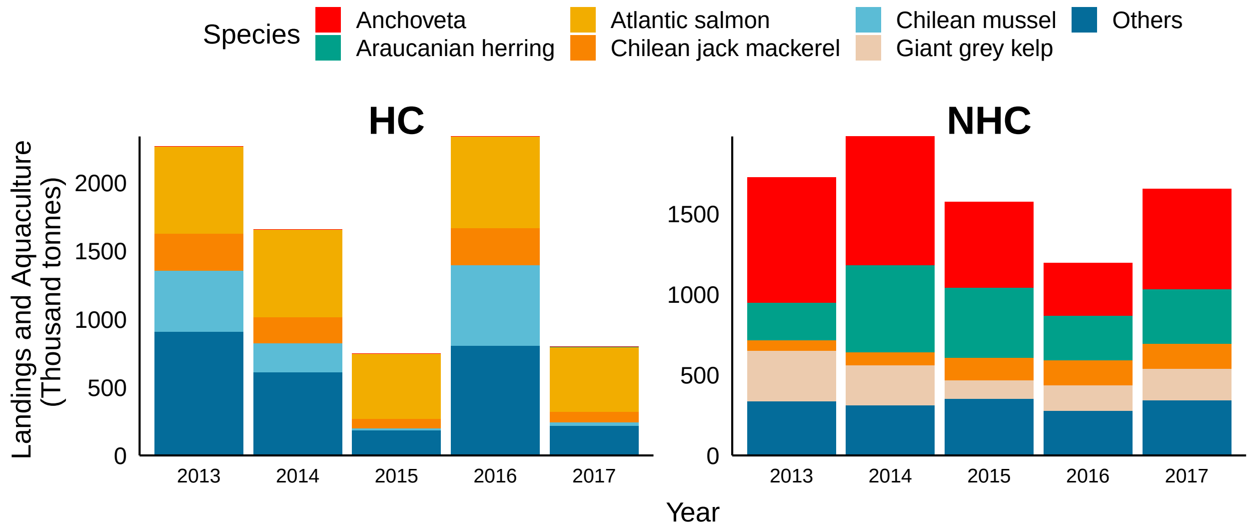


Figure 28: Main species used for products for human consumption (HC) and for non-human consumption (NHC). Dataset: SERNAPESCA.

National Seafood Supply

Species contribution to Human and Non-human consumption

As a first approach to analyze the main fisheries that countribute to human conssumption in Chile, we looked into landings and aquaculture production that goes to processing facilities as raw material for products for human consumption (HC) and for non-human consumption (NHC) (See Appendix Method Chile 2). Our results show that the main species that enter supply chains for HC are the Atlantic slamon (*Salmo salar*) and the Chilean mussel (*Mytilus chilensis*), two of the main aquaculture products from Chile (Figure 28). On the other hand, species that are used for NHC products are Peruvian anchoveta (*Engraulis ringens*) and Araucarian herring (*Strangomera bentincki*), the two main wild-caught fisheries of the country (Figure 28). A third important species for NHC is the Giant grey kelp (*Lessonia nigrescens*). Finally, Chilean jack mackerel (*Trachurus murphyi*) contributes similarly to both HC and NHC products.

We then looked into only wild-caught species and identified that the species that have historically contributed more to human consumption products are: Chilean jack mackerel (*Trachurus murphyi*), jumbo flying squid (*Dosidicus gigas*), and to a lesser extent Chilean sea urchins (*Loxechinus albus*) (Figure 29). These results also show that the amount of wild caught fisheries that go to NHC is more than the double that which goes to HC (Figure 29). We removed year 2015 from our analysis because data was not accurate (See Appendix Chile Method 1). Also, algaes are not included because we assumed that they all used for non-human consumption.

Artisanal fishers in Chile sell products directly for human consumption directly from their boats. We assumed that the artisanal catches not sent to processing facilities are sold directly by fishers (See Methods Chile 2). Results show that Southern rays bream (*Brama australis*) is the main species for every year of data (Figure 30), indicating that historically has been an important specie for direct human consumption. This aligns with results obtained in a survey implemented along Chile where 51% answered that Southern rays bream was their first preference (chile (2016)). Anchoveta (*Engraulis ringens*) for direct human consumption has decline through the years, while Chilean clam (*Venus antiqua*) has increased. There was a high increase in the amount of tonnes for human consumption in 2017, partly driven by an increase in jumbo flying squid (*Dosidicus gigas*). We removed year 2015 from this analysis becasue data on landings per sector was not accurate (See Appendix Chile Method 1).

Main fisheries for food supply

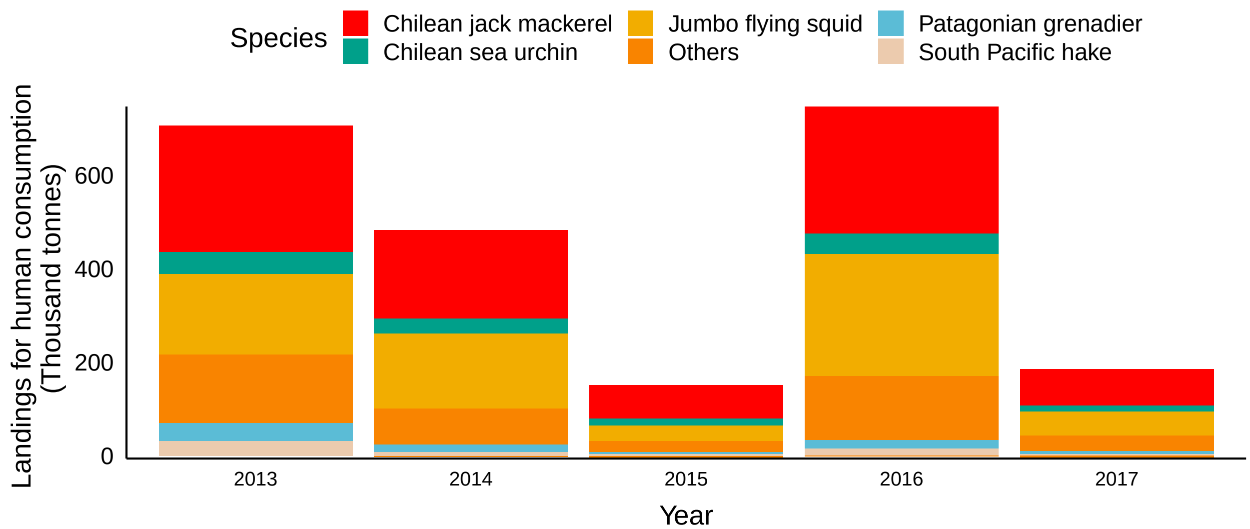


Figure 29: Tonnes of wild-cought species that are used for human consumption. Dataset: SERNAPESCA, 2018

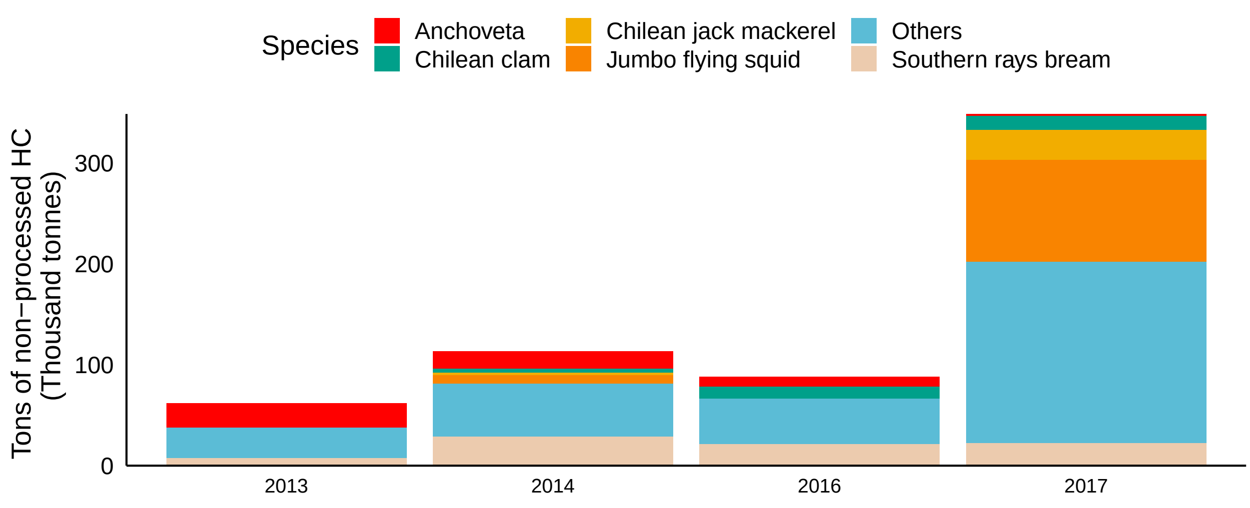


Figure 30: Main artisanal landings that are not processed in facilities. Data SERNAPESCA, 2018

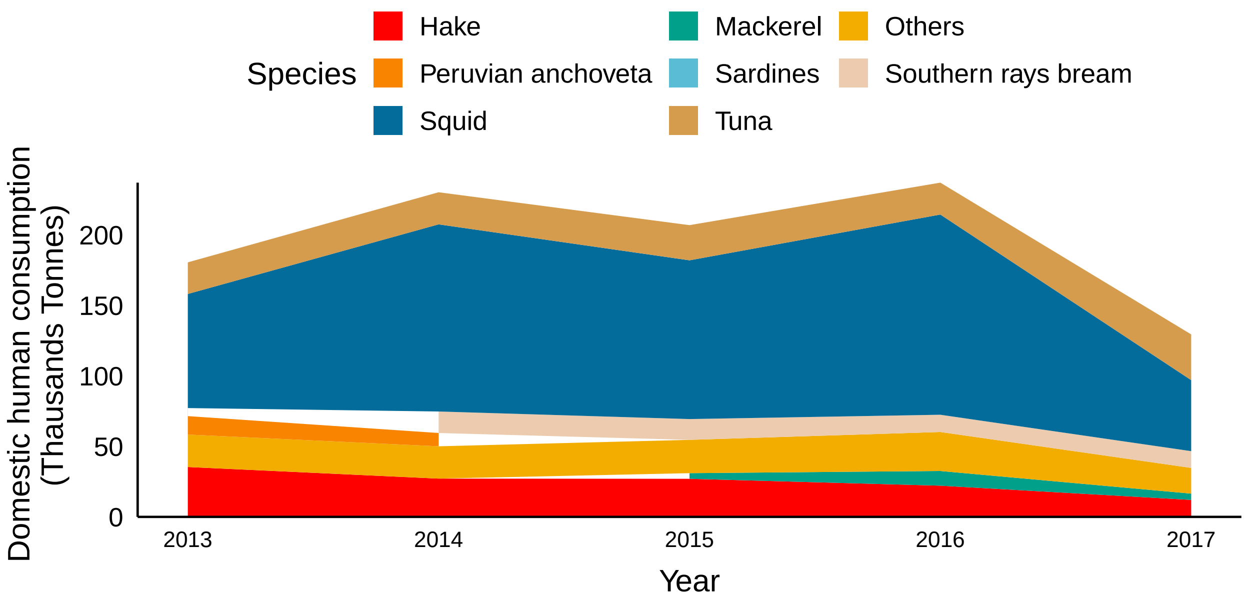


Figure 31: Main groups of species consumed by the chilean population in the last 5 years

To identify the main fisheries for human food supply in Chile we combined datasets from landings, aquaculture, raw material that goes into facilities for non-human consumption, imports and exports, assuming that all local landings and harvest that are not processed for non-human consumption products nor exported are consumed locally. Even though landings and aquaculture databases are detailed at a species level, we agreggated the data in larger groups (See Appendix Chile Method 2) to be able to combine them with the Chilean Customs datasets.

Our results show that the main fishery for local consumption across years has been squid, including Patagonian (*Loligo gahi*), jumbo flying (*Dosidicus gigas*), Argentine shortfin (*Illex argentinus*) and japanese flying (*Todarodes Pacificus*), squids. In 2017 there was a significant increase in squids exports, reducing the total amount of seafood available to be consumed locally. Other fisheries important for domestic HC in Chile are Hakes, (Including: Southern hake (*Merluccius australis*), South Pacific hake (*Merluccius gayi gayi*), Patagonian grenadier (*Macruronus magellanicus*) and Southern blue whiting (*Micromesistius australis*) and Southern rays bream (*Brama australis*) (Figure 31). It is important to mention that the Southern rays bream is classified in an unique group, therefore its relative contribution to domestic consumption is higher compared to other agreggated groups. Squids have the highest yield of all species, therefore their contribution to domestic consumption per landed tonne is higher, partly explaining its dominance in our results.

These results are similar to results obtained with the international databases, where we identify that the main sources of seafood in Chile are landings of species such as jumbo squid or mackerels, and aquaculture with species such as Atlantic salmon and Chilean mussel. However, the local analysis shows that all salmon and mussels produced in Chile are expoted, and therefore none are consumed locally. Through our model we probably underestimated salmon production or overestimated salmon exports, because even though salmon is not the most consumed species in Chile, we know that some salmon stays in the country and is sold in the supermarket.

Our model shows that the chilean population also consumes high volumens of tuna, a group of specie that is mainly imported in canns. This result alignes with popular chilean preferences based on a study along the country where 84% of the respondents answered that their favorite way of eating fish was canned, follwed by fresh (80%), and frozen fish (37%) (chile 2016). The ten most important fisheries for human consumption according to our model are provided in the Appendix (Supplemental Chile Table 4).

Total and per capita seafood consumption in the country

Based on the results of our model and the current estimated Chilean population (17.5 million), we calculated an average of 11.5 kg of seafood compsumption per person a year. This estimate is similar to what has been projected by the FAO (2016) of 10-13 kg for Chile. Total supply for HC has been stable with an average of 204 thousand tonnes a year. In 2017 we observed a drastic decrease in total and per capita HC of seafood. This model estimate maybe due to a substantial increase in exports of squid during that year.

Table 22: Total tonnes (Thousand) of seafood for human consumption and per capita consumption per year (kg) considering a population of 17.5 million

Year	Total Human Consumption	Per-capita consumption
2013	191.5	10.8
2014	238.6	13.4
2015	213.4	12.0
2016	245.1	13.8
2017	134.6	7.6

Regional differences in per capita and total consumption

We were not able to do a regional analysis for domestic consumption. Even though most of the catch data are provided at a regional level, we could not assume that what was landed in a region was consumed in the same area due to internal trade.

There is a study done in 2016 that asked peopke along the Chile how much fish they eat in a week. Regional results inidcate that the percentage of respondants that ate fish once per week was: North (62%), North-Centre (54%), Center-South (48%), Southern (45%) and Metropolitan Region (42%) (chile (2016))

National Economic Participation

The 'Fisheries' economic sector in Chile contributes to around 0.4% of the national GDP although it has highly variable production (Central 2017). An estimate for 2014 indicates that 90% of sales for the sector came from marine farmed products, reflecting the importance of aquaculture in economic terms relative to wild fisheries (SENSE 2015). Yet, the extractive sector has a higher number of firms (58% of the total) and contributes to various sectors throughout the economy (SENSE 2015). Fishing manufacturing closely relates to fisheries. Based on the latest input-output matrix for the country's economy (Banco Central de Chile, 2013), for every US$ 100 spent in the fisheries sector, a further US$ 52.2 dollars are generated in the manufacturing sector. Other sectors impacted by fisheries are the financing sector (US$ 24.8 generated for every US$100) and transportation, and communication (US$13.4 generated for every US$100).

Wild-caught Fish Economic Participation

The contribution of fisheries to regional GDP suggests that the economic importance of the sector to regional economies varies widely, ranging from almost 30% in region XI to 0% in the Metropolitan (RM) and IX regions (Figure 32).

Based on our estimates of species-specific revenue, the most important species for the artisanal sector are the Southern king crab (*Lithodes santolla*) and the Chilean sea urchin (*Loxechinus albus*) (Figure 33). Nonetheless, this varies across years. In 2017 the Patagonian toothfish (*Dissostichus eleginoides*) and the Southern rays bream (*Brama australis*) were the species that provided more revenue, followed by the pink cusk-eel (*Genypterus blacodes*).

These species are among the most expensive (Supplemental Chile Table 5). The Patagonian toothfish (*Dissostichus eleginoides*) has the highest mean ex-vessel price in the artisanal sector what explains, in part, why is one of the top five in term of revenues. We should note that the fishing costs for different types of species could vary widely and we are not accounting for this in our analysis. Yet, we can qualitatively consider the costs of different types of fishing. For example, some of these species are fished by diving near the shore like the Chilean abalone (*Concholepas concholepas*) and the Chilean sea urchin (*Loxechinus albus*), while others like the Patagonian toothfish (*Dissostichus eleginoides*), the Southern king crab (*Lithodes santolla*) or the Swordfish (*Xiphias gladius*) involve offshore fishing, which tends to be much more expensive. The

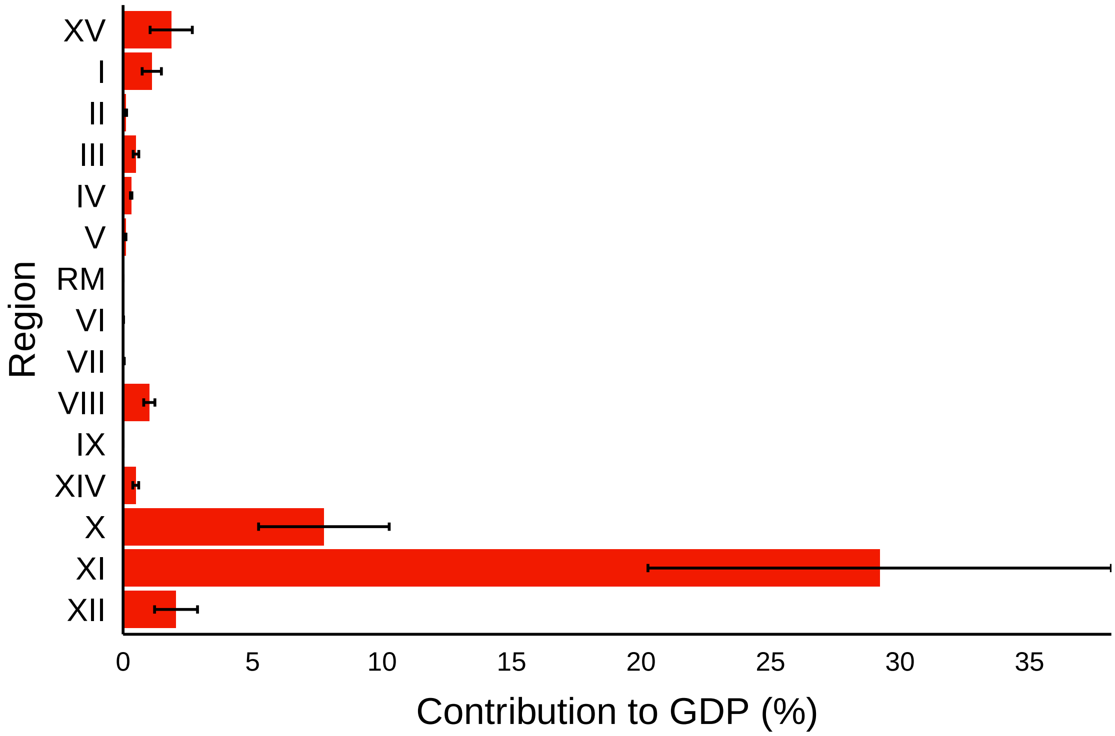


Figure 32: Percent of the regional GDP contirbuted by the fisheries sector averaging data between 2013 and 2016. Data Banco Central de Chile.

gathering of algae from the shore is arguably one of the least costly extractive activities for the artisanal sector but it is not among the ones that generate more revenue. We could not generate similar estimates for the industrial and aquaculture subsectors due to lack of data on their first-transaction prices (Figure 33).

Trade Economic Participation

Seafood products are one of the most important exports of the country. IFOP valued the exportation of fisheries-related products in US$6.28 billion dollars in 2017 (IFOP (2017)). This corresponded to ~ 9 % of the total value of national exports. By far, the most important group of species in terms of exports value are salmons, particularly the Atlantic salmon (*Salmo salar*) (Figure 34). The net value of salmons is, on average, US/$ ~3.4 billion (Table 3). They are almost exclussivelly produced by aquaculture. Mussels, specifically the Chilean Ribbed Mussel (*Aulacomya ater*) and the Chorus mussels (*Choromytilus chorus*) are also among the most valuable exports. These are landed by artisanal fishers and to a lesser extent produced in aquaculture centers, contributing with ~ US$167 million. In general, the value composition of exports is stable. Yet, salmon seems to be driving an increase in exports value since 2015 (Table 23).

The most valuable sea products in terms of exports are frozen and fresh followed by fish meal and dried algae (IFOP 2017). In 2016, fish fillets were the fourth most exported product by Chile. This commodity generates around US$2 billion per year and is mainly composed of farmed salmons (DataChile 2016) (Figure 34).

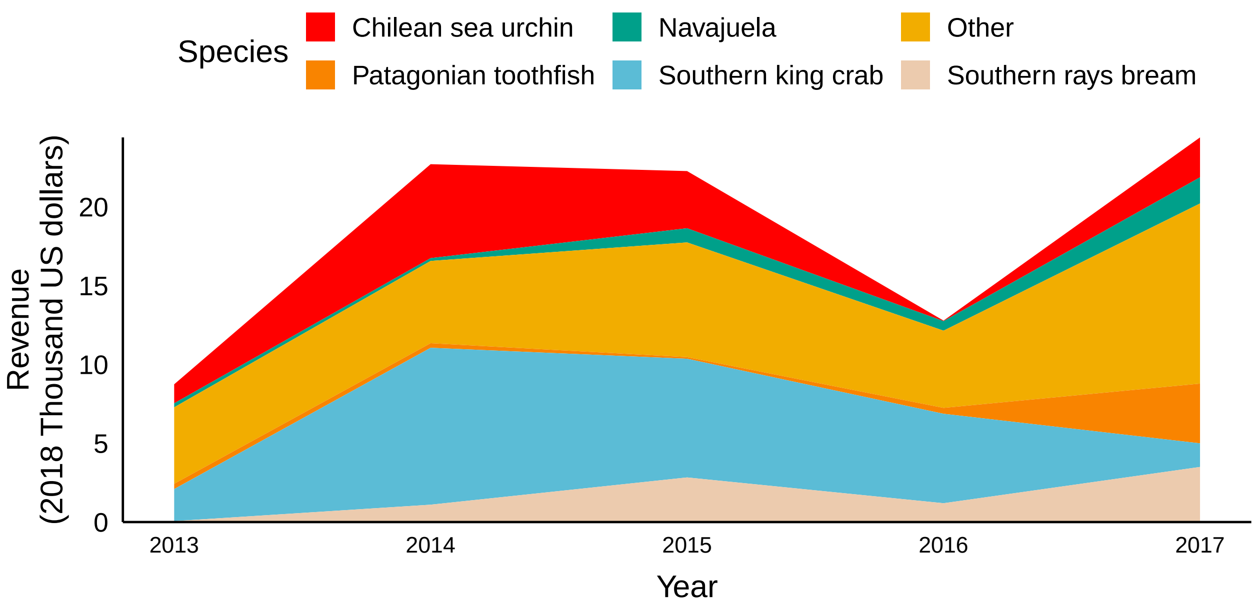


Figure 33: Species that generated the most revenue for the artisanal sector over the past five years based on records on landings and ex-vessel prices. Source: records from SERNAPESCA, 2018.

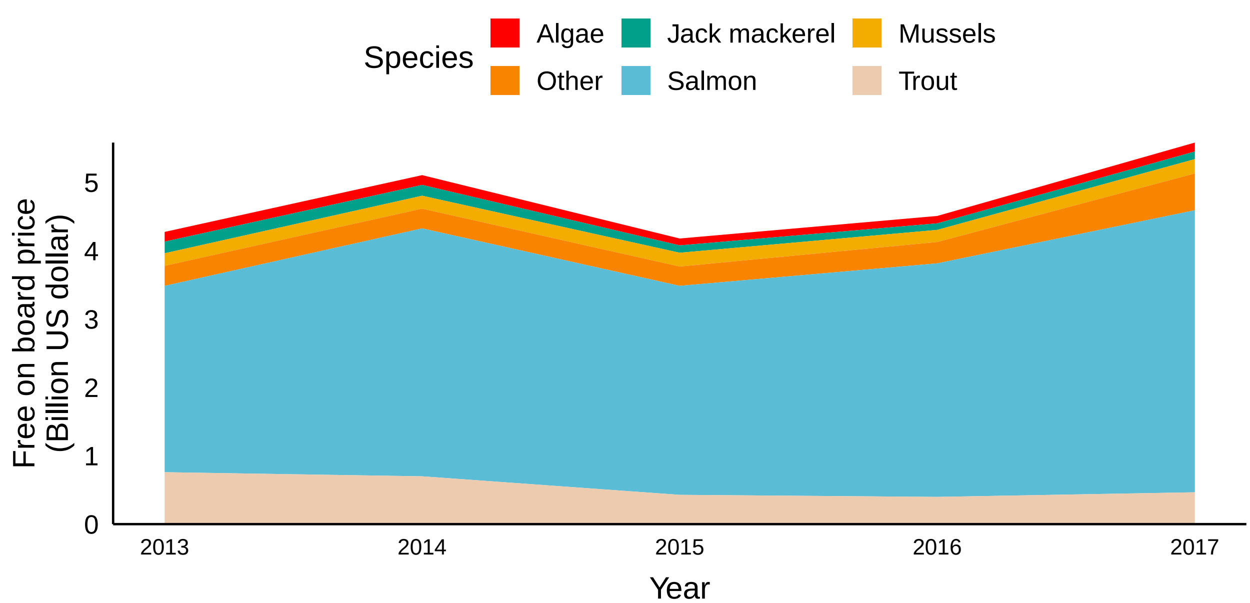


Figure 34: Main exported species in terms of econmic value. Source: Dataset Aduanas Chile

Table 23: Export and Import value, and net trade (Exports - Import) for the most exported species in Chile. Million USD.

species	2013	2014	2015	2016	2017	Total	Mean	s.d.
Exports								
Salmon	2,726.2	3,627.3	3,057.8	3,416.7	4,126.1	16,954.1	3,390.8	536.2
Trout	759.9	699.7	428.8	398.5	466.1	2,753.0	550.6	166.7
Mussels	184.1	189.0	201.7	177.2	209.8	961.9	192.4	13.2
Jack mackerel	170.4	158.3	107.8	96.0	111.4	643.9	128.8	33.2
Algae	142.1	143.0	100.7	108.2	130.6	624.6	124.9	19.5
Others	90.6	101.6	93.3	92.0	234.8	612.3	122.5	62.9
Patagonian toothfish	71.0	62.7	60.5	88.5	76.1	358.7	71.7	11.3
King crab	50.9	65.3	58.8	60.8	79.7	315.5	63.1	10.7
Hake	69.6	49.5	55.6	61.4	71.9	308.0	61.6	9.4
Sea urchin	10.5	9.6	14.0	9.6	75.6	119.3	23.9	29.0
Imports								
Others	149.3	134.4	12,014.9	11,571.6	163.0	24,033.2	4,806.6	6,379.8
Jack mackerel	17.6	9.5	2,070.3	1,342.5	14.0	3,453.9	690.8	962.2
Hake	0.9	1.3	111.0	81.9	0.8	195.8	39.2	53.3
Mussels	1.5	1.4	123.7	0.0	1.4	128.0	25.6	54.8
Salmon	0.0	0.0	24.9	25.3	0.3	50.5	10.1	13.7
King crab	0.0	0.0	0.0	13.1	0.6	13.8	2.8	5.8
Sea urchin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Algae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Patagonian toothfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Trade								
Salmon	2,726.2	3,627.3	3,032.8	3,391.4	4,125.8	16,903.6	3,380.7	539.8
Trout	759.9	699.7	428.8	398.5	466.1	2,753.0	550.6	166.7
Mussels	182.6	187.6	78.0	177.2	208.4	833.9	166.8	51.0
Algae	142.1	143.0	100.7	108.2	130.6	624.6	124.9	19.5
Patagonian toothfish	71.0	62.7	60.5	88.5	76.1	358.7	71.7	11.3
King crab	50.9	65.3	58.8	47.6	79.1	301.7	60.3	12.6
Sea urchin	10.5	9.6	14.0	9.6	75.6	119.3	23.9	29.0
Hake	68.7	48.2	-55.4	-20.5	71.2	112.2	22.4	57.2
Jack mackerel	152.8	148.8	-1,962.5	-1,246.5	97.3	-2,810.0	-562.0	985.0
Others	-58.7	-32.8	-11,921.6	-11,479.6	71.8	-23,420.9	-4,684.2	6,407.2

Fish and Aquaculture Employment

Fisheries and aquaculture are considered to be the second activity that provide less direct employment in the country, after agriculture (SENSE 2015). But, the number of people employed in the sector has been on the rise since 2010 (SENSE 2015). We estimated a total of ~278,000 job positions generated by fisheries and aquaculture. This estimate considers artisanal and industrial fishers, workers in processing facilities and aquaculture centers and indirect jobs generated by the manufacturing sector (Table 24). It does not include other indirect jobs generated by the extractive activities and its commercialization (for example, in the sectors impacted by fisheries noted above). Thus, the number of total people directly and indirectly employed by fisheries and aquaculture in Chile could be higher.

Table 24: Most recent estimates of people employed in different stages of the supply chain of sea products in Chile. Note that the estimate of indirect employment only considers the processing stage.

Stage of the supply chain	Employees	Year of the estimate	Source
Artisanal Extraction	88,968	2018	RPA (SERNAPESCA, 2018)
Industrial Extraction	3,525	2018	RPI (SERNAPESCA, 2018) and SUBPESCA website (2018)
Aquaculture Centers	17,631	2017	Maturana et al., 2017 (SERNAPESCA, 2018)
Manufacturing	65,451	2017	Maturana et al., 2017 (SERNAPESCA, 2018)
Indirect employment	102,758	2018	Own estimate based on IFOP,2015 multipliers

People employed in the fisheries and aquaculture activities have an average monthly income of US$579, the lowest mean income in the country after the agriculture sector (SENSE 2015). This value ranges from US$258 per month for people working independently and part-time to US$1,160 per month for full-time employee (Supplemental Chile Table 6).

On average, people employed in the fisheries and aquaculture sector are younger and less educated relative to the national average and are mostly men (Supplemental Chile Table 7). However, there is high variation within subsectors, for example, artisanal fishers tend to be older (Tam et al. 2018). Based on estimates from the national survey of employment (NENE, 2015), only 57.7% of the people employed in the sector are formally hired, the rest work independently, which usually means they do not have pension (SENSE 2015).

Employment in the Artisanal Sector

The artisanal sector corresponds to fishing activities performed by vessels equal to or smaller than 18 meters in length and by collectors in the inter-tidal zone (SUBPESCA 2018b). Based on the current national record of artisanal fishers (RPA), there are around 89,000 artisanal fishers along with 12,700 vessels in Chile. Figure 35-A, shows the number of artisanal fishers per region and gender. They are concentrated in the X and VIII regions and are mostly men. The main activity in the artisanal sector is harvester or collector (mostly shoreline algae collection). All regions present similar composition of fishing activities (Figure 35-B). However, region X seems to rely more on benthic resources for employment than the others since they have a greater share of divers and algae collectors.

Employment in the Industrial Sector

The industrial sector comprises activities performed by vessels larger than 18 meters. Currently, there are 475 industrial vessels and 164 vessel owners according to national industrial records (RPI), from which only 25 are individual owners and the rest are firms (Maturana et al. 2017). A further 3,500 jobs are generated through vessels operations (SUBPESCA 2018a). Based on information on the distribution of vessels (Figure 36), most industrial extractive activities occur in region VIII, as is also reflected by landings estimates discussed above.

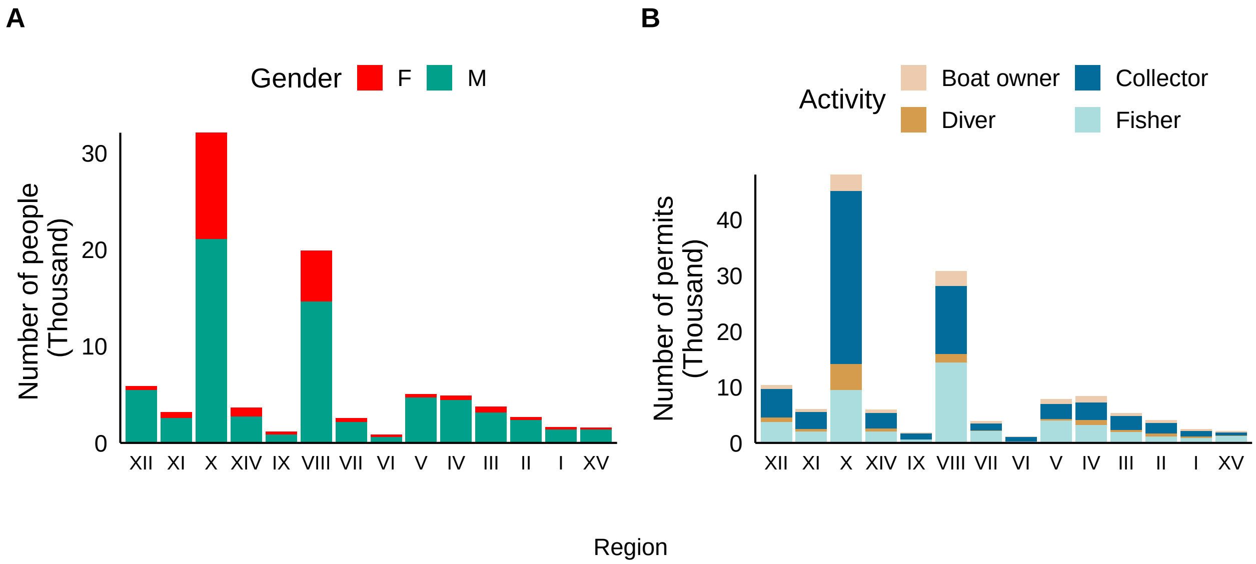


Figure 35: Total number of fishers (A) and permits (B) in each region. One person can be registered in multiple activities. Dataset SERNAPESCA

Still, vessels are registered along the entire coast. Some of the firms that own industrial vessels also own processing facilities whose employees are included in estimates as part of the processing stage.

Employment in the Industry

A rigorous study by IFOP estimated a total of ~50,000 job positions in the manufacturing of marine products in processing facilities in 2014 (IFOP 2015). However, a more recent report from SERNAPESCA suggests a total of 65,451 jobs (Maturana et al. 2017). Figure 37 displays the geographic distribution of people employed in the manufacturing sector by gender and type of product for 2015. Employment in the processing facilities is mainly in products for human consumption (HC), with ~ 40,000 job positions. Products for animal consumption (AC) generated around 5,000 positions, while algae products, mainly destined for industrial uses, employed less than 3,000 people. Most people employed by the manufacturing sector are located in the southern part of the country and the majority are men.

Employment in the Aquaculture Sector

There are 17,631 people employed among the 3,683 aquaculture centers currently registered in Chile (Maturana et al. 2017), including ~4,500 women. Figure 38 shows the distribution of aquaculture centers per region and type of farmed species. The main type of product being farmed is fish, mostly salmon, followed by mollusks and algae. Region X hosts more than half of the aquaculture centers in the country.

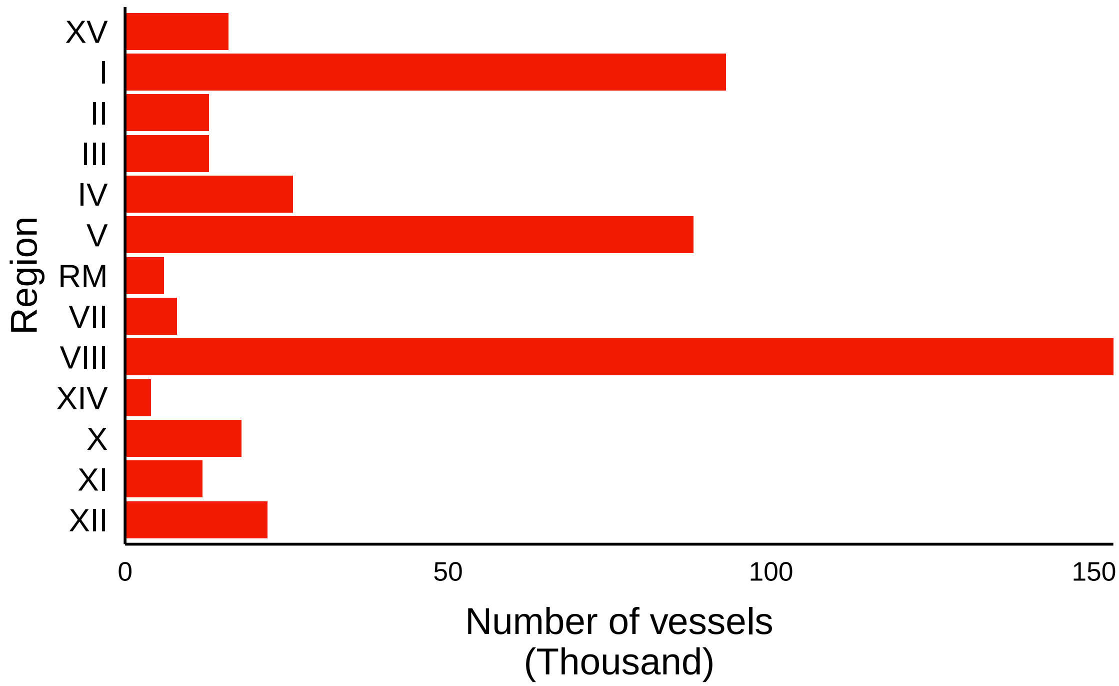


Figure 36: Number of industrial vessels per region. Dataset SERNAPESCA.

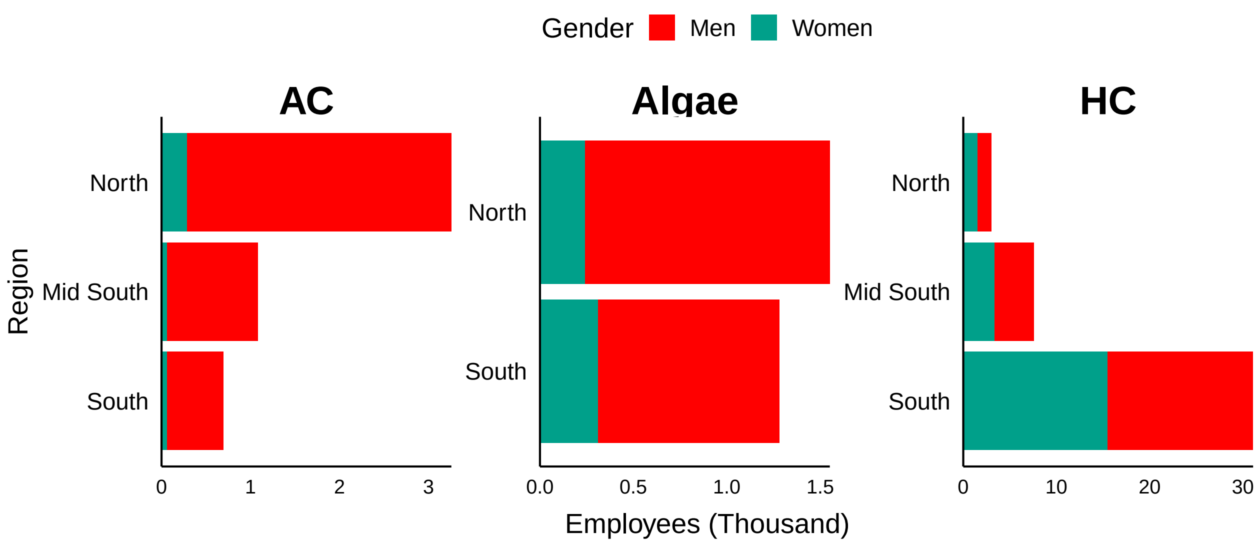


Figure 37: Number of employees in the fisheries manufacturing sector in each region by gender in 2015. AC refers to products for animal consumption and HC products for human consumption. Source: Report by IFOP based on facilities survey (IFOP, 2015)

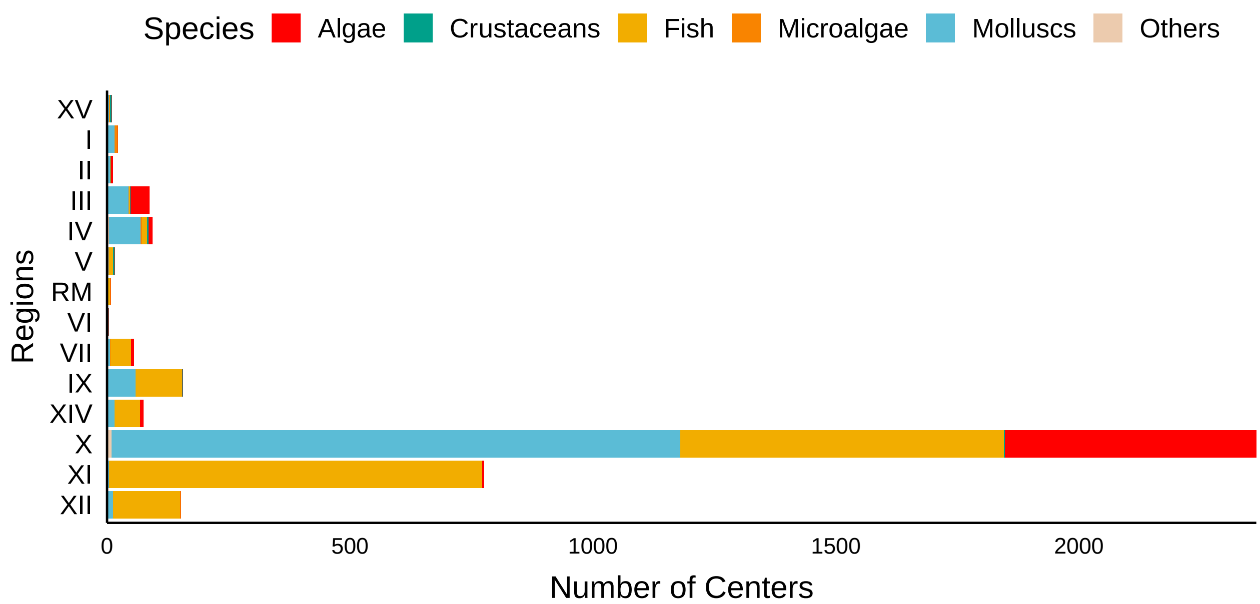


Figure 38: Number of aquaculture centers in each region by type of species in 2017. Source: Report Subsector Acuicultura 2017 by SERNAPESCA (SERNAPESCA website, 2017)

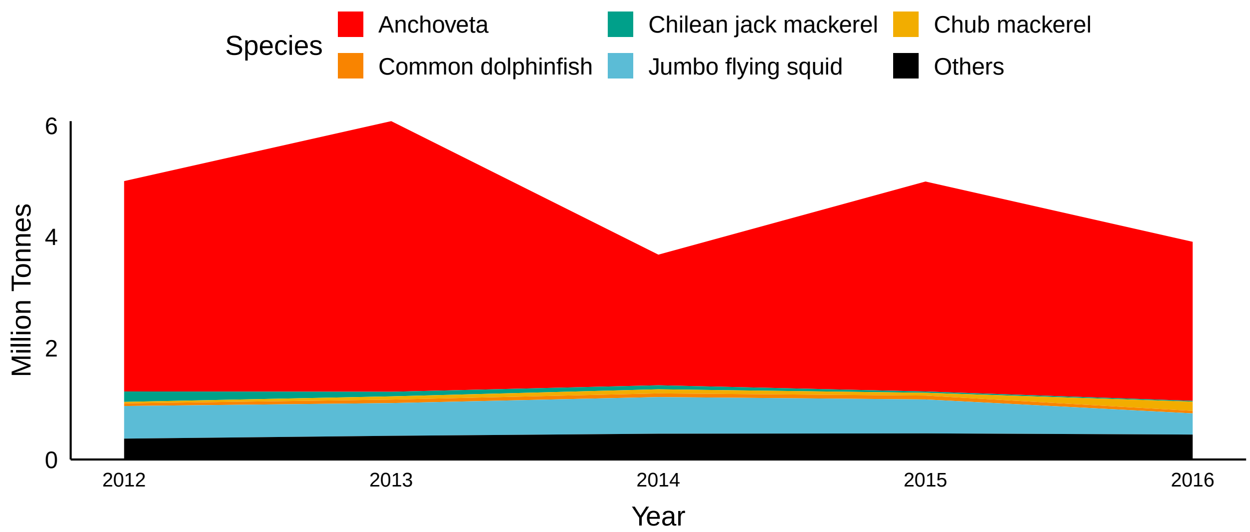


Figure 39: Top 5 groups landed in Peru

Results Peru

Fisheries Context

Based on the most recent published data by the Ministry of Production, seven species and three groups of species (i.e. shrimps, tunas and sharks) were responsible for 95% of the country's marine capture production (MCP) between 2010 and 2016 (Figure 39 and Table 25) (PRODUCE 2017). Anchoveta (*Engraulis ringens*) represented 78% of these landings. On average, 3.93 (± 1.56) million tonnes this species were annually reduced into fishmeal and fish oil (FMFO) during the studied period. Peruvian FMFO is mainly used in feed producing value chains abroad (Christensen et al. 2014; Majluf, Puente, and Christensen 2016).

Only 22% of the Peruvian MCP was used for direct human consumption (DHC) value chains (Figure 40), at a rate of 1.13 (± 0.13) million tonnes per year. Key species for DHC include: jumbo flying squid (*Dosidicus gigas*), Chilean jack mackerel (*Trachurus murphyi*), Pacific chub mackerel (*Scomber japonicus*) and Common dolphinfish (*Coryphaena hippurus*). The remaining MCP (2%) is discarded at sea, never reaching Peruvian landing sites.

Although most MCP is caught by large-scale fishing vessels using industrial purse seine nets (i.e., used for targeting anchoveta). Nonetheless, MCP for DHC is mainly caught by small-scale fishing vessels, using multiple fishing methods and gears. Mackerel species, for example, are caught using artisanal purse seine nets, common dolphinfish is caught using small-scale longlines and the jumbo flying squid is caught using manual jigs (Sueiro Cabredo and Puente 2015).

Freshwater capture production (FAP) in Peru is severely underestimated by PRODUCE and has very low species resolution (Sueiro Cabredo and Puente 2015). In the last published annual report, PRODUCE did not segregate landings by species coming from freshwater systems (PRODUCE 2017). As FAP is predominantly used for subsistence in rural Amazonian and Andean communities, the catch hardly ever reaches landing sites monitored by the regional fisheries authorities and thus is almost never registered (Sueiro Cabredo and Puente 2015). Between 2010 and 2016 Peruvian freshwater systems produced average estimated yields of 68.3 (± 10.1) thousand tonnes per year. The reported freshwater capture production by PRODUCE during the study period totaled 478 thousand tonnes (PRODUCE 2017), amounting to ~1% of the marine capture production.

Aquaculture

Table 25: Main species landed in Peru from 2012 to 2016. Thousand tons.

Species	2012	2013	2014	2015	2016	Total	Average	s.d.
Anchoveta (Engraulis ringens)	3,777	4,859	2,345	3,770	2,855	28,182	4,026	1,579
Jumbo flying squid (Dosidicus gigas)	585	587	658	609	380	3,731	533	103
Chilean jack mackerel (Trachurus murphyi)	187	82	72	23	15	654	93	94
Chub mackerel (Scomber japonicus)	27	58	74	50	165	442	63	49
Common dolphinfish (Coryphaena hippurus)	48	63	66	70	45	400	57	10
Peruvian hake (Merluccius gayi peruanus)	33	55	64	56	72	359	51	14
Eastern Pacific bonito (Sarda chiliensis)	24	39	41	93	82	306	44	32
Shrimps	23	17	22	40	24	152	22	9
Tunas (Thunnus sp.)	4	13	25	21	17	107	15	7
Sharks (Selachimorpha)	13	9	14	21	21	104	15	4

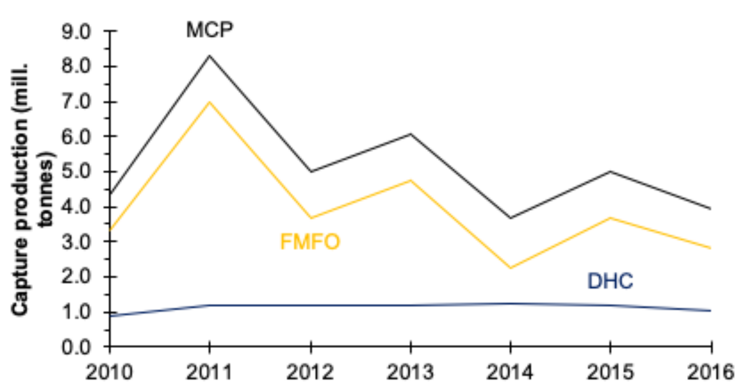


Figure 40: Peruvian MCP was used in direct human consumption (DHC) value chains

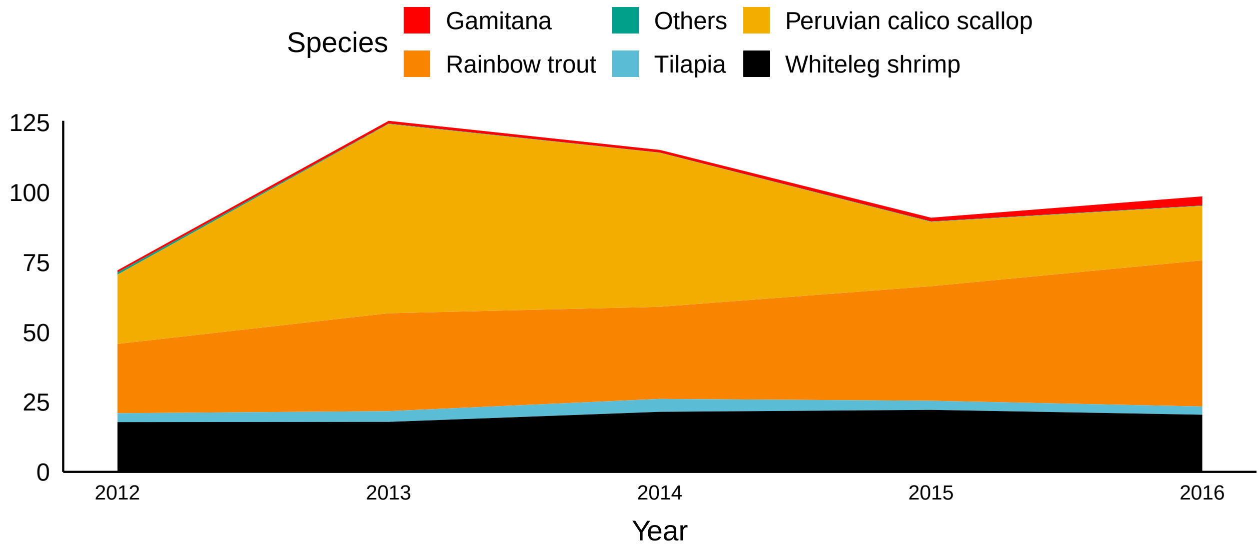


Figure 41: Main Species produced in aquculture in Peru

Marine aquaculture production (MAP) in Peru is much smaller than its MCP. MAP is mainly focused on two species: the Peruvian calico scallop (*Argopecten purpuratus*) and the White-leg shrimp (*Litopenaeus vannamei*). Scallop aquaculture is a semi-intensive to extensive industry with annual average yields of 42,913 $\pm$ 19,804 tonnes per year. Only a minor segment of the producing entities purchases seed (i.e. larvae) from hatcheries and use suspended cultures (Mendo et al. 2016; Lama et al. 2018). Most scallop aquaculture production is harvested from bottom cultures in the Sechura Bay (*Piura* Region) using seed taken from natural banks at Isla Lobos de Tierra, a marine protected area (Lama et al. 2018). Production is thus highly susceptible to changes in environmental conditions, and El Niño events have led to massive economic losses for producers along the Peruvian coast (Badjeck et al. 2009; Mendo et al. 2016).

Shrimp aquaculture has been increasing steadily during the study period, with an average annual production of 18,538 $\pm$ 3,045 tonnes per year. This is an intensive industry that uses closed-system cultures (Christensen et al. 2014) in large pools near mangrove forests in northern Peru (PRODUCE 2017). Additionally, some artisanal fishing communities are starting exploratory cultures of red algae (*Chondracanthus chamissoi*). These cultures were part of pilot projects promoted through international cooperation. However, due to weak social capital (as seen in the scallop aquaculture (Lama et al. 2018)) and lack of continuity in funding and technical oversight, production did not surpass 150 tonnes per year, and has been declining significantly since it started in 2012. Similarly, a company is developing closed-system cultures of fine flounder (*Paralichthys adspersus*) and turbot (*Scophthalmus maximus*). Nonetheless, their production is still negligible for commercial purposes or national food security (3 $\pm$ 1.26 tonnes per year between 2012-2016).

It is worth noting that freshwater aquaculture production (FAP) has increased during the studied period surpassing marine aquaculture production in 2015. FAP is based on rainbow trout (*Oncorhynchus mykiss*) grown in Andean lakes and tilapia (*Oreochromis* sp.) grown in across the Andean and Amazonian regions of Peru. Both of these are introduced species. FAP of local species like gamitana (*Colossoma macropomum*) and arapaima (*Arapaima gigas*), has also increased during the studied period but remains small in comparison (Figure 41).

Trade

Peru is both a major importer and exporter of seafood products. Based on data obtained from SUNAT, between 2010 and 2016, Peru imported 727.9 thousand tonnes of seafood products, at a rate of 103.9 $\pm$ 24.6 thousand tonnes per year (Table 26). Peruvian seafood exports, however, are much larger than imports, and

Table 26: Summary table of trade in Peru. Net exports = Exports-Imports. Thousand Tonnes.

Type	2012	2013	2014	2015	2016	Total	Average	SD
Exports								
Canned products	41.1	34.5	28.4	23.4	17.4	208.7	29.8	9.8
Cured products	6.1	4.3	3.0	4.9	1.5	25.9	3.7	1.5
Fishmeal	1,353.3	867.1	867.5	713.7	642.2	6,850.1	978.6	280.9
Fish oil	312.4	126.0	164.0	110.0	93.9	1,295.1	185.0	83.0
Fresh seafood	0.8	0.9	1.0	1.1	1.7	8.3	1.2	0.5
Frozen products	380.4	354.1	387.9	347.1	265.9	2,358.1	336.9	49.5
Others	1.4	0.6	0.9	0.7	0.9	10.4	1.5	1.3
Total	2,095.6	1,387.4	1,452.6	1,200.9	1,023.5	10,756.4	1,536.6	387.8
Imports								
Canned products	12.3	17.9	15.5	21.4	19.5	111.0	15.9	3.9
Cured products	1.9	1.6	0.9	1.2	0.3	12.3	1.8	1.1
Fishmeal	0.3	2.1	2.5	1.3	4.4	12.1	1.7	1.4
Fish oil	2.5	5.8	3.0	7.7	6.8	33.1	4.7	2.2
Fresh seafood	18.5	32.0	32.3	26.8	23.3	176.2	25.2	5.5
Frozen products	29.3	51.0	49.5	66.0	76.3	381.2	54.5	18.6
Others	0.2	0.2	0.5	0.5	0.4	2.0	0.3	0.2
Total	64.9	110.6	104.2	124.9	131.0	727.9	104.0	24.6
Net Exports								
Canned products	28.9	16.6	12.9	2.0	-2.1	97.7	14.0	12.1
Cured products	4.3	2.7	2.0	3.7	1.2	13.6	1.9	1.7
Fishmeal	1,353.0	865.1	864.9	712.4	637.8	6,838.0	976.9	282.1
Fish oil	309.9	120.2	161.0	102.4	87.1	1,262.0	180.3	84.8
Fresh seafood	-17.7	-31.1	-31.3	-25.6	-21.6	-167.9	-24.0	5.8
Frozen products	351.1	303.0	338.4	281.0	189.6	1,976.9	282.4	65.6
Others	1.2	0.4	0.4	0.1	0.5	8.4	1.2	1.4
Total	2,030.7	1,276.8	1,348.4	1,075.9	892.5	10,028.6	1,432.7	411.1

during the same period, Peru exported 10.7 million tonnes of seafood products, at a rate of 1.5 ± 0.4 million tonnes per year (Table 27 and figure 42). When only focusing on products for DHC (i.e., excluding products for the aquarium trade, fishmeal and fish oil), average exports are approximately 371.5 ± 57.9 thousand tonnes per year, with imports of 97.2 ± 57.9 thousand tonnes per year.

It is worth noting that imports of Atlantic salmon (*Salmo salar*) and basa (*Pangasius bocourti*), species which are not caught or cultivated in Peru, have recently increased. Between 2010-2016, net exports (i.e. exports minus imports) of basa were negative, occurring at an average rate of -2.9 ± 0.8 thousand tonnes per year. In the case of Atlantic salmon, a similar trend is seen. Net exports are negative and occurring at a rate of -1.7 ± 1.4 thousand tonnes per year.

Tilapia (*Oreochromis* sp.), a non-native species that is farmed in Peru, shows a similar trend where net exports negative and decreasing (-1.5 ± 0.9 thousand tonnes per year). Conversely, net exports of rainbow trout (*Oncorhynchus mykiss*), a heavily farmed introduced species, are positive, increasing and occurring at an annual average rate of 1 ± 0.3 thousand tonnes per year. It is worth noting that aside of these species (Atlantic salmon, basa, rainbow trout and tilapia), almost all remaining trade for DHC involves marine species native to Peru.

Total net seafood exports of Peruvian products were positive between 2010-2016. These totaled 2.29 million tonnes and occurred at an average rate of 327.65 ± 95.18 thousand tonnes per year. Interannual variability was mainly driven by changes in frozen jumbo squid (Dosidicus gigas) exports (Figure 43).

Trade data reveals that the Peruvian seafood market was unsatisfied by the local production during this

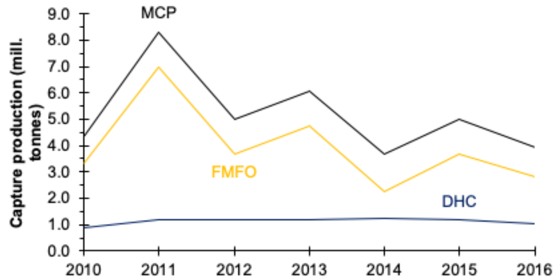


Figure 42: Peruvian species total net exports

period. This claim can be warranted by the decreasing trends in canned and fresh seafood net exports observed across time (Table 27), and by the clear difference between species that showed positive and negative net exports.

Peruvian products containing jumbo flying squid (*Dosidicus gigas*), macroalgae, anchoveta (*Engraulis ringens*), shrimps, Peruvian calico scallop (Argopecten purpuratus), Peruvian hake (*Merluccius gayi peruanus*) and common dolphinfish (*Coryphaena hippurus*) were mainly destined for foreign market. Conversely, products made out of tunas (*Thunnus sp.*), skipjack tuna (*Katsuwonus pelamis*), Chilean jack mackerel (T*rachurus murphyi*), chub mackerel (*Scomber japonicus*) and sharks (*Selachimorpha*) were mainly imported by Peruvian companies working on seafood processing and retail.

Estimating National Seafood Supply

When destined for direct human consumption (DHC) marine living resources landed (or harvested) in Peru enter one of four different supply chains: frozen, fresh (refrigerated or chilled), canned, or cured (Christensen et al. 2014). Before estimating national food supply, we were able to estimate the ratio at which fresh fish (landed) is converted to actual consumable seafood (e.g. one tonne of fish could be 400 kg of actual edible meat) by each supply chain (Figure 43).

Frozen seafood

Based on PRODUCE data, 53% of fish production was used as inputs in frozen seafood value chains during the study period, at an average rate of 623.2 ± 105.6 thousand tonnes per year, with six species responsible for 91% of the total frozen seafood production. With an average conversion ratio of 1:0.52, these inputs generated 325.2 ± 58 thousand tonnes of frozen seafood products per year. Frozen seafood production showed an increasing trend until 2014 (inputs: 741.68 thousand tonnes | outputs: 379.73 thousand tonnes), but has decreased continuously since due to reductions in the landings of jumbo flying squid and other species affected by changes in the oceanographic conditions (e.g., El Niño). The lowest frozen seafood production during the 2010-2016 period was recorded in 2016 (inputs: 466.7 thousand tonnes | outputs: 270.9 thousand tonnes).

Fresh (refrigerated or chilled) seafood

Inputs for this type of production account for 29% of the marine capture and aquaculture production destined for DHC. Fresh seafood wholesale has been increasing steadily during the study period, using on average 339.8 ± 48.2 thousand tonnes of fresh marine living resources per year as inputs. With an average conversion ratio of 1:0.55, these inputs generated 185.8 ± 30.6 thousand tonnes of fresh seafood products per year. There is a higher diversity of species found in fresh seafood products (e.g., fillets) in comparison to frozen seafood products, probably because: (*i*) this line of production requires less technological inputs, has fewer sanitary restrictions and oversight, and (*ii*) Peruvians have a strong preference for fresh seafood consumption (Higuchi, Dávalos, and Hernani-Merino 2017) – as has also been reported elsewhere in the world (Carlucci et

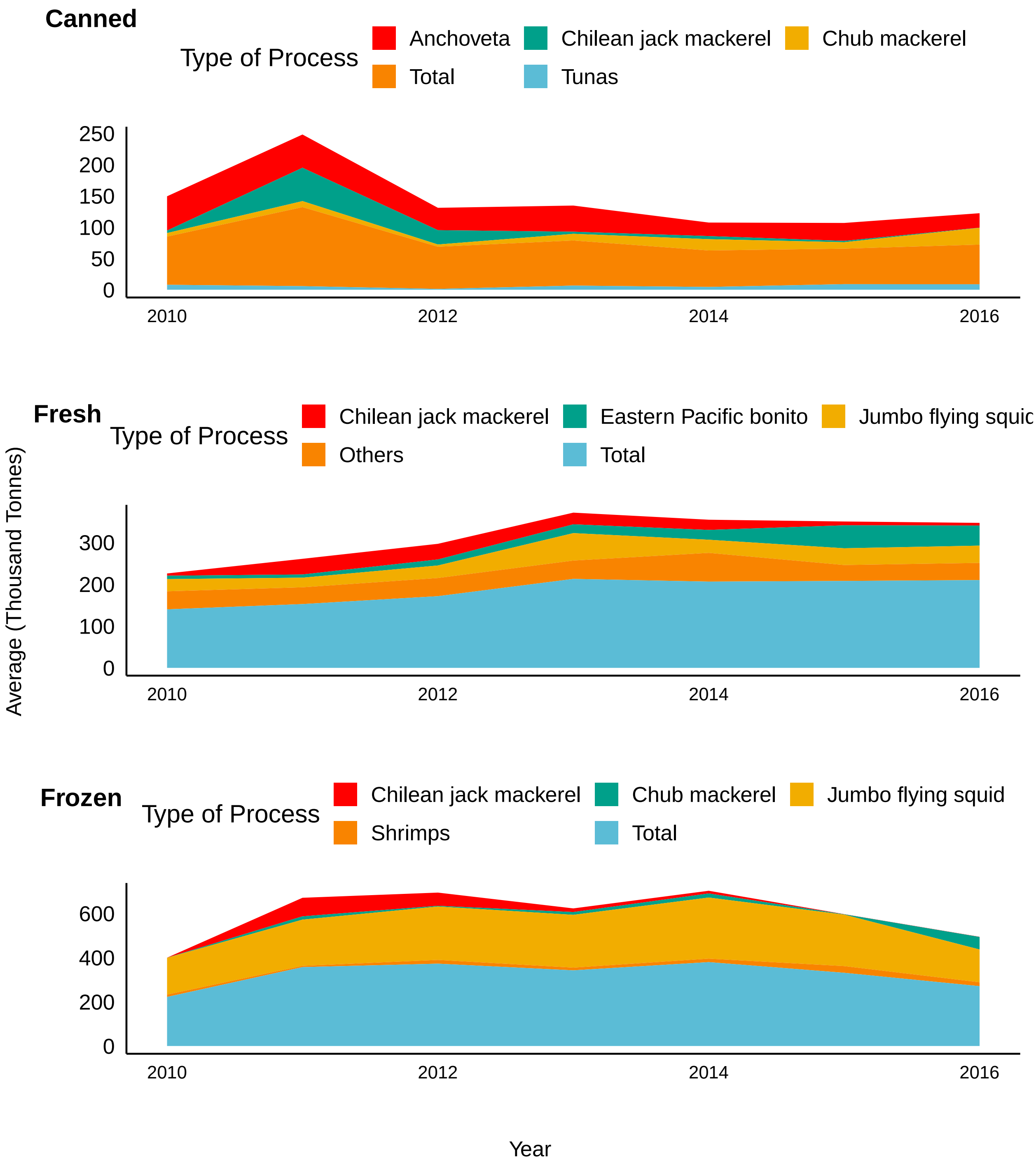


Figure 43: Main Processed seafood supply in Peru

al. 2015). Hence, eighteen species and five groups of species were responsible for 90% of the total Peruvian fresh seafood production.

Canned seafood

Canneries used 12% of the marine capture and aquaculture production destined for DHC between 2010-2016 as inputs, at an average rate of 138.75 ± 31.49 thousand tonnes per year. With an average conversion ratio of 1:0.54, the canning industry produced on average 74.50 ± 23.95 thousand tonnes of canned products (net weight – i.e., seafood in can) per year. Three species and one group of species (i.e., tunas) were responsible for 92% of the total production.

Cured seafood

The remaining 7% of the marine capture and aquaculture production destined to DHC is cured (i.e., salted and/or sun dried). Between 2010-2016, curing used a total of 595.52 thousand tonnes as inputs for production. With an average input-output ratio of 1:0.43, the curing industry produced on average 36.22 ± 4.11 thousand tonnes of cured products per year. Highest production was recorded in 2014 (43.37 thousand tonnes). Cured production was dominated by macroalgae, anchoveta and Pacific chub mackerel, which account to 94% of the total production.

Total and per capita seafood consumption

Due to the vast amount of data on Peruvian seafood production we were able to estimate seafood consumption in three different ways. The first (*Decleared seafood consumption*) is based on data from the Peruvian household survey (ENAHO) performed by INEI. Survey results include per capita seafood consumption estimates per region and species. We then estimated the total seafood consumption (in tonnes) by multiplying the national per capita consumption by the Peruvian population. Annual population estimates for Peru were downloaded from World Bank Open Data[8]. As these indicators were constructed based on survey responses that are not field verified, we referred to them throughout the text as the total and per capita Declared Seafood Consumption (DSCT and DSCpc, respectively).

The second approach to estimate seafood consumption was conducted using the method described in the section *Estimating National Seafood Supply* of this report. The Net Seafood Supply (NSS) was also divided by the Peruvian population. The resulting per capita National Seafood Supply (NSSpc) is comparable with DCSpc.

The third approach includes using all available data obtained from PRODUCE and SUNAT to estimate the total and per capita apparent seafood consumption (ASCT and ASCpc, respectively). This method is similar to the previous one, and was also followed by Smith et al. (2010)(Smith et al. 2010). The main difference between the methods is that for ASCT and ASCpc estimation we do not keep the assumption that all aquaculture production and international traded goods (i.e., imports and exports) are fully consumable - as was the case for NSS. The main difference between the methods is that the one based on NSS does not assume that all aquaculture production and international traded goods (i.e., imports and exports) are fully consumable. This is particularly relevant given that SUNAT registers the weight of shipments of seafood products leaving and entering Peru, but not the actual weight of seafood within them (e.g., accounting for packaging or non-edible content).

Thus, building upon the work conducted by Christensen et al. (2014), we used a mass-balance approach and product-specific multipliers to estimate the amount of seafood within different locally and internationally traded products (e.g., the weight of seafood within a can), then estimated the net seafood supply for each type of production (canned, frozen, fresh, cured) independently and added them together with the seafood remaining in country to estimate the ASCT. The resulting indicators for total (i.e., DSCT, NSS and ASCT) and per capita (DSCpc, NSSpc and ASCpc) seafood consumption use different approaches but are comparable amongst each other.

[8] World Bank Open Data. Available at https://data.worldbank.org

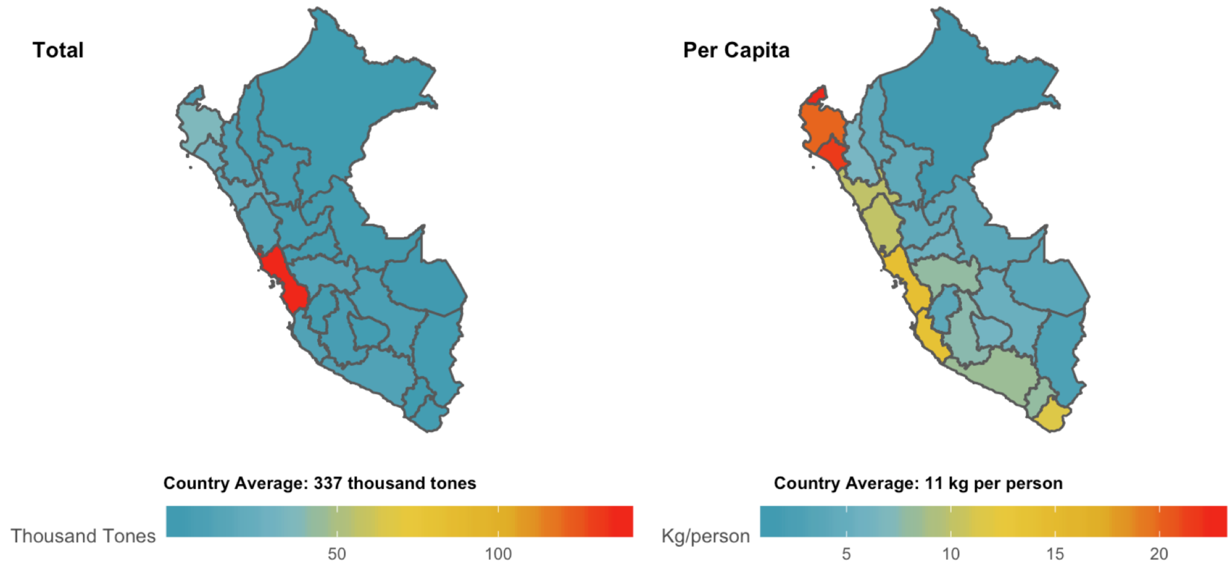


Figure 44: Total and per capita seaffood consumption in Peru by region, average between 2012 and 2016.

Declared seafood consumption (DSC)

According ENAHO, per capita consumption of aquatic resources in Peru increased by 52%, going from 10.2 kg/person in 2010 to 15.50 kg/person in 2016. This indicator includes inputs from marine capture production, freshwater capture production, aquaculture production and imports. Within the 2010-2016 period, seafood's contribution to per capita consumption of aquatic resources increased from 77% in 2010 to 80% in 2016. Per capita declared consumption of seafood (DSCpc) of Peruvians in 2016 ascended to 12.36 kg/person. When segregated by product types, most seafood was consumed in fresh presentations (85%), followed by canned products (13%). Only a minor segment of seafood was consumed in cured presentations (1%), and no consumption was reported to come from frozen seafood products.

Between 2010 and 2016 period, the total declared seafood consumption (DSCT) showed a 70% increase – growing much faster than DSCpc. In 2016 DSCT reached its highest value: 392.63 thousand tonnes. Chilean jack mackerel (*Trachurus murphyi*), Eastern Pacific bonito (*Sarda chiliensis*) and tunas (*Thunnus sp.*) were the main contributors to DSCT. These species together with 13 others were responsible for 90% of the ASCT.

When displayed by region DSCT revealed that 84% of seafood was consumed in the coastal regions of Peru (Figure 4). Lima was the largest market during the studied period, concentrating 41% of the DSCT (Figure 44). Other important markets were the Piura, Lambayeque and La Libertad regions, which respectively concentrated 11%, 8% and 6% of the DSCT. Additionally, the regional analysis of the DSCpc, revealed that Peruvian seafood consumption per capita was higher in northern coastal regions. These include Lambayeque (25.65 kg/person in 2016), Tumbes (24.43 kg/person in 2016) and Piura (23.76 kg/person in 2016). DSCpc in the Ica, Callao and Lima regions were also well above the national average. Conversely, DSCpc was lowest in the Peruvian Amazon, including the Loreto (1.66 kg/person in 2016), Ucayali (3.45 kg/person in 2016), Madre de Dios (4.20 kg/person in 2016), Amazonas (4.92 kg/person in 2016) and San Martin (5.33 kg/person in 2016) regions (Figure 44).

Net seafood supply (NSS)

With the exception of a decrease registered between 2011 (298.56 thousand tonnes) and 2012 (231.73 thousand tonnes), net seafood supply (NSS) increased continuously during the studied period. NSS increased 48% between 2012 and 2016, reaching a supply of 343.05 thousand tonnes. The estimated NSSpc also increased since 2012, but only by 40%. The highest estimated NSSpc was in 2016 with 10.80 kg/person. Fourteen

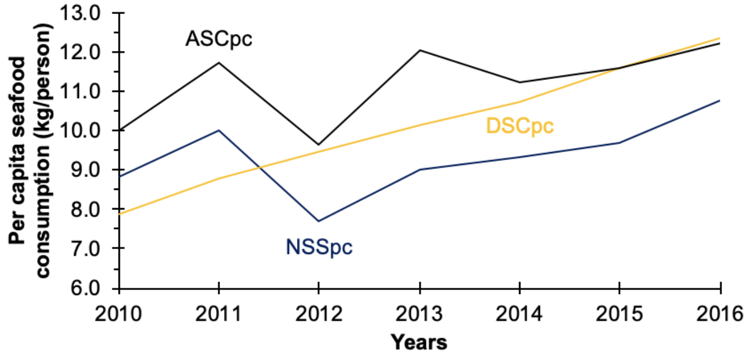


Figure 45: Peruvian seafood consumption between all approaches

species and/or groups of species were responsible for 90% of the Peruvian NSS.

Apparent seafood consumption (ASCT)

Total apparent seafood consumption (ASCT) showed an overall increasing trend during the studied period, as did the per capita apparent seafood consumption (ASCpc). ASCT showed a 32% increase between 2010 and 2016, whilst ASCpc increased by 22%. Both indicators showed high values in 2011, 2013 and 2016, peaking in 2016 (ASCT = 388.19 thousand tonnes | ASCpc = 12.22 kg/person). Most seafood (58%) was consumed fresh between 2010-2016. Fresh seafood was followed by canned products (20%) and frozen products (20%). Cured seafood consumption was minor (2%). Eighteen species and/or groups of species were responsible for 90% of the ASCT.

Comparing seafood consumption trends between the three approaches

Regardless of the method of estimation, seafood consumption in Peru is on the rise. The increase is strongest, steadiest and fastest based on data in DSCpc (Figure 45), as both ASCpc and NSSpc show a decrease in seafood consumption during 2012, which is not observed in DSCpc. It is important to highlight that ASCpc is the indicator used by FAO to compare seafood consumption amongst countries (Smith et al. 2010).

Six fish species, regardless of the indicator used, were consistently among the major contributors to national food security. These were (listed in decreasing order of importance): Chilean jack mackerel (*Trachurus murphyi*), chub mackerel (*Scomber japonicus*), Eastern Pacific bonito (*Sarda chiliensis*), anchoveta (*Engraulis ringens*), tunas (*Thunnus* sp.) and Peruvian hake (*Merluccius gayi peruanus*). Additionally, Peruvian weakfish (*Cynoscion analis*), Chilean silverside (*Odontesthes regia*) and lorna drum (*Sciaena deliciosa*) appear to be much more important in the DSCT and DSCpc than in any other indicator, while species like flying jumbo squid (*Dosidicus gigas*) and the common dolphinfish (*Coryphaena hippurus*), appear as much more important in ASCT and ASCpc than in other indicators (Table 27).

Estimating National Economic Participation

The Peruvian fisheries sector has been shown to have an almost constant economic multiplier across time. Both Dyck and Sumaila (2010) (Dyck and Sumaila 2010), using 2003 data, and Christensen et al. (2014), using 2009 data, found that the fisheries sector had an average income multiplier of 2.9. This implies that every time US 1.0 is made at sea (i.e., catching fish), activities on land (i.e., processing, distribution, wholesale and retail) produce an additional US$1.9. Christensen et al. (2014) also found that employment behaved in a similar way, estimating a multiplier of 2.9 as well.

Nonetheless, it is important to highlight that general multipliers for the Peruvian fisheries sector are severely skewed by the fish meal and fish oil (FMFO) industry (Christensen et al. 2014). This industry generates

Table 27: Summary table of seafood consumption trend between approaches. Thousand Tonnes

Species	2012	2013	2014	2015	2016	Total	Average	SD
ASC								
Anchoveta	36	42	22	29	23	259	37	14
Chilean jack mackerel	23	3	5	2	0	91	13	19
Chub mackerel	4	11	18	10	27	85	12	8
Tunas	1	7	4	9	9	44	6	3
Eastern Pacific bonito	0	1	2	2	2	9	1	1
Jumbo flying squid	0	0	1	0	0	4	1	1
Anchoveta	26	32	28	22	21	233	33	13
Chilean jack mackerel	74	60	53	55	52	472	67	23
Chilean silverside	6	4	4	3	2	27	4	1
Chub mackerel	20	42	59	41	85	296	42	23
DSC								
Common dolphinfish	9	18	13	11	6	82	12	4
Eastern Pacific bonito	16	25	27	61	53	199	28	21
Lorna drum	4	4	3	4	6	30	4	1
Peruvian hake	5	17	15	16	22	89	13	7
Peruvian weakfish	3	4	4	4	6	28	4	1
Tunas	14	20	21	26	24	142	20	4
Jumbo flying squid	30	66	31	40	41	260	37	14
NSS								
Eastern Pacific bonito	14	21	24	55	48	178	25	19
Chilean jack mackerel	37	28	24	9	6	148	21	14
Common dolphinfish	11	20	15	17	10	107	15	4
Peruvian hake	6	11	15	15	20	79	11	6
Chub mackerel	5	6	7	12	16	54	8	5
Lorna drum	4	4	3	4	6	29	4	1

~85% of the countries reported maritime landings and has an economic multiplier of 2.6. Thus, its effect on the sector's economic performance is significant. However, its impact on the total employment multiplier is much smaller, despite being low (i.e., 1.77), as it only accounts for roughly ~13% of the sector's employment.

Given that different resources had different economic and employment multipliers (Christensen et al. 2014) we estimated the total revenue and employment for the DHC industry between 2010 and 2016. In order to calculate the real contribution of the fisheries sector to the national economy, we took the ex-vessel prices and adjusted them for inflation by dividing them by the national price index for food items[9], and then turned them into US dollars by applying the official PEN-USD exchange rate. The real ex-vessel prices in $USD/tonne were then multiplied by the total landings per group, and then by the economic multipliers listed in Christensen et al. (2014) in order to estimate total economic impacts from the seafood industry.

After removing the effect of the FMFO industry the DHC sector's economic multiplier during the studied period was largest in 2011 with a value of 3.43, given the large landed volume of chub and Chilean jack mackerel. It then decreased and became more stable between 2013-2016 at an average of 3.15 ± 0.04. The average economic multiplier for the period was of 3.19 ± 0.14.

Between 2010-2016, the total revenue of the DHC sector is estimated to be $USD 23.30 billion. On average, $USD 1.04 billion per year (± USD 0.14 billion per year) were made at sea and $USD 3.33 billion per year (± $USD 0.68 billion per year) were made on land in processing and marketing. This is consistent with the total real value of imports (total: $USD 2.09 billion | average: $USD 298 ± 52 million per year) and exports (total: $USD 21.78 billion | average: $USD 3.11 ± 0.57 billion per year) published by SUNAT.

Estimating the total contribution of the sector to national employment is much harder, given that the small-scale fleet has continued to grow (IMARPE, unpublished data), and the new technological advances have potentially changed the overall employment requirements of processing facilities. Using data from the third census of small-scale fisheries (IMARPE, unpublished data), Peru had 67,427 active small-scale fishers in 2015. This represents a 53% increase since 2012, when the estimated small-scale fishermen population included 44,161 fishers (Carrasco et al. 2017). Applying the 2.9 multiplier for employment, the total contribution of the small-scale fisheries to national employment (i.e., accounting for processing, marketing, and all supporting industries) would be of 195,538 jobs (Christensen et al. 2014).

Peruvian calico scallop (*Argopecten purpuratus*) and shrimp production has increased since 2009 (PRODUCE 2017). Given that in 2009 semi-intensive scallop aquaculture employed 0.257 people per tonne and had a 1.2 employment multiplier, whilst intensive shrimp aquaculture employed 0.176 people per tonne and had a 1.5 employment multiplier, production levels of 2015 would have resulted in 9,828 jobs before harvesting (60% from scallop aquaculture) and 3,135 jobs after harvest (38% in the farmed scallop value chains). The total jobs produced by aquaculture of marine resources would add up to 12,963 jobs.

Finally, although the total number of steel purse seiners that target anchoveta for FMFO have decreased, industrial vessels targeting mackerels, tuna and hake have not. According to Elena Conterno, president of the Peruvian Fisheries Society, these vessels employ roughly 3,000 people at sea resulting in approximately another 5,700 jobs in supporting industries on land.

In summary, the DHC value chains would have employed roughly 217,202 people (80,256 at sea and 136,946 on land) during 2015. Our values are comparable with the 231,929 jobs estimated by Christensen et al. (2014) in 2009. However, our current estimate does not include the FMFO value chains, nor guano value chains, which together amounted to 13% of the fisheries sectors' employment in 2009. This suggests that DHC value chains' contribution to national employment has significant increased in recent years.

[9] Information downloaded from the Central Reserve Bank of Peru's (BCRP) official webpage. Available at http://www.bcrp.gob.pe/estadisticas.html.

Critical Analysis

Brazil

Key messages:

- *There are no national-level fisheries statistics in Brazil since 2008;*
- *Aquaculture is the fastest-growing food industry in Brazil*

Seafood Consumption

Key messages:

- *Fish and seafood consumption in Brazil as a whole is still limited compared to other parts of the world;*
- *Fishery resources are an important source of food in the poorest regions of the country, and thus key for food security;*
- *Brazil relies heavly on seafood imports to supply growing demand for seafood in the country;*
- *Canned sardines are the most consumed fish product in the country;*
- *Of the main fish species consumed in Brazil, about half are from capture fisheries and half from aquaculture.*

Domestic consumption of fish and seafood products in Brazil is still limited compared to other countries around the globe (around 10kg/capita/year). Yet, because of Brazil's large population, consumption of fish and seafood product sums up to large amounts every year. To supply the domestic market, Brazil imports over 380 thousand tonnes of seafood products every year. However, with increased aquaculture production (about 770 thousand tonnes in 2017), domestic supply of fish and seafood products are rising quickly.

Despite low per capita consumption across the country, consumption of fish in the poorest regions of the country can be very high. For example, the Amazon region has one of the highest per capita fish consumptions in the world, reaching 169 kg per year. Only in this state, it is estimated that about 80 thousand tonnes of fish is consumed for subsistence of riverine communities. In this study, we found that the poorest regions of the country are those that consume the most fish, which makes fisheries production crucial for food security. The North and Northeast regions are especially important since they have the highest fish consumption per capita in the country, while having the lowest per capita income and the largest number of registered fishers in the country.

According to the compiled databases, sardines are the most important fish for consumption in Brazil, especially through the canned market. It is an affordable alternative to other protein sources and is consumed all over the country. Other important resources for fish and seafood consumption in the country include croakers, tilapia, catfish, achuma, tunas, sharks, salmon, and hake. From these main species consumed, tilapia and cachuma are from national aquaculture production and salmon is imported mainly from Chile. The remaining species are from domestic capture fisheries. However, these results rely on data mostly from imports, aquaculture and the industrial sector (which comprises about 30-50% of catches in the country). The remaining production is from the artisanal sector, where there is virtually no information on catches. Production from the artisanal sector is mainly consumed locally, with huge social importance in the country. This sector is characterized by having hundreds of commercially exploited species, where some of the most important species are crabs, shrimps, lobster, snappers, groupers, mullet, weakfish and snook.

Fisheries Employment and Income

Key messages:

- *Fisheries has a significant social importance for Brazil, employing millions accross the entire supply chain;*
- *About 95% of the registered fishers are from the artisanal sector;*

- *According to our databases, sardine is the most valuable resource in the country;*
- *Lobster exports are an important economic activity for artisanal fishers.*

The total number of fishers in Brazil is very uncertain. According to different data sources, there are between 500 thousand and 1 million fishers in the country, with the vast majority in the artisanal sector. When considering employment along the entire supply chain, fishing activities have enormous social importance for the country.

According to our databases, sardines are the most valuable species in the country. The canned sardine and tuna market is crucial for the country's economy. Seafood industries that process these and other fish have an aggregate revenue of multiple billion dollars every year. Lobsters are also highly valuable for the country. It is the main exported species in Brazil and is captured exclusively by the artisanal fleet.

Data Uncertainty and Gaps

During the study we identified several important data gaps in our analysis. First, there has been no collection of national-level fisheries statistics in the country since 2008, which made it challenging to meet our objectives and required more extensive field efforts and collation of multiple sources of data. Second, and related to data availability in general, there is no data on fisheries production from the artisanal sector, which likely accounts for more than half of the seafood production in the country. Third, there are very few studies on fish consumption in the country, with the most reliable studies dating back almost ten years. Fourth, there is very little information on seafood supply chains, especially in the artisanal sector. For the industrial sector, many of our databases did not have information on prices, which made it difficult to estimate the total income generated. More specific uncertainties on key datasets are provided below:

1. SIGSIF - This database contains self-reported data from seafood industries across the country, who report the weight of all seafood that entered their company. This seafood can be sourced from aquaculture farms, fishing boats, local markets and other seafood companies, as noted in the "origin" column. It is therefore important to select only seafood that originated from a producer (aquaculture or fisheries; "PRODUTOR") to avoid overestimating production (i.e., double-counting seafood bought from another company). Another potential source of bias in this database, is through self-reporting errors. In one such case from 2016, production in one company from Rio de Janeiro exceeded 2 million tonnes, a clear typing error.
2. CEAGESP - CEAGESP data is generally trustworthy and data collection is done by a contracted company that controls all the products that enter the market daily.
3. MDIC - This database does not contain any major sources of uncertainty, since all traded products are rigorously checked by the government health authority.
4. State fisheries landings - These data have major sources of uncertainty. As with most landing data, in some years monitoring was not carried out in all landing sites. For example, in Santa Catarina state, landings monitoring for 2014-2016 did not include all landing sites due to lack of funding, generating an important bias on these years. In many cases, sampled catch was extrapolated to the entire fleet, also creating an important source of bias. These landings data nonetheless are the most complete in the country.
5. IBGE - This data relies on questionnaires from a random household sample in each region of the country. Therefore, there may be sampling biases if samples were concentrated near large metropolises. Especially for seafood products, highest consumption rates are from isolated coastal and riverine communities. However, IBGE is recognized internationally for high quality research and for having robust sampling of all areas in the country. Perhaps the largest clear source of uncertainty is that the last survey was done in 2008, which may not reflect fish consumption today.
6. Fishing Permits - Although this database provides important information, there is a huge uncertainty regarding the number of fishers in the country. An important fraud is currently being investigated by non-fishers that are registered as artisanal fishers to receive a compensation for fisheries closure periods.

According to the investigation, more than half of compensation claims have irregularities. In addition, many actual fishers do not have a fishing permit. Thus, this database is highly uncertain and clarifying the true amount of fishers in the country would be a good first step for improved management.

Chile

Key messages:

- *The most landed species in Chile are the Peruvian anchoveta, the Araucanian herring, and the Chilean jack mackerel. All of these species are fish by both the industrial and artisanal sectors;*
- *An important volume of artisanals' landings comes from algae, especially from the Giant grey and brown kelp;*
- *The group of species that is most imported to Chile is Tuna, while the most exported are salmons;*
- *Salmons are by far the most important species in terms of volume for aquaculture, followed by mussels.*

Seafood Consumption

Key messages:

- *Most importants species in terms of food consumption in Chile are jumbo Squid and Southern rays bream followed by hakes and mackerel;*
- *Trends in food consumption show that in general the species that contribute to domestic food consumption have been constant through time except from Hake, that has been slowly declining;*
- *Tuna is one of the main groups of species consumed in the country but is mainly imported;*
- *Most of wild-caught fish is processed for non-human consumption products;*
- *Despite its massive production, aquaculutre is not a major source of food supply for the Chilean population. Most of its production is exported or are too expenssive to be accessed by lower income groups which is the population of interest in the contxt of food security.*

Chile is one of the main fish producing countries worldwide (FAO 2016a), yet studies suggest the Chilean population does not have a particulary high seafood consumption rate (Gonzales 2018). We found that on average the chilean population eats ~11kg of seafood a year. This is lower than the 20 kg a year recommended by Food and Agriculture organization (2016). According to the National Health Survey (Ministerio de Salud 2018), only 9.2% of the Chilean population eats fish at least two times a week as recommended. This value has decreased since the early 2000s where this percentage was 10.7% (Ministerio de Salud 2018). World Data (Ritchie and Roser, n.d.) also shows a decrease in the amount of per capita seafood consumed per year by the Chilean population from ~16kg consumed in 2004 to 12.5kg in 2013.

Looking into what type of seafood the Chilean population consumes, a study done in 2012 showed that 60% of the seafood consumed are pelagic fishes, 12% are mollusk and 2% are crustaceans (Villena 2012). The most important groups of species for domestic food consumption are squids, tuna, hake, and the Southern ray beam. However, it is likely that we have overestimated squid consumption. It is worth noting that tuna is mostly imported into the country, while most of the species produced in aquaculture like salmon, trouts and mussels are mostly exported. This reflects the importance of market forces on world-wide seafood destirbution and supply. Salmon and trouts get better prices abroad and are expensive for Chileans in general.

Seafood consumption in Chile has been shown to be correlated with income, as in other parts of the world. However, the data is spotty and is probably missing some of the consumption that occurs in coastal communities. According to a study done in 2016 by Fundación Chile and Adimark (chile 2016), the frequency of seafood consumption varies along socio-economic groups in Chile; 55% of the high-income group consumes seafood at least once a week compared to 38% of the lower-income group. It has also been identified (Ministerio de Salud 2018) that people with less years of schooling tend to eat less fish (only 6.3% eats seafood twice a week) than people that have completed high school education.

Economic participation

Key messages:

- *Aquaculture, specifically that of Atlantic salmon, is the marine activity that contributes the most to the national economy;*

- *Valuable benthic species like the Chilean sea urchin and the Loco have a high potential to bring revenues to the artisanal sector due to their high ex-vessel prices and relatively low costs of fishing;*
- *Despite being spread along the entire coast, fishing activities and the processing of marine products concentrate mostly in the South and Austral South of the country;*
- *While there are estimates about how many people directly and indirectly relies on fisheries a source of income an employment there is lack of official data;*
- *A large share of the people employed in the sector are not formally hired which contributes to a lack of retirement benefits.*

Aquaculture is the most important activity in the fisheries sector in terms of economic value; their profits come mainly from the export of salmon products. Wild-caught species that currently contibue the most to exports are jack mackerel (*Trachurus murphyi*) and the jumbo squid (*Dosidicus gigas*). The latter is used for DHC and is targeted by both the artisanal and industrial sector. Particularly valuable species for the artisanal sector are the Southern king crab (*Lithodes santolla*) and the Chilean sea urchin (*Loxechinus albus*). The first fishery occurs only in the South of the country while the latter is ditributed along the coast of Chile.

Although direct employment in aquaculture centers is low relative to artisanal fishers, it is very likely that an important share of jobs in the manufacturing sector are supported by aquaculture, particularly in the South of Chile.

The role of algae in terms of employment in the artisanal sector is also worth noting; revenues of these species are not particularly high, but the lower costs of extraction relative to other types of fishing make algae collection an attractive activity for coastal communities.

Data Uncertainty and Gaps

- Most of our analysis relied on publicly-available data collected by government institutions. Although data collection has improved over the years and there have been important national efforts towards transparency, there are still some potential biases in data. Particularly concerning is landings data, since they are mainly generated via landings declarations. This requires fishers to announce their intention to land their catch to the authority in charge in their macrozone who must weight and certify the catch. Without the certification of their catch, fishers cannot sell it in legal establishments and they risk their permits and penalty fees. Still, incomplete enforcement may generate incentives to underreport. Illegal unreported and unregulated (IUU) fishing has been highlighted in Chile, even in systems where fishers are expected to have high incentives against it, such as Territorial Users Rights systems (Oyanedel et al. 2018).

- A lack of consistency in data collection between and within agencies brings another source of uncertainty for an analysis like ours. A major challenge was to match trade and landings data. SERNAPESCA collects data under common names, while Aduanas Chile record exported and imported products under the International Harmonized System nomenclature.

- We found a lack of consistency in two datasets provided from SERNAPESCA for the year 2015. Data segregated by sector, month and region did not match aggregated data published in a differen document. This confirms that even though official data is our most reliable source, it also involves uncertainty.

- It is possible that we have overestimated export volumes for some species since some products combine species of interest with non seafood ingredients. We could not account for this since we did not have data' composition. However, for the most exported products this is not a major issue since fish fillets and fresh products are usually almost 100% made by fish meat or shellfish. Similarly, we lacked data on species-specific yields to estimate how many kg of a species translates into different marine products. We found our analysis to be particularly sensitive to assumptions on the ratios of fresh catch to marketed products, highlighting the importance of improving this aspect of the model.

- A major information gap we identified is the lack of publicly available data on ex-vessel prices and employment for the industrial sector. To our knowledge, neither SERNAPESCA, IFOP nor SUBPESCA collect data on this regard. Even though we were able to estimate the total impact of the fisheries industry (supply chain) in the country's GDP using the SAU data and the multiplier developed by Dyck and Sumaila (Dyck and Sumaila 2010), there is no detailed information from national sources for the industrial sector as there is for the artisanal sector in Chile. Thus, identifying the most valuable species for the industrial sector was not possible. One possibe future exploration could be to derive ex-vessel prices from trade data (Melnychuk et al. 2017). The fisheries sector for which we found most available information was the artisanal sector. We were able to estimate direct employment generated by this sector through the National Record of Artisanal Fishers (RPA). Even though the RPA is an official registry for fishers, we know enforcement is weak, especially in remote areas of the country. We were also able to estimate species-specific revenues by using landings and prices of first transactions. Finally, information on employees in processing facilities was also available. However, some values were unrealistic since some were larger than the entire population of the country. Thus, we relied on a survey study performed by IFOP to fullfill this estimate.

- We also lacked data on the transportation of landings and products between Chilean regions and final destinations. This prevented us from applying our model of food supply at the regional level.

Peru

Fisheries context

Key messages:

- *Most Peruvian capture production is still destined for fishmeal and fish oil production.*
- *Aquaculture production continues to increase throughout Peru.*
- *Most capture and aquaculture production enter frozen seafood value chains that aim to produce frozen seafood for export.*

Peru is well known as an anchoveta (*Engraulis ringens*) fishing country. Due to changes in oceanographic conditions (e.g., el Niño) and precautionary approaches to management, anchoveta landings have decreased by 40% in the last five years (in comparison to the previous five-year period) (PRODUCE 2017). However, this species still dominates national capture production. Most of its catch is used for reduction, even though Peruvians have severe nutritional deficits and a transition to value chains for direct human consumption (DHC) would increase the contribution of this marine living resource to the economy (Majluf, Puente, and Christensen 2016).

As revealed by this study, DHC capture production in Peru is mostly used in value chains that target foreign markets, where jumbo flying squid (*Dosidicus gigas*) plays a key role. Moreover, marine aquaculture production is also tailored to foreign markets. As a result, freshwater aquaculture production is increasing at a much faster rate and supplying both national markets and foreign markets.

Seafood consumption

Key messages:

- *Seafood consumption is increasing in Peru, regardless of the method used to estimate it;*
- *The Andes mountain range is a major barrier for supplying seafood to Peruvian regions located in the highlands and the Amazon;*
- *Peruvians living in the Amazon declare high levels of consumption of freshwater species, locally caught or farmed for subsistence.*

As previously reported by De la Puente (2017) (Puente 2017), overall catches for direct human consumption in Peru have remained somewhat stable between 2006 and 2016. Given that total and per capita seafood consumption continues to rise in Peru, Peruvian dependence on seafood imports is rapidly increasing in order to ameliorate the growing unsatisfied local seafood demand. Greater demand for seafood is thought to be jeopardizing certain key species for the restaurant trade, and hence local NGOs have started to work with chefs to strengthen the sustainable seafood movement (Lama et al., n.d.).

The multiple methods used to estimate seafood consumption in Peru revealed that Peruvians mostly eat highly nutritional fishes (e.g., mackerels, bonito and small pelagics), with relatively low tropic levels (except for tunas and sharks). Nonetheless, the Andes mountain range is a serious barrier to seafood consumption, as can be seen by the low DSCpc reported for Peruvian regions found in the highlands and the Amazon. These regions have the highest nutritional deficits and have some of the lowest values of GDP per capita within Peru (A Comer Pescado 2015; Majluf, Puente, and Christensen 2016). This is key to understanding regional seafood availability. As seafood consumption increases with growing household incomes (A Comer Pescado 2015; Higuchi, Dávalos, and Hernani-Merino 2017), seafood continues to remain close to shore and particularly in Lima, given that the coastal regions of Peru report the largest economic growth within the country (Puente et al. 2013).

It is also worth noting that some key species for DSCT were not relevant for ASCT and vice versa. The Chilean silverside (*Odontesthes regia*), lorna drum (*Sciaena deliciosa*) and Peruvian weakfish (*Cynoscion analis*) were more important contributors to total food security in DSCT than in ASCT. This could be explained by ENAHO revealing a higher unreported supply of these fishes in Peru or consumers being misled (consumer fraud) and sold mislabeled seafood at their local markets. These species have been traditionally consumed in Peru (Sueiro Cabredo and Puente 2015) and are sough-after by consumers (A Comer Pescado 2015). As seafood products are easier to sell when consumers know the species being sold and have a history of consuming it (Carlucci et al. 2015), perhaps this reveals a market strategy aimed at securing a purchase whilst diluting environmental limitations (i.e., decrease in local supply of a particular species) (Crona et al. 2016). This could also explain why jumbo flying squid (*Dosidicus gigas*) and common dolphinfish (*Coryphaena hippurus*) are not as important for DSCT in relation to ASCT. Both of these species are relatively new to Peruvian consumers and not heavily sought seafood items (Sueiro Cabredo and Puente 2015). This is an important aspect to consider when promoting seafood consumption in the Peruvian Andes and Amazon. Increased seafood supply will not necessarily translate to increased consumption, if it is not accompanied by efforts to: (a) promote positive interactions between seafood and local populations, and (b) teach people how to preserve and prepare seafood.

Additionally, ENAHO does not report frozen seafood consumption. This is a result of local legislation, as seafood wholesalers and retailers are not required to inform consumers whether or not the seafood item being sold is local or if it was previously frozen (Puente 2017).

Moreover, when comparing ASCT and NSS, the latter presented much lower values. This is because SUNAT registers the weight of the shipments entering and leaving the country and not the net weight of seafood within them. Given that Peru is a net exporter of seafood, the NSS method will tend to underestimate the seafood supply that remains within the country. On this note, PRODUCE used to publish values for total and per capita apparent consumption of fish and aquatic invertebrates in Peru in their annual statistical reports (PRODUCE 2013). They claim to use the same method for estimating ASCT as we did, however they produce much higher values, and have been heavily criticized for overestimating seafood consumption due to lack of precision and inappropriate assumptions (A Comer Pescado 2015).

Finally, it is important to highlight that people living in the Peruvian Amazon are not deprived of fish and subsistence fishing is very important for local nutrition (Mendo and Wosnitza-Mendo 2014; Sueiro Cabredo and Puente 2015). For example, Loreto only reports a DSCpc of 1.66 kg per person; however, when including local freshwater species, the total declared consumption of aquatic living resources reaches 47.4 kg per person.

This reveals a a continuous challenge for fisheries management in Peru that originates from the large extent of catch underreporting in the Amazon. PRODUCE and DIREPRO are unable to prioritize actions to improve fisheries monitoring in the Amazon as landings appear to be insignificant in the national statistics. Given that they are unaware of trends in species biomass, catches or catches per unit of effort, the government is unable to implement actions to improve fisheries managements. As these institutions are unaware of how fisheries actually operate in these areas, and fishers hardly ever interact with government officials, regulations tend to be inadequate and are systematically ignored by local stakeholders (Sueiro Cabredo and Puente 2015). The total lack of government oversight is not only problematic for communities seeking support to block large infrastructure projects (e.g., dams) that would negatively impact their food security, but also makes them highly vulnerable to climate change and overfishing.

Economic participation

Key message:

- *The contribution of direct human consumption value chains to the national economy is severely underestimated by the Ministry of Production, however it is increasing and gaining importance over fishmeal and fish oil value chains.*

PRODUCE estimates the fisheries sector's contribution to the national economy disregarding seafood processing for direct human consumption. The latter's contribution to employment and GDP is rather counted as part of the manufacturing sector (Puente et al. 2013; Christensen et al. 2014). Hence, DHC industries have not received the attention needed, both in terms of regulations and enforcement. This has led to a progressive weakening of the rule of law (Puente and Sueiro 2013). This argument is supported by the ever-growing Peruvian artisanal fishing fleet. Despite multiple legal bills and other regulatory efforts to close access to new vessels aiming to target fully exploited marine living resources, this fleet continues to increase and profits are in decline [Carrasco et al. (2017); IMARPE, unpublished data]. Fishers are already seeing their profits eroded and continue to be pushed into perverse and very resilient cycles of Malthusian overfishing (Finkbeiner et al. 2017).

Our estimates of the sector's overall revenue show a relative decrease in the value of DHC value chains since 2011. It is important to highlight, however, that these values are only estimates using multiple datasets and various assumptions; a much closer look is needed to understand the economic dynamics of the Peruvian fisheries sector. This is definitely a research gap that needs to be dealt with in order to properly balance trade-offs and assess the economic and social impacts of alternative fisheries policies aimed at advancing towards the ecosystem-based management of the Humboldt current and its marine living resources.

Data Uncertainty

Key messages:

- *Although data is readily available, its reliability remains unclear;*
- *Government systems for fisheries data collection, including trade data, can bias national statistics and hinder their interpretation.*

PRODUCE estimates the monthly capture and aquaculture production by compiling various sources of governmental information (monthly reports from DPAs, IMARPE and DIREPROs, together with monthly affidavits from industrial fisheries processing facilities and aquaculture producing sites). However, the methods used by PRODUCE for combining the multiple data sets have never been published and were not available when requested for the present work. This lack of transparency can weaken trust in the information provided by PRODUCE.

It is key to highlight that PRODUCE's estimates of marine and freshwater capture production are a reconstruction of landings rather than the catch (Puente et al. 2013; Sueiro Cabredo and Puente 2015). For some species, like sharks for example, the catch is severely underestimated because these fishes are beheaded and gutted on board (Puente 2017). Important discards are not accounted for in landings other species including common dolphinfish (*Coryphaena hippurus*) (Puente et al. 2015), and jumbo flying squid (*Dosidicus gigas*) (Paredes and Puente 2014).

Moreover, PRODUCE underestimates the maritime capture production because it does not account for illegal unreported and unregulated (IUU) fishing, which can be very significant in the small-scale fisheries of Peru (Mendo and Wosnitza-Mendo 2014). A potential source for this is the data-collection system itself. Species listed in industrial affidavits and/or reports from DIREPROs and DPAs are described using common names, which often vary from site to site (e.g., '*jurel*', '*furel*' and '*cairel*' are all used in reference to the Chilean Jack mackerel *Trachurus murphyi*) or are used to describe different species (e.g., '*pampanito*' is used for the Peruvian moonfish *Selene peruviana*, the starry butterfish *Stromateus stellatus*, and the Paloma pompano *Trachinotus paitensis*), or often use non-informative categories (e.g., '*tollo*' or '*tiburón*' can be used to describe any shark species [López de la Lama, Puente, and Riveros (2018)). As a result, landings of marine living resources reported by IMARPE for the 1997-2015 period include registries for at least 258 fish species, 43 species of mollusks, 30 species of crustaceans, 4 species of echinoderms, 4 species of brown algae, 2 species of red algae and 1 species of tunicate; whilst landings reported by PRODUCE only included 45 species and/or groups of species, reported using common names only (29 for fishes; 9 for mollusks, 2 for crustaceans, 1 for echinoderms, 1 for macroalgae and 3 for unspecified resources – other fishes, other invertebrates, other species).

Additionally, affidavits from industrial seafood processing companies are hardly ever verified (Patricia Majluf and Hector Soldi , pers. comm.). As a result, some products had very unrealistic yields (e.g., landings of macroalgae were much smaller than the reported cured algae production and export), or manifested mistaken information (e.g., landings of Atlantic salmon reported off Lima). Contracts for DPA administration, as well as operational manuals for DPA administrators, do not include mandates regarding data collection for fisheries management (PRODUCE 2010). As a result, DPAs lack common or standardized formats for data collection, leading to confusion and error. Moreover, as DPAs are taxed in reference the amount of the fish (and marine invertebrates) landed at the sites, their administrators have a strong economic incentive to underreport them. DPAs ought to be monitored by DIREPROs and PRODUCE, but these institutions lack the man-power and resources to properly impose the rule of law within the fisheries sector (Puente and Sueiro 2013).

Like marine captures, freshwater capture production is severely underestimated (Sueiro Cabredo and Puente 2015). Most of the catch never goes through a landing site and is used for subsistence, as can be seen from the difference in volume reported by PRODUCE and from ENAHO (A Comer Pescado 2015; Sueiro Cabredo and Puente 2015; PRODUCE 2016).

Finally, regarding trade, SUNAT records shipments coming in and going out of Peru with great care. They conduct a census of the shipments, rather than just sampling them. However, shipments are sorted by 'customs codes', which group together multiple product types and species. Using the general and specific commercial description of each shipment, it is possible to re-arrange their dataset into something more meaningful for monitoring international trade of fisheries and aquaculture products. However, some shipments include multiple species without detailing how much of the total weight corresponds to a particular species (e.g., shipments labeled only as 'frozen shrimp and mahi-mahi'). The latter are hardly ever segregated with certainty. Nonetheless, the practice of cleaning SUNAT's data is not something undertaken by PRODUCE, due to limited manpower. As a result, they use customs codes to assess trends in trade, which can lead to interpretation errors.

In synthesis, it is clear that Peru has very high-quality fisheries and aquaculture data systems, though uncertainty is an issue that requires closer attention and it is of paramount importance to improve transparency. This not only includes data for fisheries governance (Puente and Sueiro 2013; Heck Franco 2015; Gutiérrez, Sueiro, and Sueiro 2017), but also data used to inform policy (Puente et al. 2013; Sueiro Cabredo and Puente 2015). This is not just an issue for decision makers within the government, but also is a key requirement to secure compliance with international agreements such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Luckily, Peru has recently signed the Agreement of Escazú (i.e., *Acuerdo Regional sobre el Acceso a la Información, la Participación Pública y el Acceso a la Justicia en Asuntos Ambientales en América Latina y el Caribe*), which is aimed at increasing available information to assist decision making processes, increase public participation and foster transparency.

Conclusions

Brazil

Regardless of data challenges, this study gathered the best information available in Brazil, highlighting the huge importance of fisheries for income, employment and food security in the country. With data from the seafood industry and seafood markets, we now have a better understanding of the main seafood products consumed in the country. With data from IBGE and fisheries licenses, we were able to highlight the importance of fish and seafood products for food security in the poorest parts of the country. Regional landings data helped us better understand the main species caught in some of the most important ports in the country. Import and export data showed the magnitude of the seafood deficit in the country, with a huge potential for aquaculture to fill this gap.

More importantly, this study highlights the need for better data collection programs and fisheries management policies in Brazil. There is a huge discrepancy between the social importance of this sector and actions of the government to ensure the sustainability of this activity. Urgent action is needed to better understand the dynamics of seafood production and consumption throughout Brazil and to gain the attention of policy makers to invest in fisheries management and associated environmental and social policies.

To invest in fisheries reform in Brazil, it is important to start with a reform of the legal structure around fisheries governance. The lack of fisheries data and management in the country is mainly caused by a huge confusion in the government around the responsibilities and obligations regarding fisheries governance, which is currently under both the secretary of fisheries and the ministry of environment. For example, from our conversations with people in the departments themselves, it is not clear which department is responsible for fisheries statistics in the country. Therefore, to begin solving Brazil's fisheries management and data problems, aside from badly-needed investments in staffing and operational budgets, the country urgently needs a new national fisheries law. This could define clear roles and responsibilities for government agencies, create a permanent fisheries institute to deal with data collection and management (that is independent of politics), and establish clear policies for artisanal and industrial sectors. The creation of a new fisheries law is a challenging task, but highlights the current situation of overall fisheries and aquaculture governance, and is thus a critical first step towards fisheries sustainability in Brazil.

Chile

The main takeaway of our analysis regarding the contribution of domestic fisheries for human consumption is that most of the wild-caught fish currently does not go to human consumption, but for fish meal and oil or algae products. In addition, most of the aquaculture production in the country is for human consumption but it is exported elsewhere. Less than 30% of local production stays in the country for human consumption. Additionally, one of the most relevant species for human consumption in Chile is tuna, which is mainly imported and can. In economic terms, aquaculture is more important than fisheries, producing ~ 90% of the sales of the economic sector. Nontheless, fisheries are more important in terms of employment if we consider the artisanal and industrial sectors.

There is poor undertanding regarding the specific species that support food and economic security in Chile. There has been research into this issue but no systematic data collection and analysis. An approach like the one presented here could be easily automatized to keep track of the trends in domestic seafood consumption. Nonetheless, this would require some improvements, transparent assumptions, and improved data availability.

A major challenge we faced was to combine all datasets without losing species resolution, and there is more potential in using trade databases. Other two things that would improve the estimates we obtained here are species-specific IUU estimates and yields per type of product for Chilean species. IUU estimates increasingly recognized as important and different methods have been developed for estimate them, ranging from eliciation tasks to more model driven approaches (Oyanedel et al. 2018).

Chile is increasingly pushing for an increase in seafood consumption. Currently, there are programs that promote seafood consumption like *Del Mar a Mi Mesa*.

This transition to a more fish-based diet, and the increase in domestic seafood demand that it implies, will require an improved picture of the state of marine ecosystems and fisheries in the country. More than just promoting an increase in seafood consumption, it is necessary to identify potential winners and losers from national level policies. In order to ensure sustainable food security, it is also necessary to promote eating fish from well-managed fisheries and aquaculture.

Finally, it would be interesting and timely to study Chilean preferences and attitudes towards seafood products that have not been historically consumed but are becoming important in terms of landings, such as algae and squids. Understanding the potential of these species as viable fisheries and food items, and the new value chains they could support, may help improve access to seafood throughout the country, regardless of socioeconomic status.

Peru

Peruvian seafood production plays a key role for national food security. Locals mostly eat highly nutritious species like mackerels, bonito, tunas and hake. However, the country's most important fisheries (i.e., anchoveta and jumbo flying squid fisheries) and mariculture species (i.e., Peruvian calico scallop and shrimps) mainly supply foreign markets. As a result, the local seafood demand is unsatisfied and becoming more reliant on seafood imports and freshwater aquaculture production, a phenomenon that is heightened in years with low catches of traditional seafood items (e.g., mackerels, bonito, tunas and sharks).

Consumers are unaware of this because seafood retailers are not required to communicate whether or not what they are selling was locally caught, imported or previously frozen; moreover, mislabeling is common in Peruvian markets. These issues downplay marine signals indicating ecological stress, while reducing stakeholder interest, participation and support for promoting improved fisheries management and marine conservation.

Seafood's contribution to the economy is growing in Peru. They are responsible for creating and sustaining most jobs it the Peruvian fisheries sector (on land and at sea) and are gaining significance over reduction industries in regard to exports and their participation in the country's GDP. However, value chains supplying the local seafood demand are not properly understood and hence have not received sufficient government attention.

Key future actions should seek to improve public understanding of seafood value chains and a strengthened awareness of the links between local ecosystems daily seafood consumption. This is of paramount importance in gaining support to promote new regulations and policies in favor of strengthening fisheries management. Furthermore, it has the potential to strengthen the contribution of marine ecosystems to Peruvian food security, increase the fisheries sector's participation in the economy and reduce its vulnerability to climate change, a critical theme for Peru's marine ecosystems. These efforts should be coupled with the development of outreach campaigns to promote consumer awareness on seafood related issues and foster sustainable consumer practices. This can range from campaigns aiming to increase knowledge and respect for regulations (e.g., minimum landing sizes and seasons), to others highlighting sustainable seafood choices for consumers, or promoting improved seafood labeling regulations.

This requires improving data collection and management systems across government institutions. A good first step in the right direction could be the participatory development data protocols that describe the specific actions for government employees and contractors (including DPA administrators) in regard to why, how, when and where to collect, store and upload data. Government workers should be trained and in the application of these protocols and their implementation should be closely monitored to continuously strengthen the system. Additionally, it is of key importance to assess current data management processes and provide short-term solutions for reconstructing past information and reduce bottlenecks for cross-institutional data sharing.

Furthermore, seafood traceability issues are currently hindering trade. This should be dealt with in the short-term by fostering changes in the regulations that would require stakeholders to submit and collect specific information along the seafood value chains. This should be a participatory process, that considers the attitudes, objectives and capacities of the different players (e.g., DPA administrators, PRODUCE and SUNAT personnel, processing companies, exporters, fishers, among others), and explicitly considers their potential costs and gains from improving traceability. Related to this, a useful contribution could be collaborating with IMARPE and PRODUCE in developing predictive models that encompass the ecological and social dimensions of marine ecosystems, which could be used by these stakeholders to assess trade-offs amongst alternative public policies regarding fisheries management and seafood trade.

Appendix

Chile

Fisheries Context

Estimates of landings and harvest

- To evaluate the volume contribution of specific fisheries over the last five years, we used records of landings and aquaculture harvests from SERNAPESCA (2013-2017). These records include species-specific landing per region or month (not both simultaneously) for each subsector (i.e. industrial and artisanal). We downloaded them for each year since 2007, cleaned them and compiled them in a signle tidy database of landings and harvests to make visualizations and get estimates.
- We identified an abrupt increase in landings for year 2015 in the artisanal sector. After consulting with other databases and reports and reviewing our coding, we concluded that observations for 2015 were not reliable. SERNAPESCA has another dataset called *Anuario* avaiable at their website, that lists species-specific landings but no detail regarding region nor sector. We used this dataset to compare landing values and test whether they matched. We found no differences for years other than 2015, but the landing estimates did differ between our detailed dataset and *Anuario* in 2015. We assumed that *Anuario* is more accurate since its estimates were more similar to other years. Nontheless, we keep on using the detailed dataset whenever we wanted to identify trends within sectors or regions but, ignoring 2015.

Estimates of trades

We use data from *ADUANAS Chile* to quantify the volumes and value of each group of species being imported or exported into the country. These records detail the weight and value of traded products, which are recorded under an id code for prodcuts categories. These categories are not species-specific, although a lot of them aggregate products of species that belong to the same genus o family. To come up with categories that we could match between import and export dataset as well as between trade and landing datasets, we generated a linking datset (See Index of Species below). To generate this index we first review all the datsets and then, came up with categories that were broad and detail enough that allowed us to identify groups of species between datasets of SERNAPECA and ADUANAS Chile. Using these databases we categorize exported and imported products into species groups that could be matched to calculate net trade.

National Seafood Supply

Species contribution to human and non-human consumption

Landings come either from industrial, which includes fabric vessels (l_i), or artisanal vessels (l_a). Here, we assume that all l_i are send to processing facilities while l_a can either go to processing facilities or be sold as non-processed products, which we assume, are used for HC (NP_{HC}).

Landings can either be sold as non-processed products (NP_{HC}) or go to processing facilities where they will be transformed in products for human consumption (P_{HC}) or products for other uses (P_{NHC}). In our analisys we are considering the following types of products to be use for human consumption: fresh, frozen, salty dry, salty wet, smoked, canned, dehydrate. While fish meal, oil, dehydrate, dried algae, and other algae derivatives are use for non human consumption. We assumed that all agae are for non human consumption therefore removed.

Aquaculture (Aq) reffers to the harvest of different species being farmed at the sea or freshwater centers. We assume all the volumes coming from aquaculture center enter processing facilities. In Chile, almost all L_i and Aq are send to processing facilities while only some of the L_a is processed. We assume that the rest of the artisanals' catch that is not sent to processing facilities is sold as non-processed products for human consumption (NP_{HC}). To get an estimate of NP_{HC} we substracted Aq and L_i to all the raw material entering processing facilities and use the residual as the volume of L_a that is processed. We then, substracted this volume from L_i to get NP_{HC}, which is the rest of the artisanals' catch that is not being processed. The assumptions behind this method are (i) that all the raw material in processing facilities that is not being supplied by industrial fishing or aquaculture is supplied by artisanals, and (ii) all the catch that artisanals do not sell to processing facilities is sold directly for human consumption.

Main fisheries for food supply

On order to develop the model described in the general methods, we had to match all products impoted and exported with the species landed or harvested. We used as references products that containd multiple species within the Aduana's databases. All species classified under a same *Aduna code* (Using the International Harmonized System) where put together in the same group. Whenever possible we mantaind single species. This allowed us to aggregate products per groups of species and match volumes and values to landing record by SERNAPESCA. In addition, SERNAPESCA applies several variations of a species common name between databases. This difficults the calculation of aggregated estimates. We solve this by generating a dataset that categorize all the names currently used by SERNAPESCA under a common group among the import and export data (See supplemental for group details).

We found inconsistencies between two databases of landings published by SERNAPESCA in their website. They differed in the level at which data was aggregated. One database was clasified per sector (artisanal, industria, fabric vessels) and the other was the summary for landings and aquaculture for each year per region. When we aggregated the most detailed database to the same level as the anual summary database we observed differences in landing volumes for the year 2015. We considered this to be part of the measurement error involved in any process of data collection or data entry. We used the summary annual data for our domestic human consumption model because 2015 data alinged better with amounts reported all other years.

We calculated yield by estimating an average between the range of losses from discards and processing provided by Christensen et al. (2014) for Peruvian species. For species that did not have a direct matching yield we used the yield of the most similar species. Yields within a group of species where averaged for the final calculations of the model. See table 21 for details on yeilds per sepcies used in our analysis.

We use the processing facilities raw material and product data as a way to account for discard. SERNAPESCA provided us with a databased that contains tonnes of raw material per species that goes into facilities. We summed up all the raw material for products not for human consumption and discounted it from landings to the corresponding groups of speceis.

Total and percapita seafood consumption in the country

Our models is highly sensitive to species yield, therefore in many cases results of our calculations return a negative number implaying that exports are higher than the product of the yield times the local production (landings and aquaculture) minus all tonnes that go for non-human consumption products. Assuming that all negative numbers do not contribut to domestic consumption because they are mainly exported or used for non human consumption (eg:algae) and none is imported, we calculated a per capita consumption per year. We summed all the human consumption per year (Table XX, chunk below) and devided by the chilean population of 17,574,033. (Instituto Nacional de Estadisticas Chile 2018).

Economic Participation

Any conversion from Chilean pesos to dollars was done by first converting the amount in Chilean pesos to its value in Chilean Units of account (UF, a monetary unit corrected by inflation) of the respective year. Then, transformed to the equivalent in 2018 Chilean pesos using the 2018 UF value and finally, converting the 2018 value in Chilean pesos to its equivalent in 2018 US dollars, based on the conversion for Dec, 2018 (US$ 1 corresponds to 676 Chilean pesos).

We combined different sources of data to answer questions of economic participation. We collect data from the Central Bank of Chile to understand the contribution of fisheries to regional economies. To estimate net trade, we use the ADUANAs Chile trade database and products of imports and exports in matching categories. To generate estimates of species-specific revenue, we use data from SERNAPESCA on artisanal ex-vessel prices by species, year and region and multiply them by the landed volume per species, year and region. Most estimates of employment were extracted from reports but some of them were done using data from SERNAPESCA on processing facilities.

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Results

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