Fisheries Centre

The University of British Columbia

Working Paper Series

Working Paper #2015 - 92

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Year: 2015

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This working paper is made available by the Fisheries Centre, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

RECONSTRUCTION OF TOTAL MARINE FISHERIES CATCHES FOR JUAN FERNÁNDEZ ISLANDS AND THE DESVENTURADAS ISLANDS (CHILE) FOR 1950-2010

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ABSTRACT

Total reconstructed catch taken in the EEZ waters of the Chilean Juan Fernández Islands and Desventuradas Islands was estimated to increase from 470 t in 1950, to a peak of 1.3 million t in 1995, before declining to 228,000 t in 2010. This trend is almost entirely driven by catches of jack mackerel (*Trachurus murphyi)* taken by industrial vessels coming from mainland Chile. Although local small-scale fisheries represent a negligible amount of the total catch, these fisheries are vitally important to the locals who live on the islands.

INTRODUCTION

Juan Fernández Islands

The Juan Fernández Islands are situated 600 km off mainland Chile, and are composed of three main volcanic islands; Robinson Crusoe, Alejandro Selkirk and Santa Clara Island. Due to the biological uniqueness, these islands were declared a National Park in 1935 and a UNESCO biosphere reserve in 1977. Thirty-five of the 46 mollusks and more than 440 of the 660+ species of invertebrates are also endemic.

The islands are mainly known for having been the home to the sailor Alexander Selkirk for four years, which may have inspired the novel Robinson Crusoe. Robinson Crusoe Island is the second largest of the Juan Fernández Islands and has the greater population of the two inhabited islands in the archipelago. The archipelago's population reached 900 (843 on Robinson Crusoe[1]) as of 2012, the majority of which reside in the capital, San Juan Bautista, in Cumberland Bay on the north coast of the island. The islands belong administratively to Chile's Valparaiso's region, which also includes Easter Island (Figure 1). Note that Easter Island fisheries were reconstructed separately (see Zylich *et al.* 2014). The islanders depend on fisheries and tourism as a major source of income.

[1] "Censos de poblacion y vivienda". Instituto Nacional de Estadísticas (2012). Available at: http://www.ine.cl/ [Accessed: 2 January 2013].

Desventuradas Islands

The Desventuradas Islands are a group of four small islands (San Ambrosio, San Fleix, Islote Gonzalez and Islote Catedral) located 850 kilometres (530 mi) off the coast of Chile, northwest of Santiago in the Pacific Ocean. San Ambrosio rises from the sea as sheer cliffs on almost all sides, is 4.5 km long by 850 m wide, and primarily basaltic. San Felix is slightly smaller, 1.4 km^2, and has two small peaks, reaching 193 m, which are denuded by high winds.

There are no human settlements in the Desventuradas; however, a naval base was established in San Felix Island in 1976. The Desventuradas are formed from the extension of submarine mounts where the Nazca and Sala y Gomez ridges meet. The Desventuradas Islands lie in the transition of subtropical and subantarctic waters. Scientific research of this area is scarce and only 32 algae species, 14 invertebrates and 43 fish species have been identified. Deep water species which are found between underwater seamounts are highly endemic.

Fisheries characteristics

Historically, these isolated islands have maintained their simple and traditional way of fishing for more than 120 years. The Juan Fernández artisanal fishers possess an effective tenure system called *Marcas*. *Marcas* are fishing spots owned by local families; there are a total of 3,762 *marcas*. The *marcas* are only transferable by local agreement and cannot be sold; it can be transferred through inheritance to family members. Only the fisherman who owns the *marcas* knows where they are located. Newcomers are not admitted since an '*instalación*' or settling period is needed to understand the system and to be accepted on the fishing grounds by the other fishers. This system has kept the effort and fishing fleet size stable. In addition to the tenured *Marcas* system, there are identified locations for bait fishing, also called *Marcas de pescado* or fish marks. Lobster bait consists of whitefish and/or morena (moray eels).

Fisheries in the Juan Fernández archipelago mainly target Juan Fernández lobster (*Jasus frontalis*), *cangrejo dorado* (*Chaceon chilensis*), *centolla de Juan Fernadez (Paromola rathbunae*), *la jaiba remadadora (Ovalipes trimaculatus*) and *langosta chata* (*Scyllarus delfini*). Other benthic species of importance are *erizo negro* (*Plesiodiadema microtuberculatum*) and Juan Fernández abalone (*Concholepas concholepas fernandezianus*).

The most abundant known species in coastal waters is lobster which is exploited by 150 artisanal fishers. A closed period for the lobster fishery for San Feliz and San Ambrosiso (Desventuradas islands) runs from June 30th until September 1st. For Juan Fernández archipelago the closed season starts May 15th and ends on September 30th. Fishing of females with eggs is prohibited all year long, despite their size. Minimum catch size is set at 11.5 cm in length.

The Juan Femández Island Golden crab (*Chaceon chilensis*), which is endemic in Juan Fernández and the Desventuradas Islands, has gained importance since 2000. Golden crab fisheries started as a diversifying fisheries strategy, this fishery takes place further from the coast. Fishing grounds for *Chaceon chilensis* are located 400 m deep in the northwestern part of the island from 2 to 5 nautical miles from the coast of Robinson Crusoe, unlike the lobster fishery which is mostly a coastal fishery. In 2000, the first available records for the Golden crab fishery (*Chaceon chilensis*) were found (Arana and Vega 2000) and a second study was completed in 2005/2006 (Arana *et al.* 2006; Ahumada and Arana 2009).

Artisanal fishers from Robinson Crusoe Island travel sporadically to Desventuradas and stay short amounts of time in the rocky islands. In 2008, there were 4 fishing boats which travelled yearly to capture lobster. The number of boats travelling to Desventuradas has remained constant in the past 50 years.
In the early 1990s, after a scientific study discovered the presence of alfonsino (*Beryx splendens*) and orange roughy (*Hoplostethus atlanticus*), industrial trawler fleets started their exploitation, for five years, but the fishing of orange roughy was banned due to a drastic population decrease and slow recovery. For alfonsino yearly quotas were established.
Historically, Chilean jack mackerel (*Trachurus murphyi*) catches and South Pacific hake (*Merluccius gayi gayi*) have been practiced by industrial trawler fisheries. However, all landings are aggregated as mainland administration of the Vth region and not as an individual entity. Therefore, reconstructing the annual catches of and in the Desventuradas and the Juan Fernández islands individually will highlight the importance of the abundance of biomass of several species in this region. It is important to note also that most industrial fishing around this zone is exclusively performed by Chilean vessels and rarely by international fleets.

METHODS

Artisanal fisheries

Juan Fernández Islands

Recorded information of fisheries landings for Juan Fernández were found for some species for the period 2002 to 2010. These records were extracted from data provided by the national statistics fisheries agency SERNAPESCA and local recording books from the island which were transcribed (Ernst *et al.* 2010a). These data were assigned as industrial catches by mainland Chile fishers and artisanal catches by local islands fishers based on personal communication with fishers from Juan Fernández. For the artisanal catches, since the artisanal fleet remained relatively the same over the time period, values were extrapolated assuming a 10% reduction since 1950, except for Juan Fernández lobster, where fishery catches were reconstructed from fleet and gear composition data. Data gaps in the 2002-2010 time period

were filled in by interpolation or by carrying forward or backward the last or first available data point, respectively.

Juan Fernández lobster fishery

In 1945, a total of 41 fishing boats were reported by Lobell *et al.* (1947). In the 1970s, the total fishing capacity remained at 50 fishing boats. Fishing boats remained the same from 1950 to 2007; boats were made of wood and were between 8 to 11 m long, with 18 HP outboard motors. In 2007, some fiberglass boats were introduced and after the tsunami of 2010 many more wooden boats were replaced by fiberglass (Arana and Vega 2000; Arana *et al.* 2006).

Fishing gear has remained the same with only small changes since 1950. Traps changed their design to improve efficiency in 1981, and winches to raise traps have been the main improvements in the gear/equipment. The use of winches has substantially increased the number of traps handled per trip (Henriquez *et al.* 1985). Lobster fishers on Robinson Crusoe Island were interviewed and even though they agreed that the fleet size has remained the same for the past 60 years, they also admitted that cages have doubled per boat.
Written records were destroyed in the 2010 tsunami but a study conducted in 2004 transcribed most of the lobster fisheries information (Ernst *et al.* 2010a). Records for lobster fisheries were found from 1990 to 2010. Also yield per trap decreased considerably since 1950, according to our interviews, from 1-2 lobsters per trap in 1950, to 0.48 in 2010 (Arana *et al.* 2011 and Bahamondes *et al.* 1948).

To estimate lobster catch per year we assumed 9 trips per year (Arana *et al.* 2006) multiplied by the number of traps per boat (local fishers, pers. comm.), times the number of boats registered (Ernst *et al.* 2013) and the average weight and yield of lobster per trap (Arana 1983; Arana and Toro 1985; Arana 2010).

Bait

Fish used as bait is not considered in landings reports despite being an important fisheries catch source. The lobster fishery uses a considerable amount of fish as bait (Arana 1976; Arana 2006; Quierolo *et al.* 2011). Studies conducted by Queirolo *et al.* (2011) registered the amount of bait used in one lobster season, by species and weight. This amount was extrapolated according to the amount of lobster fished each year since 1950 to 2010.

Table 1. Fish used as bait in lobster fishing in Juan Fernández archipelago.

Common name	Scientific name	Tonnes used as bait in one lobster fishing season (Oct 2009-March 2010)[1]
Anguila/Anguilla	*Gymnothorax porphyreus*	12.6
Breca	*Nemadactylus gayi*	37.6
Mackarel	*Pseudocaranx chilensis*	22.2
Vidriola	*Seriola lalandi*	3.5
Vieja/biya	*Malapterus reticulatus*	5.5

[1] Data from Quierolo *et al*. 2011

Desventuradas

Government data were also available for Desventuradas Islands from 2002-2010, although there is no catch recorded until 2007 (only swordfish reported). These data were considered to represent artisanal catches by Juan Fernández fishers who travel to Desventuradas. According to the information provided from artisanal fishers, the catches reported for Desventuradas have not changed in the past 50 years. As the data seem to be most complete in 2009, this year was used as the anchor point. As this fishery has not changed much over the time period, it was assumed that the proportion of the Desventuradas catch to the artisanal catch taken from Juan Fernández waters remained constant for the whole time period. Although boat numbers were said to remain the same, the proportion was kept constant instead of the catch in order to account for yearly variations in fisheries catch. Species composition was also assumed to have stayed the same for the whole time period.

Industrial fisheries

As described above, part of the catch reported in the SERNAPESCA data for the Juan Fernández Islands were indicated as being caught by industrial fishers from the Chile mainland. However, as opposed to the artisanal fisheries which were assumed to be 10% greater in 1950, it was assumed that industrial fishing around the islands only started at the beginning of the 1950s and therefore catches were interpolated from zero in 1949 to the first point of data in 2002 (data gaps in the 2002-2010 time period were filled by interpolation or by carrying forward or backward the last or first available data point, respectively).

As mentioned before, all landings from the islands are reported in mainland Chile specifically in Region V. Since the year 2000, industrial fleets are traced by a satellite positioning system which reports their catch species composition at a given site. SUBPESCA provided us with the general spatial catch information for jack mackerel and South Pacific hake for 7 years (2000 to 2007). We estimated that approximately 30% of Jack mackerel and Southern hake of the total catch in the Chilean EEZ are taken from the EEZ waters surrounding the islands (SUBPESCA 2012). Therefore, 30% of the total catch of these species (both reported and unreported landings) were allocated to these waters from the Chile mainland reconstruction

(van der Meer *et al.* 2015). The same discard rates used in the Chile mainland reconstruction were used here (van der Meer *et al.* 2015). This resulted in a 4% discard rate being applied to the jack mackerel landings and a 6.75% discard rate applied to the South Pacific hake (25% by-catch with 27% of it discarded). The species breakdown was also taken from the Chile mainland reconstruction. Lastly, it was estimated that approximately 73% of the catch from the islands' waters was from the EEZ surrounding Desventuradas (estimated from the spatial information provided by SUBPESCA). We therefore assigned 73% of the jack mackerel, South Pacific hake and the associated discards to the Desventuradas EEZ and the remaining 27% to the Juan Fernández EEZ.

Other important fisheries which have been documented are alfonsino and orange roughy, which started being exploited in the late 1990s and therefore the recorded catches are accurate.

Subsistence fisheries

Robinson Crusoe currently has 843 inhabitants. They receive bimonthly food supplies from mainland Chile, and rely mostly on fish as their main protein intake. We assumed that this coastal population eats at least 5 portions of 250 g a week. The species distribution was given to the most popular fish species found in their diets. *Vidriola* (*Seriola lalandi*), *breca* (*Cheilodactylus gayi*), lobster (*Jasus frontalis*), jack mackerel (*Trachurus murphyi*) and crab (*Cancer* spp.) are the predominant species in their diets and were therefore given percentages according to what was recorded in their diets and by interviewing people in the town regarding their fish and crustacean intake per week.

In the 1970s, Juan Fernández tooth fish (*Polyprion oxygeneios*) was also used for human consumption; nevertheless, a steep decrease in the stock in the early 1980s decreased catches of this species. We therefore accounted for this by adjusting the amount of jack mackerel in relation to the change in the stock of Juan Fernández tooth fish.

RESULTS AND DISCUSSION

Artisanal fisheries

In the period from 1950 to 2010, almost 10,900 t were fished by artisanal fisheries. Catches decreased from 215 t in 1950 to 75 t in 1993 (Figure 2). Catches then gradually increased to 130 t in 2002 and then rapidly increased to almost 240 t in 2003 before peaking at 370 t in 2008. Artisanal fisheries are not a very large portion of the total catch of these islands; nevertheless economically, they represent an important if not the only source of income. Lobster (*Jasus frontalis*) is the most important fishery and represents their most valuable fisheries species. High lobster catches with large inter-annual variations are noted from 1950 to

the mid-1960s, these variations are mostly attributed to unfavorable fishing conditions due to climate constraints (i.e. high winds). From the mid-1960s to 1980 a gradual decrease of lobster catches are noted attributed to increased effort with a declining CPUE. From the late 1980s until 2010 inter-annual fluctuations are also attributed to climate conditions and catches have steady increased and remained steady for the past 4 years. The elaborate management schemes have maintained this fishery at a fairly constant catch rate over the time period. Overall, lobster represented 38% of the artisanal catch (Figure 2). Other important species in the artisanal fishery include *breca* (*Nemadactylus gayi*; 27%), *anguila* (*Gymnothorax porphyreus*; 13%), mackerel (*Pseudocaranx chilensis*; 9.6%) and v*idriola* (*Seriola lalandi*; 3.5%; Figure 2). Many of these taxa are also caught as baitfish, which represented 35% of the artisanal catch. If we look at the artisanal catch without the baitfish we see that lobster becomes ever more dominant, representing almost 60% of the catch. We also see that species used as baitfish are also landed with *breca* (17%), *anguila* (11%) and v*idriola* (3.1%) still contributing considerably to the catch. S*ierra* (*Thyrsites atun*; 2.7%) is also an important landed taxa.

Our assumptions led to an estimated 89% of the artisanal catch coming from the waters surrounding the Juan Fernández Islands and the remaining 11% from the Desventuradas Islands. Note that the catch composition from Desventuradas waters shows a slightly different trench with lobster (25%), *sierra* (16%), *anguila* (16%), *breca* (13%) and *nanue* (*Girella nebulosa*; 5%) being the most important species.

Industrial fisheries

Due to the large EEZ around the islands, industrial fisheries from the Chilean mainland fleet have increasingly been accessing the resources from these waters. From the period 1950 to 2010, 18.4 million tonnes have been landed from this region. Catches were assumed to increase from just over 2,700 t·year^{-1} in the 1950s to a peak of 1.3 million t in 1995 (Figure 3). Catches have been declining since, equating to 228,000 t in 2010. All industrial catches from the Desventuradas and Juan Fernández are landed in mainland Chile and not on the islands itself. Historically most the most fished industrial species are jack mackerel and South Pacific hake, with jack mackerel dominating the industrial catch with 92% overall and South Pacific hake representing the second most important species with 5% (Figure 3). Hake contributed the majority of the catch up to 1969, averaging almost 80% of the catch. The decline in fisheries stocks of South Pacific hake and Jack mackerel since the year 1999 has been following the same pattern constantly throughout the region. This decline has been attributed to overfishing and temperature changes from El Niño phenomenon. Discards associated with the jack mackerel and South Pacific hake fisheries contributed almost 4% to the reconstructed total industrial catch.

If we look at the industrial catch excluding jack mackerel and South Pacific hake, as well as their associated discards, we see alfonsino and orange roughy bottom trawling fisheries increased in importance since 1999 where they were fished over sea mounts. Bottom trawling in vulnerable areas was prohibited in 2012. The alfonsino fisheries started at 300 tonnes in 1998 and were quickly increased to 8,800t in 2003. Quotas

were given to the fishery in 2005 and catches remained steady until 2008 with 2,500 tonnes a year. Orange roughy catches fluctuated wildly and peaked in 2001 with 1,900 t. The fishery dropped off almost completely in 2007 recording only 5 t and then 1 t in 2008. The fishery has been closed since then.
It was estimated that 73% of the reconstructed total industrial catch came from the EEZ waters surrounding the Desventuradas Islands and the remaining 27% from the Juan Fernández Islands.

Subsistence fisheries

Subsistence catches for the 1950 to 2010 period were estimated to be 1,500 t. Catches increased from 20 t in 1950 to almost 40 t in 2010 (Figure 4). The overall species breakdown was estimated to be 27% *breca*, 27% *vidriola*, 20% lobster, 13% jack mackerel, 8% crabs and 5% Juan Fernández tooth fish (Figure 4).

Reconstructed total catch

The reconstructed total catch increased from 470 t in 1950, to a peak of 1.3 million t in 1995. Catches then decreased dramatically to 420,000 t in 1999, and then continued to decrease more slowly to 228,000 t in 2010. The reconstructed total catch was dominated by the industrial fishery (99.9%) which consists of vessels from the mainland. Discards contributed almost 4% to the total catch. Although artisanal and subsistence catches only contributed minimally to the overall catch (0.06% and 0.01%, respectively), in terms of derived benefits, these sectors are very important to the local population. As a proportion of the small-scale catch, artisanal catches contributed 86% and subsistence catches the remaining 14%. Considering the importance of these sectors to the local population, assessments of the health of the ecosystem and the impact of the industrial sector on those resources are very important to ensure the sustainability of the fishery and the continued availability of that resource to the people who need it the most.

ACKNOWLEDGEMENTS

This is a contribution of the *Sea Around Us*, a scientific initiative supported by The Pew Charitable Trusts and the Paul G Allen Family Foundation.

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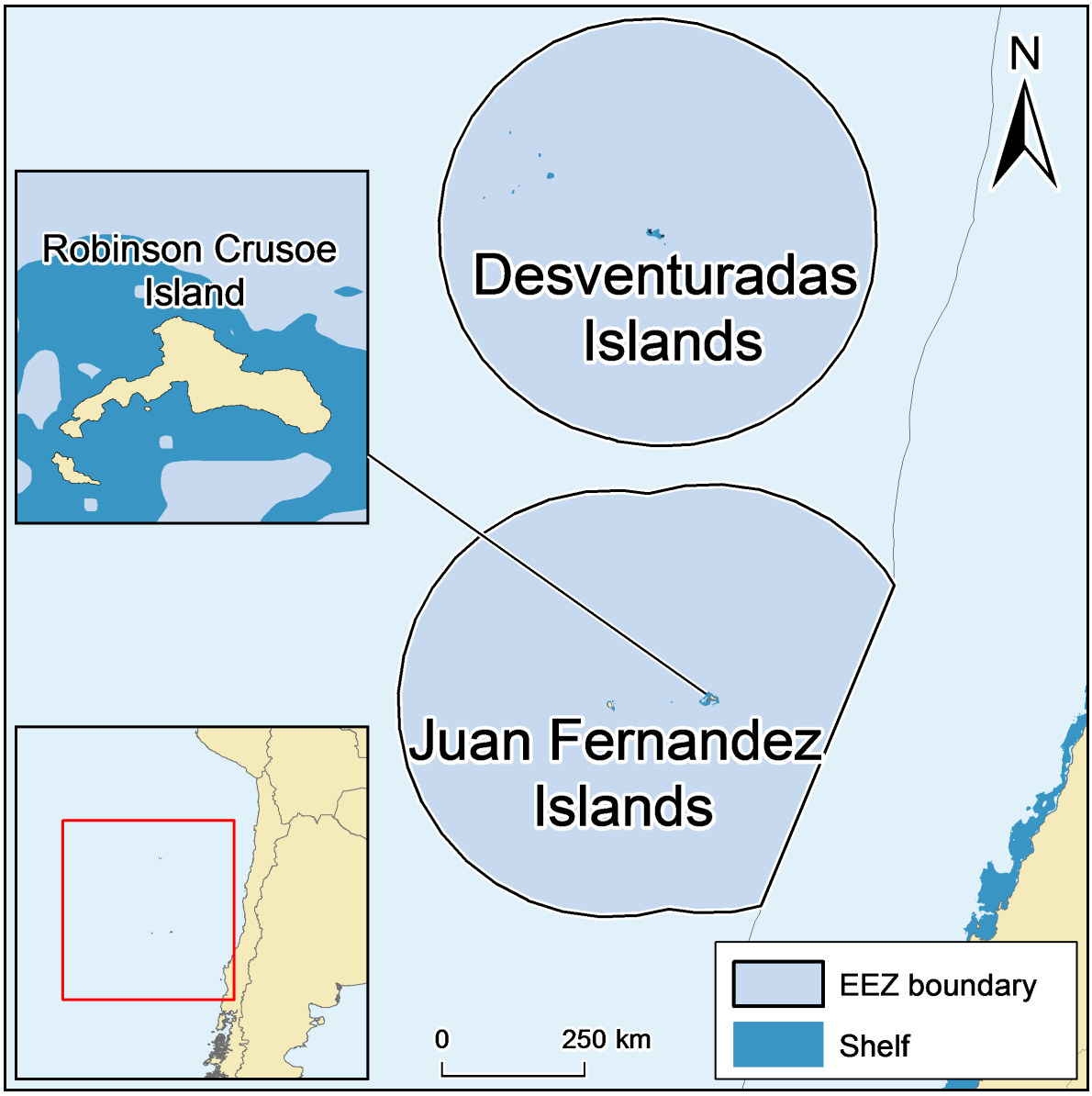

Figure 1. The Chile mainland EEZ as well as the EEZs of the associated oceanic islands: Juan Fernández Islands, Desventuradas Islands and Easter Island.

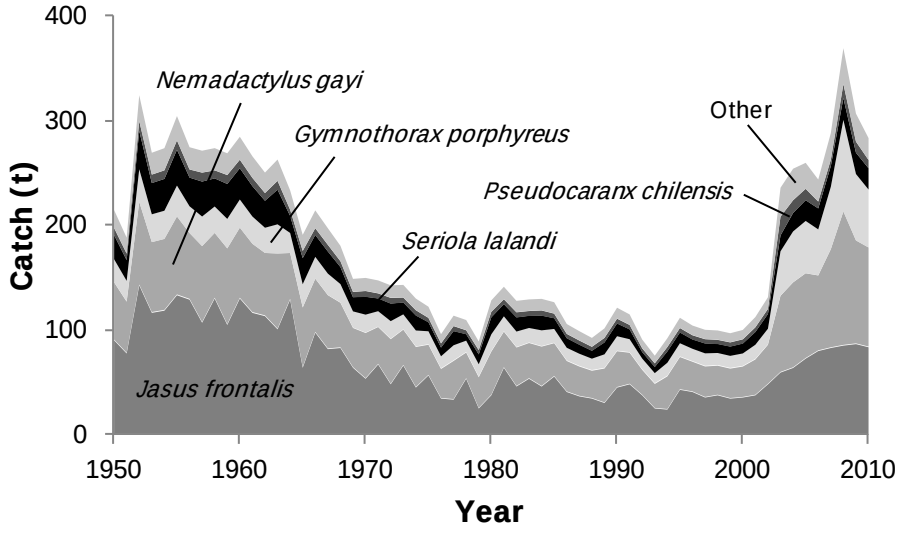

Figure 2. Reconstructed total artisanal catch from the EEZ waters of the Juan Fernández and Desventuradas Islands, 1950-2010, by major species. 'Other' represents 27 additional taxonomic categories.

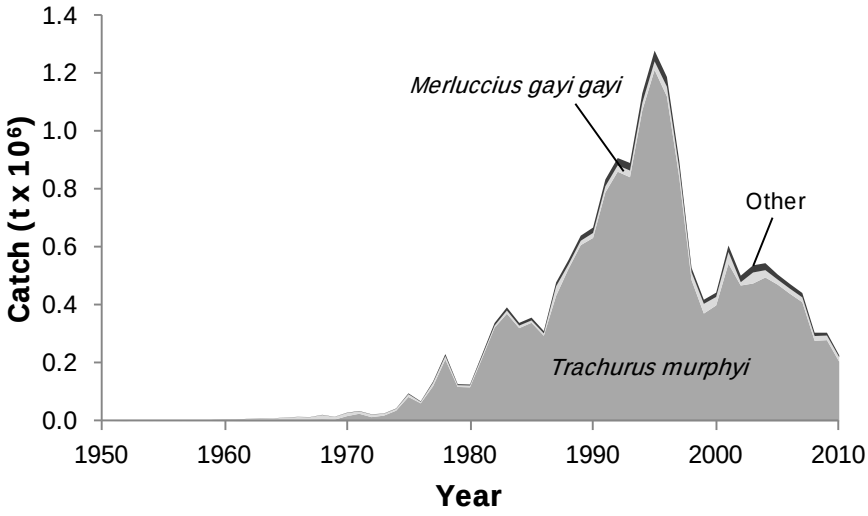

Figure 3. Reconstructed total industrial catch from the EEZ waters of the Juan Fernández and Desventuradas Islands, 1950-2010, by major species. 'Other' represents 44 additional taxonomic categories.

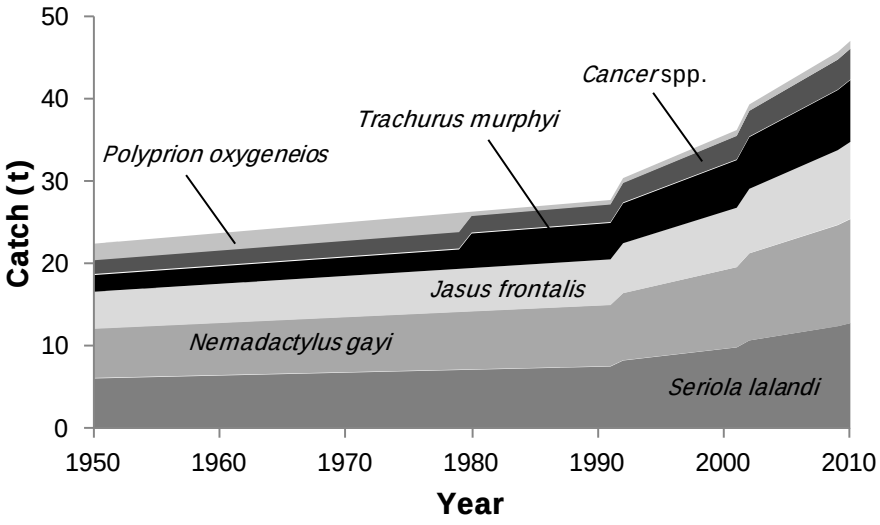

Figure 4. Reconstructed total subsistence catch from the EEZ waters of the Juan Fernández and Desventuradas Islands, 1950-2010, by species.