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Research Article

Fishing in Easter Island, a recent history (1950-2010)

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ABSTRACT. Easter Island (Rapa Nui) is well studied in terms of its archaeology; however, information regarding the history of fishing is extremely limited. Marine resources have likely been exploited from the time the first Polynesians arrived on this remote island. While large pelagics are part of the traditional Rapa Nui diet, inshore fish and invertebrates have also made their way into the diet. Official records of fisheries catches in what is now the Easter Island Province of Chile, which also includes the uninhabited island of Salas y Gómez, are very limited and were available for only some years. Using anecdotal information, historical descriptions and the limited quantitative information available, we reconstructed fisheries catches in the Exclusive Economic Zone (EEZ) of the Easter Island Province over the 1950-2010 time period. Totaling almost 6,000 ton, legal catches have been increasing rapidly since the late 1970s, but are now stagnating at around 150-200 ton yr^{-1}. The main species targeted were Pacific chub or '*nanue*' (*Kyphosus sandwicensis*) and yellowfin tuna or '*kahi ave ave*' (*Thunnus albacares*), with spiny lobster or '*ura*' (*Panulirus pascuensis*) being the most important invertebrate species. There are indications of a substantial illegal fishery for large pelagics in the EEZ of the province, estimated at 200-2,000 ton yr^{-1}, which may have operated for two decades and may be the cause for the declining artisanal catch of tuna by Rapa Nui fishers. Continued pressure on these geographically remote oceanic and inshore marine species, especially those popular amongst tourists, makes accounting for fisheries catches an even greater priority.

Keywords: catch, reconstruction, artisanal fishing, subsistence fishing, illegal fishing, Rapa Nui, Chile.

La pesca en Isla de Pascua, una historia reciente (1950-2010)

RESUMEN. La Isla de Pascua (Rapa Nui) ha sido ampliamente estudiada en cuanto a su arqueología, sin embargo, la historia de los recursos pesqueros es extremadamente limitada. Los recursos marinos han sido explotados desde la llegada de los primeros polinésicos a esta remota isla. Especies pelágicas, peces costeros e invertebrados son parte de la dieta tradicional de los habitantes de Rapa Nui. Los datos oficiales de captura de pesca en Rapa Nui, Provincia de Isla de Pascua, Chile, también incluyen la inhabitada isla Salas y Gómez, son muy limitados ya que están disponibles sólo para algunos años. Mediante descripciones históricas e información cuantitativa disponible, se reconstruyeron los desembarques para la Zona Económica Exclusiva (ZEE) de la Provincia de Isla de Pascua en el periodo 1950-2010. Se cuantificó casi 6.000 ton, donde se incrementaron rápidamente los desembarques desde finales de 1970, pero recientemente estos se han mantenido entre 150-200 ton $año^{-1}$. Las principales especies registradas fueron el '*nanue*' (*Kyphosus sandwicensis*), el atún de aleta amarilla o '*kahi ave ave*' (*Thunnus albacares*), y la langosta espinuda o '*ura*' (*Panulirus pascuensis*) como el invertebrado más importante. Hay indicios de una sustancial pesca ilegal de grandes pelágicos fuera de la ZEE de la provincia de Isla de Pascua, estimada en 200-2.000 ton $año^{-1}$, la que podría haber estado operando durante dos décadas y podría ser la causa de la disminución de las capturas de atún por parte de los pescadores artesanales de Rapa Nui. La continua presión pesquera sobre especies oceánicas y costeras de áreas geográficamente remotas, especies que son especialmente populares entre los turistas que visitan Isla de Pascua, hacen que la recopilación de información tenga una prioridad aún mayor.

Palabras clave: captura, reconstrucción, pesca artesanal, pesca de subsistencia, pesca ilegal, Rapa Nui, Chile.

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INTRODUCTION

Easter Island, or Rapa Nui in the Polynesian language of its original inhabitants (also called Rapa Nui and known as 'Isla de Pascua' in Chile), is located at 27º10'S, 109º20'W in the middle of the Eastern Pacific Ocean, 3,760 km southwest of mainland Chile (Fig. 1). Recent dating places the earliest human habitation around 1200 AD (Hunt & Lipo, 2011), with peak population occurring from 1400-1700 AD (Hunt, 2007). In 1968, the completion of an airstrip brought an influx of migrants and tourists, mainly from Chile (Maino, 1985), and today it is inhabited by roughly 5,800 residents and visited by upwards of 70,000 tourists annually (Kootnikoff, 2010).

Easter Island Province (including Salas y Gómez Island) has a land area of 163.6 km^2 and an Exclusive Economic Zone (EEZ) of over 720,400 km^2. The uninhabited Salas y Gómez Island is located 415 km to the east. Other than that, the nearest land is the Pitcairn Island group, 2250 km to the west (Randall & Cea, 2011). This extreme geographic isolation has resulted in an unusual assemblage of species unique to the island (DiSalvo *et al.*, 1988). A portion of the waters surrounding the nearby Island of Salas y Gómez were recently designated as a no-take marine park (Eilperin, 2010). The 150,000 square km marine park surrounding the uninhabited island is a substantial stride toward protecting its unique marine life. Indeed, the waters around Easter Island Province are generally unproductive (Longhurst, 2006), but their isolation has generated a high level of endemism across all groups (see Fernández *et al.*, 2014).

The fishes of Easter Island have been particularly well studied, notably by an expedition funded by the World Health Organization in the early 1960s, which included two scientists from the University of British Columbia, Ian Efford and then graduate student Jack Mathias (Reid, 1965). Also, work by ichthyologist John Randall and colleagues Louis H. DiSalvo and Alfredo Cea also contributed immensely to understanding the fish fauna of Easter Island (DiSalvo *et al.*, 1988; DiSalvo & Randall, 1993; Randall & Allen, 2004; Randall & Cea, 2011).

Easter Island's embayed coastline offers easy access to near-shore fish and shellfish (Anderson, 2001). Archeological evidence suggests that early Rapa Nui employed a diverse range of fishing techniques, including both single and compound hooks, and lures and sinkers (Anderson, 2001). Bones of tuna, shark and swordfish have also been found in numerous excavations (Anderson, 2001), indicating that offshore fishing also occurred. Archeological evidence also exists for inshore angling and other collection methods such as net, snare and spear (Ayers, 1979; Arana, 2014).

While some archeological work has described the marine fauna and discussed the diet of the early inhabitants, information on the recent history of marine resource exploitation is extremely scarce, which limits understanding the current impacts and status of the island's marine ecosystems. However, it is quite likely that early and later human settlements on the island have had a strong impact on the inshore ecosystem over time (DiSalvo *et al.*, 1988). Although included in the fisheries jurisdiction of the Valparaíso Region (Chile), few records exist that document fisheries catches and effort from the waters of Easter Island, except for the very recent years (since, 2000). Traditionally, the Rapa Nui people engaged in small-scale fishing in near-shore waters (Muñoz, 2011). In 1970, for example, registered artisanal fishers and boats numbered 66 and 19 (Eberhard & Inostroza, 1977), respectively. According to a report published by Servicio Nacional de Pesca (SERNAPESCA, 2012), in 2011 the number of fishers had increased to 126, while 33 boats were registered. The number of unregistered and/or subsistence fishers is not known. Over the time period considered in this study (1950-2010), local consumption of marine species includes both fish and invertebrates. The main fish consumed are yellowfin tuna or '*kahi ave ave*' (*Thunnus albacares*) and Pacific chub or '*nanue*' (*Kyphosus sandwicensis*). Lobster, sea urchin and octopus are also commonly eaten.

Besides commercial fishing, the tourism sector may also, indirectly, pose a substantial threat to the marine biota, as species such as lobsters are caught to meet the demand generated by an increasing number of tourists (Boyko, 2003). The most popular lobster served to tourists is the Easter Island spiny lobster or '*ura*' (*Panulirus pascuensis*), whose populations have severely declined in recent years (Disalvo & Randall, 1993). This lobster species was also traditionally consumed by locals. Two other endemic lobster species, Easter Island mitten lobster and Easter Island slipper lobster (*Parribacus perlatus* and *Scyllarides roggeveeni*, respectively), are caught and sold, albeit to a lesser extent than *P. pascuensis*. With the decrease of the spiny lobster populations, annual catches of the other two species have increased (Boyko, 2003). Warning of potential over-exploitation of lobster species came as early as the 1980s (Castilla, 1987 in Glynn *et al*., 2003). These species are now quite rare in shallow waters, difficult to trap in deeper waters, and rarely appear in local markets and restaurants (DiSalvo *et al.*, 1988; Glynn *et al.*, 2003). Corals, mollusc shells and other marine invertebrates are often collected and sold as jewelry and curios, putting further pressure on these

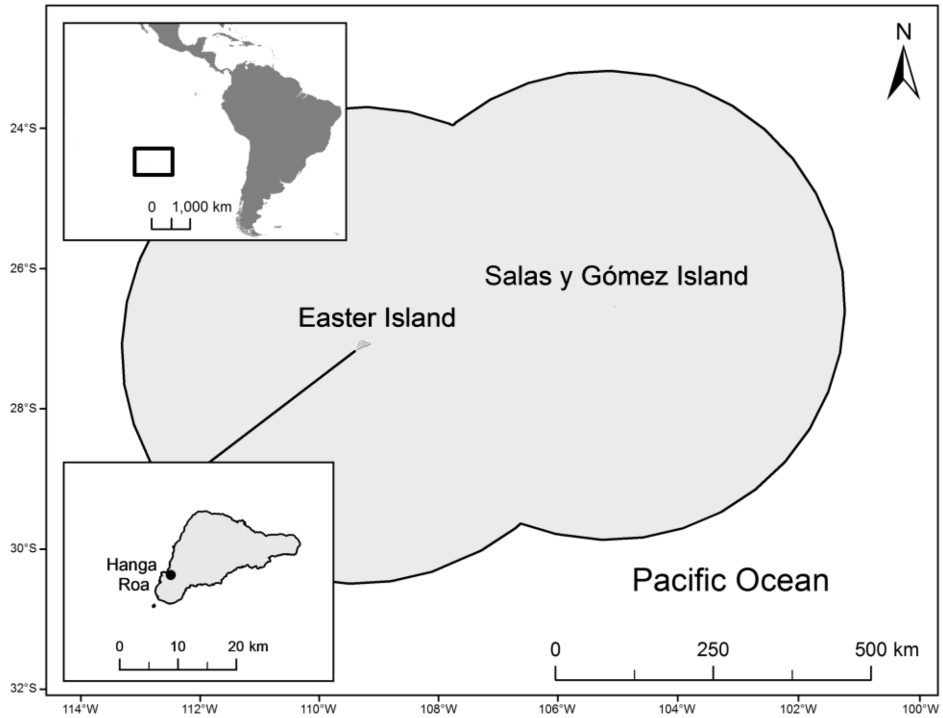

Figure 1. The Exclusive Economic Zone of the Easter Island Province (Chile), which is comprised of Easter Island proper (or Rapa Nui) and Salas y Gómez Island.

resources (DiSalvo *et al.*, 1988; DiSalvo & Randall, 1993; Glynn *et al.*, 2003). Octopus or '*pulpo*' (*Callistoctopus rapanui*) and sea urchin or '*hatuke*' (*Echinometra insularis*) are also traditional food items of the Rapa Nui people. Octopus may be at risk of overfishing, as an increasing numbers of Chileans, with a taste for octopus, move to the island (Boyko, 2003). Populations of sharks, including the Galapagos shark (*Carcharhinus galapagensis*), the most common shark species around Easter Island, have likely decreased due to fishing pressure on sharks and their prey (DiSalvo *et al.*, 1988), and possibly, because they are part of the by-catch of illegal industrial pelagic fisheries (see below).

While some information exists on what species are caught by Rapa Nui fishers, the details of exactly how much is caught remain elusive. As all fish and invertebrates caught in Easter Island are consumed locally, continuous fisheries statistics are lacking, as is enforcement of fishing regulations (Glynn *et al.*, 2003). However, understanding past and present resource exploitation is fundamental for ensuring sustainable use into the future, and thus this study aims to reconstruct marine fisheries catches in the waters surrounding Easter Island for the period 1950-2010. This should provide a useful baseline for improving the protection and management of fisheries resources.

MATERIALS AND METHODS

A thorough literature review unveiled few records of fisheries catches for the time period being considered (1950-2010). Despite severely limited data, we estimated fisheries catches using the reconstruction approach described in Zeller *et al.* (2007), which we modified as required.

For the early period (the late 1970s), Inostroza (1979) provides information on catch levels and on catch composition. For the more recent period (2000-2010), national catch statistics by taxa were obtained from the National Fisheries Service (SERNAPESCA), based on records from fisheries officers located in the town of Hanga Roa. Fishers from Rapa Nui also provided information on catches throughout the time period.

The human population, which was lowest at the end of the 19th century, has since steadily increased from 1,155 in 1960 (Porteous, 1993) to 5,000 in 2009 (Randall & Cea, 2011), but is probably an underestimate (E. Figueroa, Director, Centro Nacional del Medio Ambiente, Universidad de Chile, *pers. comm.*). The complete time series of the Easter Island population was estimated using various anchor points with linear interpolation in between (Loret &

Tanacredi, 2003; www.populstat.org). Ninety percent of the population of Rapa Nui is concentrated in and around Hanga Roa (Kirksey, 2003; Baker, 2012).

For the artisanal (small-scale commercial) sector, there was a study conducted over a one year period which started in May of 1977 and continued until May of 1978. Catches were sampled from the cove Hanga Roa Otai, where up to 90% of the catch of the artisanal fleet was being landed (Inostroza, 1979). Although Inostroza (1979) estimated that his sample represented 85% of total landings, local knowledge suggested that it was likely the sample was closer to being representative of 70% of the catch (R. Vega, *pers. obs.*). A secondary source was used to support this assumption. If this adjustment is made assuming that the sample represents 70% of the total artisanal catch, the estimate obtained is 47.4 ton which also corresponds with the estimate from Eberhard & Inostroza (1977) of approximately 50 ton annually over a five-year period from the mid- to late-1970s. Catches were disaggregated by species and presented as being either 'coastal' or 'offshore'. The total catch of these two components were raised to account for the missing 30% of the total catch. These were our anchor points for artisanal catch in 1977. For the offshore catches, the proportional species composition of the sample catch was applied directly to the new total catch (Table 1). For the coastal catch, the species composition from the sample was modified slightly (Table 2). Local fishers stated that the lobster catch was at least 300% higher than the amount reported in Inostroza (1979) (S. Pakarati, Rapa Nui fisher, *pers. comm.*). When modifying the breakdown we also considered the lobster catch from the subsistence fishery as part of the missing 300% in order to remain conservative in our raising of the lobster percentage. The coastal and offshore artisanal total catches were converted into *per capita* catch rates for 1977. These *per capita* catch rates were kept fixed back to 1950 and applied to the population for each year. The species breakdown was also carried back, unaltered. These assumptions were made as we had no additional information.

Data obtained from SERNAPESCA, provided artisanal landings estimates for the 2000-2010 time period. These landings, which include both fish and invertebrates, and information on the tonnage of each species caught, were taken to be representative of the artisanal sector. Data for the year 2002 appeared to be an outlier (*i.e.*, a data error) and were replaced, for each species, by an interpolation between the catch from 2001 and 2003. A second outlier in 2009 was adjusted as well (albacore and swordfish appeared to be an order of magnitude too high). The data for 2000-2010 were separated into coastal and offshore catches by species, with the 'miscellaneous fishes' category divided proportionally between the two areas. To derive a complete time series of catches from 1950 to 2010, the tonnages, by species (for both coastal and offshore catches), were interpolated from the 1977 anchor point to the first point of SERNAPESCA data in 2000.

In addition to the commercial sector, catches by subsistence fishers need to be estimated. Information from fishers indicated that in the late 1970s shore-based fishing for direct subsistence purposes would reach approximately 20 ton (S. Pakarati, *pers. comm.*). It was therefore assumed that in 1977, subsistence catches reached 20 ton. This was converted to a *per capita* catch rate, which was kept fixed back to 1950. Combining the *per capita* rate with the population time series, subsistence catches were estimated from 1950-1976. Information from local fishers also indicated that in the recent time period (2000s) approximately 25% of the total catch goes unreported (S. Pakarati, *pers. comm.*; M. Hey, SERNAPESCA, *pers. comm.*), with these catches representing shore-based subsistence fishing. There fore, from 2000-2010, the SERNAPESCA data (representing artisanal catches) were taken to represent 75% of the total catch, and were used to calculate the missing 25% subsistence catch. To derive a complete time series, the estimated subsistence catch in 2000 was converted into a *per capita* catch rate. The *per capita* subsistence catch rates for the years between 1977 and 2000 were then interpolated, and combined with population information to complete the time series of subsistence estimates.

As there was no specific information pertaining to the species composition of subsistence catches, a composition was derived using information on coastal catches (Inostroza, 1979) along with local expert knowledge (R. Vega, *pers. obs.*). This composition (Table 3) was applied to the subsistence catch for the whole time period.

As part of the reconstruction we have evaluated the uncertainty in our reconstructed catches by 'scoring' the quality of the estimates in each sector (artisanal and subsistence) in three different time periods (1950-1969, 1970-1989 and 1990-2010). To 'score' the estimates, we have adapted the method used by the Intergovernmental Panel on Climate Change (IPCC; Mastrandrea *et al.*, 2010) for assessing uncertainty, *i.e.*, using assessments of agreement (between multiple sources) and evidence (strength of) in order to apply a confidence interval to our overall reconstructed catch (Table 4).

Some (legal) catches of swordfish, sharks, marlins and other pelagic species are commonly made in the EEZ of Easter Island Province in the course of prospective or other surveys by Chilean vessels (Vega *et al.*,

Table 1. Taxonomic breakdown (percent contribution) of offshore artisanal fisheries catches for Easter Island (from Inostroza, 1979, and SERNAPESCA). The percentage breakdown between 1977 and 2000 was interpolated. From 2000-2010, catch statistics were available and therefore the average percentage breakdown from that data is shown. Local and English names were verified in Randall & Cea (1984, 2011) and/or on FishBase.

Local name	English name	Scientific names	1950-1977 (%)	2000-2010 (%)
Kanakana[a]	Wahoo	*Acanthocybium solandri*	6.6	0.0
Auhopu[a]	Skipjack tuna	*Katsuwonus pelamis*	0.6	0.0
Ra'i ra'ionga[a]	Labyrinth fish	*Schedophilus velani*	9.6	5.7
Toremo[a]	Yellowtail amberjack	*Seriola lalandi*	14.7	2.9
Kahi mea	Albacore	*Thunnus alalunga*[c]	2.6	0.6
Kahi ave ave[a]	Yellowfin tuna	*Thunnus albacares*[c]	18.7	73.6
Kahi māta tata[a]	Bigeye tuna	*Thunnus obesus*[c]	31.5	0.5
Īvi heheu[a]	Swordfish	*Xiphias gladius*	15.7	5.2
Pescado no clasificado[b]	Marine fishes nei	Marine fishes nei	0.0	11.5

[a]Rapa Nui name, [b]Spanish name, [c]*Thunnus alalunga* and *Thunnus albacares* are listed as Near Threatened and *Thunnus obesus* is listed as Vulnerable (A2bd) on the IUCN Red List of Threatened Species (2014.1).

Table 2. Taxonomic breakdown (percent contribution) of coastal artisanal fisheries catches for Easter Island (derived from Inostroza, 1979; SERNAPESCA and R. Vega, *pers. obs.*). The percentage breakdown between 1977 and 2000 was interpolated. From 2000-2010, catch statistics were available and therefore the average percentage breakdown from that data is shown. Local and English names were verified in Randall & Cea (1984, 2011) and/or on FishBase/SeaLifeBase.

Local name	English name	Scientific names	1950-1977 (%)	2000-2010 (%)
Papara'uri[a]	Jack	Carangidae	0.5	0.0
Po'opo'o[a]	Deepwater jack	*Carangoides equula*	0.8	5.7
Ruhi[a]	Black trevally	*Caranx lugubris*	0.0	1.0
Māngo[a]	Galapagos shark	*Carcharhinus galapagensis*[c]	0.5	1.3
Remo[a]	Rainbow runner	*Elagatis bipinnulata*	0.0	11.4
Pāratoti[a]	Ruby snapper	*Etelis carbunculus*[d]	0.7	0.0
Mata uira[a]	Glasseye	*Heteropriacanthus cruentatus*	0.0	6.7
Nānue[a]	Pacific chub	*Kyphosus sandwicensis*	74.0	30.0
Calamar[b]	Squid	Ommastrephidae	0.0	0.2
Ura[a]	Spiny lobster	*Panulirus pascuensis*	4.0	0.4
Kōpuku haharoa[a]	Hapuku wreckfish	*Polyprion oxygeneios*	0.0	0.2
Konso	Oilfish	*Ruvettus pretiosus*	2.5	4.7
	Pomfret	*Taractes rubescens*	0.0	0.8
Sierra[b]	Snoek	*Thyrsites atun*	17.0	26.1
Pescado no clasificado[b]	Marine fishes nei	Marine fishes nei	0.0	11.5

[a]Rapa Nui name, [b]Spanish name, [c]*Carcharhinus galapagensis* is listed as Near Threatened on the IUCN Red List of Threatened Species (2014.1), [d]Note that in Randall & Cea (2011) this species was listed as *Etelis marshi*. *Etelis marshi* remains a synonym, but is no longer the valid name.

2009). These are included in official Chilean national catch statistics simply as 'Chilean catches'. The quantities involved here are, however, likely dwarfed by the catches of other, non-Chilean pelagic fleets operating in the EEZ of Easter Island Province, based on observations from the inhabitants of Easter Island who frequently observe the lights of industrial vessels operating at night, and the remains of longline fishing gear washing up on the shores (Yáñez *et al.*, 2007; Muñoz, 2011). These observations point to the possible presence of illegal fishing in Easter Island's EEZ, but do not offer solid proof. Additional resources were accessed to investigate this issue further.

To assess whether illegal fishing was occurring in Easter Island's EEZ, preliminary results of a remote-sensing study performed by SkyTruth (skytruth.org) for The Pew Charitable Trusts' Global Ocean Legacy Project were made available by Mr. Paul Woods (SkyTruth,

Table 3. Taxonomic breakdown (percent contribution) of subsistence fisheries catches for Easter Island based on Inostroza (1979) and expert opinion (R. Vega, *pers. obs.*). Local and English names were verified in Randall & Cea (1984, 2011) and/or on FishBase/SeaLifeBase.

Local name	English name	Scientific name	%
Nanue[a]	Pacific chub	*Kyphosus sandwicensis*	42.2
Remo[a]	Rainbow runner	*Elagatis bipinnulata*	24.0
Ra'i ra'ionga[a]	Labyrinth fish	*Schedophilus velani*	18.0
Ruhi[a]	Black trevally	*Caranx lugubris*	4.5
Ura[a]	Spiny lobster	*Panulirus pascuensis*	2.5
Hatuke[a]	Sea urchin	*Echinometra insularis*	0.6
Pulpo[b]	Octopus	*Callistoctopus rapanui*	0.6
Po'opo'o[a]	Deepwater jack	*Carangoides equula*	0.4
Tollo o tiburón[b]	Galapagos shark	*Carcharhinus galapagensis*	0.3
Pescado no clasificado[b]	Marine fishes nei	Marine fishes nei	6.9

[a] Rapa Nui name, [b] Spanish name

Table 4. 'Score' for evaluating the quality of time series of reconstructed catches, with their confidence intervals (IPCC criteria from Figure 1 of Mastrandrea *et al.* (2010)

Score		Confidence interval		Corresponding IPCC criteria*
		-%	+%	
4	Very high	10	20	High agreement & robust evidence
3	High	20	30	High agreement & medium evidence or medium agreement & robust evidence
2	Low	30	50	High agreement & limited evidence or medium agreement & medium evidence or low agreement & robust evidence.
1	Very low	50	90	Less than high agreement & less than robust evidence

*Mastrandrea *et al.* (2010) note that "confidence increases" [and hence confidence intervals are reduced] "when there are multiple, consistent independent lines of high-quality evidence".

pers. comm.). The approach used in the study involved two different, satellite-based detection methods, one being based on picking up the signals given by the globally available Automatic Identification System (AIS) (*i.e.*, by ships transponders), the other (more expensive) detection method being radar-based. We assumed that any vessel identified by radar within the Easter Island EEZ with its transponder switched off was not innocently passing through, but was (illegally) fishing. A rough estimate of the magnitude of the illegal catch taken from the EEZ of Easter Island was attempted here based on SkyTruth's study.

In the six months from January to June 2013, SkyTruth estimated 295 vessel-days of illegal fishing. Thus, this equates to 590 vessel days per year if proportionality can be assumed, or two vessels fishing 250 days a year to remain conservative. These vessels were likely pelagic trawlers or longliners (*i.e.*, vessels that require catching between 100 and 1,000 ton yr^{-1} (metric tonnes per year) to operate profitably; see Fig. 3 in Pauly *et al.*, 2013). This means catches may be in the range of between 200 and 2,000 ton yr^{-1}, or to take the geometric mean of these extremes (Weinstein, 2012), about 630 ton yr^{-1}, which is over 3 times the current Rapa Nui catch. When this illegal fishery began is unknown; however, the maps of ship surface observation presented by Parrish (1989), which refer to 1984-1987, suggest that at the time, the large Soviet fleets targeting Chilean horse mackerel ('*jurel*'; *Trachurus murphyi*) did not operate in the vicinity of Easter Island. Therefore, we assumed that foreign fleets began fishing in the area in 1990 and reached their mean catch by 1995, and then maintained that catch, assumed to consist mostly of *T. murphyi* and fish from the family Scombridae.

RESULTS

Total reconstructed domestic catches (*i.e.*, excluding the above tentative estimates of illegally caught fish) for Easter Island over the 1950-2010 time period were estimated to be almost 6,000 ton (Fig. 2). Total catches were, on average, 37 ton yr^{-1} in the 1950s, increasing steadily until 2000 (175 ton yr^{-1}), after which catches display year to year fluctuations, averaging 185 ton yr^{-1}

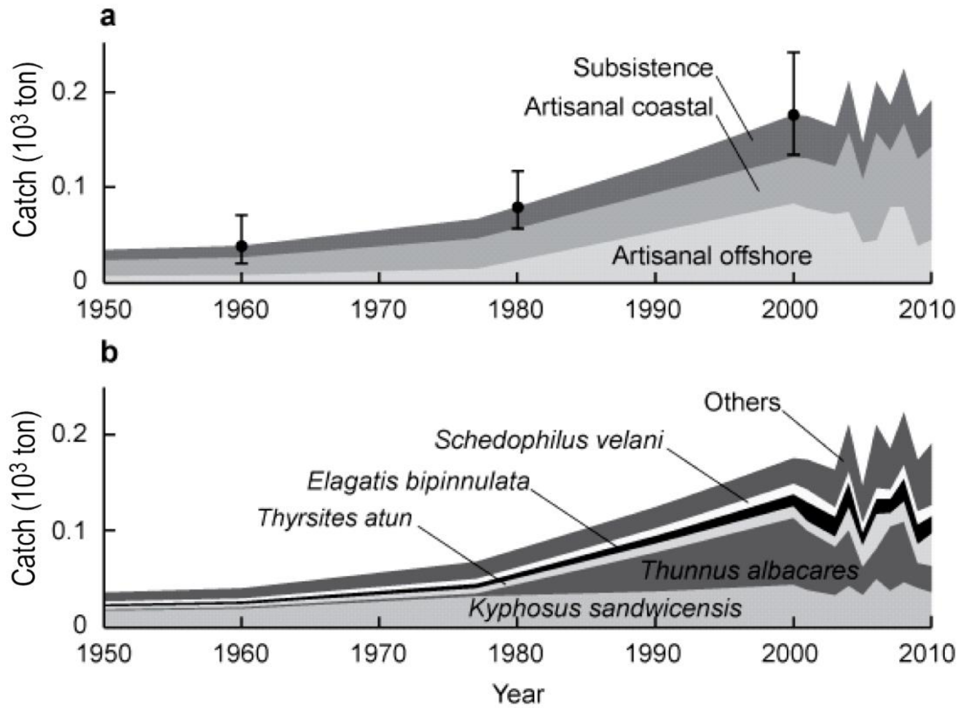

Figure 2. Total reconstructed domestic catches for Easter Island, 1950-2010, by a) fishing sector, with confidence intervals shown for three periods (1950-1969; 1970-1989 and 1990-2010), and b) taxonomic breakdown (see Tables 1 and 2 for the corresponding common names). The 'others' category consists of 20 additional taxonomic groups. The data associated with Figures 2a and 2b are available through the supplementary online material in Appendix Table A1 and A2, respectively.

ton yr^{-1} in the 2000s (Fig. 2a). Over the entire time period considered, subsistence catches represented just over 1,500 ton (26% of total catches) and artisanal catches amounted to 4,400 ton (74%; Fig. 2a; Data pertaining to the reconstructed catch by sector is shown in Table 5). Subsistence catches increase only gradually over the time period, whereas artisanal catches increase from 47 ton yr^{-1} in 1977 to almost three times that amount (130 ton yr^{-1}) in 2000. See Fig. 2a for the ranges of uncertainty calculated for the total reconstructed catch estimate for the time periods from 1950 to 1969, 1970 to 1989 and 1990 to 2010.

The main fish species caught were *K. sandwicensis*, *T. albacares*, snoek or '*sierra*' (*Thyrsites atun*), and rainbow runner or '*remo*' (*Elagatis bipinnulata*), with approximately 1,870, 1,400, 510 and 480 ton, respectively, over the 1950-2010 time period (Fig. 2b; data pertaining to the reconstructed catch by major taxa is available in Table 6). Invertebrate catches were dominated by *P. pascuensis* with approximately 80 ton over the study period, while *O. rapanui* and *E. insularis* each accounted for 9 ton over the same period.

Artisanal catches consisted of 2,100 ton of offshore catches and almost 2,300 ton of coastal catches. The offshore catches dramatically increased after 1977 from 16 ton yr^{-1} to a peak of 83 ton yr^{-1} in 2000. Offshore catches then declined to 43 ton yr^{-1} in 2005, before experiencing a resurgence in 2007-2008 of 80 ton yr^{-1}, and then declining thereafter (Fig. 3a). Coastal catches increased steadily from 16 ton yr^{-1} in 1950 to 47 ton yr^{-1} in 2000. In the 2000s, coastal catches increased suddenly to a peak at 110 ton yr^{-1} in 2006. After a sudden decline in 2007, catches have been increasing steadily and were 97 ton yr^{-1} in 2010 (Fig. 3b).

Artisanal offshore catches were dominated by *T. albacares* with 1,400 ton (65% of offshore catches; Fig. 3a). Bigeye tuna or '*kahi māta tata*' (*Thunnus obesus*) and swordfish or '*ivi heheu*' (*Xiphias gladius*) are the next highest contributors to the catch (8% and 7%, respectively). Artisanal coastal catches were dominated by *K. sandwicensis* with 1,200 ton (53% of the coastal catch; Fig. 3b). *T. atun* and *E. bipinnulata* were the next most important contributors to the coastal catch (22% and 5%, respectively). Subsistence catches were also dominated by *K. sandwicensis* with 650 ton (42% of subsistence catches; Fig. 3c). *T. atun* and labyrinth fish or '*ra'i ra'ionga*' (*Schedophilus velani*) were the next most important contributors (370 and 280 ton, respectively). See FishBase (www.fishbase.org) for a

Table 5. Total reconstructed catch (in ton) by sector, for Easter Island (1950-2010). These data correspond to Figure 2a.

Yr	Offshore artisanal	Coastal artisanal	Subsistence
1950	8.4	16.4	10.5
1951	8.5	16.6	10.6
1952	8.6	16.8	10.7
1953	8.8	17.0	10.9
1954	8.9	17.2	11.0
1955	9.0	17.4	11.1
1956	9.1	17.6	11.3
1957	9.2	17.8	11.4
1958	9.3	18.0	11.5
1959	9.4	18.2	11.6
1960	9.5	18.4	11.8
1961	9.9	19.2	12.3
1962	10.3	19.9	12.7
1963	10.6	20.7	13.2
1964	11.0	21.5	13.7
1965	11.4	22.2	14.2
1966	11.8	23.0	14.7
1967	12.2	23.7	15.2
1968	12.6	24.5	15.6
1969	13.0	25.2	16.1
1970	13.4	26.0	16.6
1971	13.8	26.8	17.1
1972	14.2	27.5	17.6
1973	14.5	28.3	18.1
1974	14.9	29.0	18.5
1975	15.3	29.8	19.0
1976	15.7	30.5	19.5
1977	16.1	31.3	20.0
1978	19.0	32.0	20.7
1979	22.0	32.8	21.3
1980	24.9	33.5	22.0
1981	27.9	34.2	22.7
1982	30.8	34.9	23.4
1983	33.7	35.7	24.1
1984	36.7	36.4	24.8
1985	39.6	37.1	25.6
1986	42.5	37.8	26.3
1987	45.5	38.6	27.1
1988	48.4	39.3	27.9
1989	51.4	40.0	28.6
1990	54.3	40.7	29.4
1991	57.2	41.5	30.6
1992	60.2	42.2	31.8
1993	63.1	42.9	33.3
1994	66.1	43.6	34.7
1995	69.0	44.4	36.2
1996	71.9	45.1	37.7
1997	74.9	45.8	39.2
1998	77.8	46.5	40.8
1999	80.7	47.3	42.3
2000	83.7	48.0	43.9
2001	78.7	51.8	43.5
2002	75.6	50.8	42.1
2003	72.6	49.9	40.8
2004	75.3	82.8	52.7
2005	43.0	66.2	36.4
2006	45.7	111.9	52.5
2007	80.3	58.5	46.3
2008	80.4	86.9	55.8
2009	39.7	90.3	43.3
2010	46.0	96.9	47.6

complete list of the fishes occurring in Easter Island, including their Rapa Nui names, their threat status and other information.

Finally, illegal catches were estimated at about 630 ton yr^{-1}, totalling 11,655 ton over the 1990-2010 time period.

DISCUSSION

The fishing history of Easter Island, as reconstructed here, suggests that domestic fisheries catches have increased substantially since the late 1970s. This is due to an increase in offshore catches, specifically *T. albacares*. The increase in tuna and other large pelagics from the late 1970s to the recent time period may be partially due to the increase in tourist arrivals to the island. In addition to the resident population, many tourists visit Easter Island every year. The opening of the airport in the late 1960s brought the first tourists, estimated at roughly 5,000 per year by 1970 (Maino 1985; Porteous, 1993). By the mid-1990s, approximately 14,000 tourists visited the island annually (Randall & Cea, 2011), increasing to 22,000 by the early 2000s (Ross, 2008) and 70,000 by 2009 (Kootnikoff, 2010). While seafood consumption by tourists was not estimated directly, a portion of the small-scale catch is sold to and served at local restaurants, while the remainder of the tourist demand is being met by seafood flown in from the Chilean mainland.

Over the 1950-2010 time period, approximately 6,000 ton of domestic catch (excluding illegal estimates) was taken. Although catches from the artisanal sector in recent years appear to be documented in official records, it is unknown whether such catches were also included in previous years. Nevertheless, detailed fisheries catches for Easter Island were not readily avai- lable for this study (with the exception of the 2000-2010 time period), suggesting that such data are also not easily obtained for management and conservation purposes. Furthermore, the data that are available are very incomplete. Subsistence fishing is not captured by official landing statistics, despite being important when discussing food security issues. Enumeration of catches, even if small in comparison

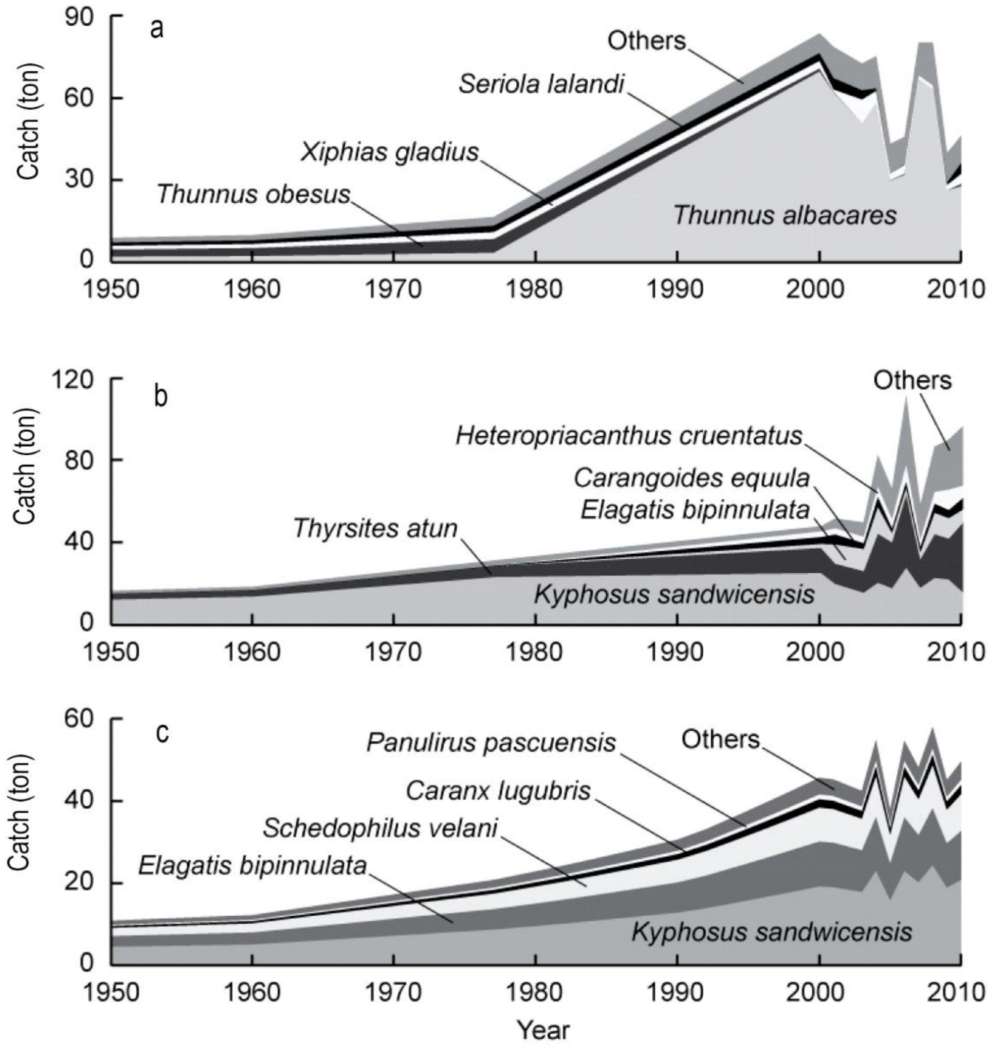

Figure 3. Total reconstructed domestic catches for Easter Island, by taxa, 1950-2010, for a) the artisanal offshore sector, b) the artisanal coastal sector, and c) the subsistence sector (see Tables 1 and 2 for the corresponding common names).

with other countries, is crucial to fisheries management, particularly for remote islands where people are reliant on local resources (Zeller *et al.*, 2006).

Another major concern is the status of the tuna stocks. Tunas are oceanic fishes with often long migration routes. If there have been recent declines in landings of *T. albacares*, the main species caught in Easter Island, the reason could thus be depletion by foreign fleets in neighbouring waters, among others (Castilla *et al.*, 2013). The catch estimated here as being taken by fishing vessels operating illegally within the EEZ of Easter Island Province, moreover, should also have an adverse impact on the domestic catch of oceanic fishes such as *T. albacares*, given the oligotrophic (*i.e.*, unproductive) nature of the waters in that EEZ. Thus, even though this estimate is very tentative, its magnitude highlights the importance for Chile of monitoring and surveillance in the waters of Easter Island province, particularly if, in addition to the existing marine reserve of Salas y Gómez Island, a marine reserve should be declared around Rapa Nui.

With increasing migration from mainland Chile and a developing tourism market, Easter Island's natural environment appears to be under threat of overexploitation. Although the terrestrial landscape was stripped away long ago, the marine environment can still recover. The fate of this unique ecosystem and the array of endemic species present depend on the ability to establish areas where fishing and invertebrate collection is prohibited (DiSalvo *et al.*, 1988). Protection of key marine areas such as islets (*motus*) off the southwest point of the Island would extend protection to important archeological and species-rich sites (DiSalvo *et al.*, 1988; DiSalvo & Randall, 1993). A fishery management plan for coastal species could ensure the availability of species for domestic consump-

Table 6. Total reconstructed catch (in tonnes) by major species, for Easter Island (1950-2010). 'Others' includes data from 20 additional taxonomic categories. This data corresponds to Figure 2b.

Year	*Kyphosus sandwicensis*	*Thunnus albacares*	*Thyrsites atun*	*Elagatis bipinnulata*	*Schedophilus velani*	Others
1950	16.6	1.6	2.8	2.5	2.7	9.2
1951	16.8	1.6	2.8	2.5	2.7	9.3
1952	17.0	1.6	2.9	2.6	2.8	9.4
1953	17.2	1.6	2.9	2.6	2.8	9.5
1954	17.4	1.7	2.9	2.6	2.8	9.6
1955	17.6	1.7	3.0	2.7	2.9	9.8
1956	17.8	1.7	3.0	2.7	2.9	9.9
1957	18.0	1.7	3.0	2.7	2.9	10.0
1958	18.2	1.7	3.1	2.8	3.0	10.1
1959	18.4	1.8	3.1	2.8	3.0	10.2
1960	18.6	1.8	3.1	2.8	3.0	10.3
1961	19.4	1.8	3.3	2.9	3.1	10.7
1962	20.1	1.9	3.4	3.1	3.3	11.2
1963	20.9	2.0	3.5	3.2	3.4	11.6
1964	21.7	2.1	3.6	3.3	3.5	12.0
1965	22.4	2.1	3.8	3.4	3.6	12.4
1966	23.2	2.2	3.9	3.5	3.8	12.9
1967	24.0	2.3	4.0	3.6	3.9	13.3
1968	24.7	2.4	4.2	3.8	4.0	13.7
1969	25.5	2.4	4.3	3.9	4.1	14.1
1970	26.2	2.5	4.4	4.0	4.3	14.6
1971	27.0	2.6	4.5	4.1	4.4	15.0
1972	27.8	2.6	4.7	4.2	4.5	15.4
1973	28.5	2.7	4.8	4.3	4.6	15.8
1974	29.3	2.8	4.9	4.5	4.8	16.3
1975	30.1	2.9	5.1	4.6	4.9	16.7
1976	30.8	2.9	5.2	4.7	5.0	17.1
1977	31.6	3.0	5.3	4.8	5.1	17.5
1978	32.0	5.9	5.6	5.0	5.3	17.8
1979	32.3	8.8	5.9	5.3	5.5	18.2
1980	32.7	11.7	6.2	5.5	5.7	18.5
1981	33.1	14.6	6.5	5.8	5.9	18.8
1982	33.5	17.5	6.8	6.0	6.1	19.1
1983	33.8	20.4	7.1	6.3	6.3	19.5
1984	34.2	23.3	7.4	6.6	6.5	19.8
1985	34.6	26.2	7.7	6.8	6.7	20.1
1986	35.1	29.1	8.0	7.1	6.9	20.5
1987	35.5	32.0	8.3	7.4	7.1	20.8
1988	35.9	34.9	8.6	7.6	7.3	21.2
1989	36.3	37.8	8.9	7.9	7.5	21.5
1990	36.7	40.7	9.2	8.2	7.8	21.8
1991	37.3	43.6	9.5	8.6	8.0	22.3
1992	37.9	46.5	9.8	8.9	8.3	22.7
1993	38.6	49.4	10.1	9.4	8.7	23.1
1994	39.3	52.3	10.4	9.8	9.0	23.6
1995	40.0	55.2	10.8	10.2	9.3	24.0
1996	40.7	58.2	11.1	10.7	9.7	24.5
1997	41.4	61.1	11.4	11.1	10.0	24.9
1998	42.2	64.0	11.7	11.6	10.4	25.4
1999	42.9	66.9	12.0	12.1	10.7	25.8
2000	43.7	69.8	12.3	12.5	11.1	26.3
2001	38.1	62.0	9.9	19.8	13.1	30.9

Continuation

Year	*Kyphosus sandwicensis*	*Thunnus albacares*	*Thyrsites atun*	*Elagatis bipinnulata*	*Schedophilus velani*	Others
2002	35.4	56.4	10.2	20.2	11.5	34.8
2003	32.7	50.8	10.6	20.6	9.9	38.7
2004	42.6	58.4	24.1	25.8	11.5	48.4
2005	33.1	29.6	22.5	13.4	10.5	36.7
2006	49.9	31.7	35.9	15.8	11.1	65.5
2007	37.5	67.1	14.0	14.6	9.9	42.0
2008	46.3	63.2	21.4	23.9	14.3	54.0
2009	40.3	26.0	20.0	20.4	13.8	52.8
2010	35.9	27.5	34.0	17.9	11.2	64.0

tion on the island. We hope that a way will be found to protect the marine environment of this unique landscape, which has such an interesting ecological and anthropological past.

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