

## Marine catch reconstruction of Polynesia: Update to 2018\*

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### Abstract

The original marine catch reconstructions for the various Polynesian island areas were completed independently, and have been updated to various years and carried forward to 2018 as documented in this contribution for the Cook Islands, French Polynesia, Niue, Pitcairn Island, Samoa, Tonga, Tokelau, Tuvalu, and Wallis and Futuna. For small island societies such as those in Polynesia, fisheries are essential to food and nutritional security, tradition and the economy. Through various reported or estimated data sources available from FAO, governments or independent sources, we have conservatively accounted for the reported and unreported domestic catches in these waters. Descriptions of the methods used to reconstruct catches are presented in EEZ-specific sections.

### Introduction

The Polynesian island areas include the Cook Islands, French Polynesia, Niue, Pitcairn Island, Samoa, Tonga, Tokelau, Tuvalu, and Wallis and Futuna Islands, and underlying catch data reconstructions were originally completed independently and by a variety of authors. These reconstructions have been independently updated to either 2014 (Pitcairn Island, Wallis & Futuna), 2016 (French Polynesia, Samoa, Tonga, Tokelau) or 2017 (Cook Islands, Niue, Tuvalu) and carried forward to 2018 and are briefly presented here. The catch reconstruction update for Rapa Nui (Easter Island) is included in the chapter covering Chile (Page et al. 2020).

Domestic fisheries in Polynesia are primarily small-scale in nature, with the majority of catches used for home consumption (i.e., subsistence) or local market-based sale (i.e., artisanal). There were few true domestic industrial fisheries, as most industrial fishing targets large pelagic species and requires large vessels and gears not widespread on the islands. The large pelagic fisheries, often by foreign distant water fleets or locally reflagged or chartered vessels, were addressed in a separate study on global fisheries for large pelagic species by Coulter *et al.* (2020). Descriptions of the methods used to reconstruct catches are presented in country-specific sections.

### Materials and Methods

#### Cook Islands

The Cook Islands are a self-governing island country in free association with New Zealand, composed of fifteen islands and located 3200 km north-east of New Zealand. The Cook Islands' marine fisheries catches were originally reconstructed for 1950-2010 by Haas *et al.* (2012), see also Haas *et al.* (2016), and have since been updated to 2017 and carried forward to 2018. Data reported by the FAO were accepted as the reported

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data baseline for the entire time series. Large pelagic taxa assumed to be caught industrially were considered separately by Coulter *et al.* (2020). However, approximately 10% of tunas (albacore, bigeye, skipjack and yellowfin tuna) were considered caught by the domestic small-scale sector. As such, this portion was retained in the reconstructed data presented here (Haas *et al.* 2012).

### **Seafood consumption**

Following the methods of the original reconstruction by Haas *et al.* (2012), total domestic marine catch was assumed equal to total domestic seafood demand. Catch data were updated to 2017 using recent population estimates from national data and per capita fresh fish consumption rates minus per capita imported fish consumption (via imports of canned fish at 10.8 kg·person<sup>-1</sup>·year<sup>-1</sup>).

According to Gillett and Tauati (2018), catch levels in the Cook Islands are influenced by fish aggregation devices, population distribution and decline, unemployment, ciguatera poisoning, and the high cost of fresh fish alternatives. These factors have likely influenced the decline in domestic small-scale fisheries catches in recent years. In particular, increased ciguatera fish poisoning from fish around Rarotonga, the most populated island of the Cook Islands with the highest incidence of ciguatera poisoning globally, has discouraged local fish consumption (Rongo and van Woesik 2013). Although cases have declined, the occurrence of ciguatera has been linked to cyclones (Rongo and van Woesik 2013). The decrease in catch after 2011, particularly in 2015 and 2016, may have been influenced by cyclones during the 2015/2016 El Niño events (Dunstan *et al.* 2018).

Thus, since no recently updated data were found for domestic consumption rates and the reduction in local fish consumption, it was assumed the per capita consumption rate was continuing to decline at the same rate as from 116 kg·person<sup>-1</sup>·year<sup>-1</sup> in 1989 (Solomona *et al.* 2009; Haas *et al.* 2012) to 64.2 kg·person<sup>-1</sup>·year<sup>-1</sup> in 2006 (Moore 2006) resulting in 30.7 kg·person<sup>-1</sup>·year<sup>-1</sup> for 2017. The seafood import adjusted fish consumption rate was estimated to be 19.9 kg·person<sup>-1</sup>·year<sup>-1</sup> for 2017. The annual consumption rates were then multiplied by the updated population data. The allocation between artisanal and subsistence catch was determined by linear interpolation between anchor points for 1950 (10% artisanal and 90% subsistence) to the most recent split of 35.2% artisanal and 64.8% subsistence for the year 2014 based on (Gillett 2016). The ratio of these estimated domestic catches that were deemed unreported were calculated by subtracting the FAO reported landings, excluding the large pelagic taxa addressed in Coulter *et al.* (2020) from the total estimated domestic catches. If the adjusted reported FAO amounts were greater than the reconstructed amounts, then FAO data were accepted as totals, and it was assumed no unreported landings occurred. In July 2017, the Cook Islands established a 1.9 million km<sup>2</sup> marine protected area, Marae Moana. The marine protected area will likely impact local coastal catches, and this needs to be assessed in future updates.

### **Large pelagic species fisheries**

Catch of large pelagic species from the FAO data were compared with the Tuna Fishery Yearbook 2017 published by the Western and Central Pacific Fisheries Commission (WCPFC 2018b), and the larger published catches were used. FAO catches for 2015-2017 were higher, except for skipjack tuna in 2016. These large-scale tuna catches (i.e., albacore, bigeye, skipjack, and yellowfin tuna) were then divided into 90% industrial and 10% small-scale (Haas *et al.* 2012). Other large pelagic species—black marlin, blue marlin, marlins, sailfishes, Indo-Pacific sailfish, shortbill spearfish, striped marlin, and swordfish—were considered caught exclusively by the industrial sector. Small-scale tuna catches were retained in the domestic catch data; see above.

### **Transition from 2017 to 2018**

The catch reconstructed to 2017 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

The Cook Islands have agreed to protect their biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) (Marine Conservation Institute 2020).

The Cook Islands have one MPA, the Shark Sanctuary, which covers all the EEZ of 1,960,000 km<sup>2</sup> (Haas *et al.* 2016). It was designated in 2012 (Marine Conservation Institute 2020) and established by regulations under the Marine Resources Act of 2005 (Pacific Islands Conservation Initiative 2012). This country, together with French Polynesia, American Samoa and Tokelau, formed the Shark Sanctuary protect species such as scalloped hammerhead and whale shark.

“The sanctuary bans the sale, trade, and possession of sharks aboard all commercial fishing vessels in its EEZ as well as the use of shark-targeted fishing gear, known as wire leaders” (Marine Conservation Institute 2020). Fines are a minimum of \$100,000 NZD and a maximum of \$250,000 NZD per offence. “As a result of these regulations, community and commercial fishermen have realized the importance of reporting their shark catches accurately for research purposes. Although sharks will no longer be brought on board any vessel, information such as size estimate, species, condition and location will be recorded” (Pacific Islands Conservation Initiative 2012).

### **French Polynesia**

French Polynesia, an overseas collectivity of France, is composed of five archipelagos located in the south-central Pacific Ocean. The original reconstruction of French Polynesia’s marine fisheries catches for 1950-2007 (Bale *et al.* 2009), was updated to 2010 (Bale *et al.* 2016), and has since been updated to 2018 with new information, such as the ban on shark fishing in 2012 (Fache and Pauwels 2016). The reported baseline from the original reconstruction was compared to the newest available data reported by the FAO on behalf of French Polynesia to detect retroactive changes to reported catch amounts. A discrepancy in data was noted from 1993 onward due to the addition of reported landings of *Thunnus alalunga*, *T. albacares*, *T. obesus*, various billfish taxa, and sea cucumbers to FAO’s reported data. Reports by Misselis (2002) and Petit *et al.* (2015) indicate that a tuna longline fishery began in French Polynesia in 1990, catching various tunas and billfishes as well as frigate tunas (*Auxis* spp.), opah (*Lampris guttatus*), and dolphinfish (*Coryphaena hippurus*). These taxa were added to the list of taxa previously outlined by Bale *et al.* (2009) as being fished in an industrial capacity. Landings of large pelagic taxa by industrial fisheries have since been reconstructed in a separate study by Coulter *et al.* (2020), and were not included here.

### **Artisanal fisheries**

Industrial catch amounts for the tuna and other large pelagic data from Western and Central Pacific Fisheries Commission (WCPFC 2018) were subtracted from the FAO reported data to derive artisanal catches of tunas and other large pelagic species. Artisanal catch reported nationally (Anon. 2018) was compared with the data released by the FAO and found to match. Industrially caught species and catch components were allocated to the industrial sector (used in Coulter *et al.* 2020) and subtracted from the FAO total reported catch to estimate artisanal reported catch. Miscellaneous marine fishes catch (FAO category “Marine fishes nei”) was disaggregated by sector and taxa following Bale *et al.* (2009). Unreported artisanal catch was calculated for

2011-2016 as an additional 15% of the catch of all taxa disaggregated from the “Marine fishes nei” and Carangidae FAO categories (Gillett 2016).

### **Subsistence fisheries**

Subsistence catch was reconstructed following the original methods in Bale *et al.* (2009). The total population of French Polynesia for 2013-2014 was divided among population groups according to the 2012 ratio for each island group, and Tahiti’s rural population was calculated following similar methods. For 2015-2016, island group populations were determined by extrapolating between the latest year in the French Polynesian national census. Due to evidence of declining subsistence fishing rates (Gillett 2016; Smith 2013), a conservative estimate of 10% was used as a tonnage decrease from 2011 to 2016.

### **Transition from 2016 to 2018**

The catch reconstructed to 2016 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

French Polynesia has agreed to protect biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) (Marine Conservation Institute 2020).

French Polynesia has one MPA, the Shark Sanctuary, which equals 100% of the EEZ of 4,771,088 km<sup>2</sup> (Bale *et al.* 2016). It was designated in 2012 (Marine Conservation Institute 2020), and it is established by regulations under the Marine Resources Act (2005) (Pacific Islands Conservation Initiative 2012). A shark fishing and finning moratorium was established in 2006 due to the local interests in fishing mako sharks. This country, together with the Cook Islands, American Samoa and Tokelau, forms the Shark Sanctuary, which protects species such as mako, hammerhead and thresher sharks (Marine Conservation Institute 2020).

Other emblematic group of species in French Polynesian waters are manta rays, including *Mobula alfredi* and *M. birostris*, both being of cultural and economic interest. “Analysis of photographs of individuals bearing sublethal injuries (n = 68) suggests that *M. alfredi* are more likely to be injured at inhabited islands (Maupiti or Bora Bora; 75% of all injured individuals) than at uninhabited islands, with 75% of injuries related to boat propeller strikes and fishing gear entanglements” (Carpentier *et al.* 2019). These findings suggest that the region’s expanding marine megafauna tourism industry and coastal development may threaten these species as well as endangered turtles, such as the green sea turtle (*Chelonia mydas*), which were using these waters in the past glacial as refugium and are predicted to be a refugium under future warming conditions (Boissin *et al.* 2019). In Moorea Island, anthropogenic factors have been also found to be the principal drivers of coastline changes in the Island (Moussa *et al.* 2019).

### **Niue**

The original catch reconstruction for Niue from 1950 to 2010 was completed by Zyllich *et al.* (2012), see also (Zyllich *et al.* 2016), and has since been updated to 2017 and carried forward to 2018. Data from the FAO continues to be the reported baseline for this reconstruction.

### **Small-scale fisheries**

The reconstructed artisanal catch was assumed to be 10 tonnes per year for 2007-2010 and 11 tonnes in 2014 (Gillett 2016). The total reconstructed subsistence catch was calculated using population statistics and consumption rates derived from Gillett (2016). The consumption rate in 2007 was 89.7 kg·person<sup>-1</sup>·year<sup>-1</sup> and

was interpolated to the 2014 consumption rate of 96.1 kg·person<sup>-1</sup>·year<sup>-1</sup>. As it was assumed that artisanal fisheries were better reported than subsistence fisheries, the reported landings were first assigned to the artisanal sector up to 10 tonnes per year, after which the remainder was assigned to the subsistence sector. In cases where the data reported by the FAO were less than the reconstructed artisanal catch, the difference was considered as unreported artisanal catch. Discards for the small-scale fisheries sectors were considered to be negligible, and none were estimated here. The taxonomic composition was conserved from Zylich *et al.* (2012).

### **Large-scale fisheries**

Catches of large pelagic species by industrial vessels flagged to Niue were not included in this update as these are covered in Coulter *et al.* (2020).

### **Transition from 2017 to 2018**

The catch reconstructed to 2017 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

Niue has agreed to protect its biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) and the World Heritage Convention (Marine Conservation Institute 2020). “It was interesting that Niue signed diplomatic relations with Indonesia, given that Indonesia abstained from voting for a UN resolution to strengthen UN engagement in the Pacific through the Pacific Islands Forum in order to achieve the Sustainable Development Goals [...]. [...] climate change has been described as a top priority for Niue — as illustrated by the millions of dollars invested in renewable energy and the adoption of a Niue Climate Action Plan” (Talagi 2020).

“The commitment also reflects the investment and sustainable practice contributed to by the Niuean people for many hundreds of years. As emphasized by Niue Premier Sir Toke Talagi: This commitment is not a sacrifice, it is an investment in the certainty and stability of our children's future. We simply cannot be the generation of leaders who have taken more than they have given to this planet, and left behind a debt that our children cannot pay. Climate change, plastic rubbish, pollution, overfishing - these are all debt collectors we cannot out-run. Our ocean needs to heal - it is not rocket science - she just needs the space and time to do it” (United Nations Development Programme 2017).

Niue has 86 MPAs and two marine managed areas, which jointly cover 958 km<sup>2</sup> (Marine Conservation Institute 2020), corresponding to 0.0013% of an EEZ of 1,596,464 km<sup>2</sup> (Zylich *et al.* 2016).

Niue doesn't have many fishers, but due to subsistence and international fleets in these waters, overfishing is a problem. This could reduce the small number of tourists that find their way to the island and harm the country's economy. “Some tourists travel to Niue specifically for fishing and diving, but without fish Niue again detracts from and limits its tourism attractions. Niue could lose one of its major attractions and therefore reduce the pool of tourists that are interested in travelling to Niue” (de Haas 2002).

### **Pitcairn Islands**

Marine fisheries catches for the Pitcairn island group were first reconstructed to 2009 by Chaitanya *et al.* (2012), and updated to 2010 by Chaitanya *et al.* (2016), and updated to 2014 by Coghlan *et al.* (2017), before being carried forward to 2018. The human population of Pitcairn Island has remained steady at approximately 50 people for the last decade, and the mean fish consumption rate of 71.5 kg·person<sup>-1</sup>·year<sup>-1</sup> derived from a

2011 survey on the island was maintained from Coghlan *et al.* (2017). Artisanal catches were also held constant, with cruise ship driven lobster catch of 0.4 t·year<sup>-1</sup> and finfish 0.6 t·year<sup>-1</sup> from Coghlan *et al.* (2017). Large pelagic taxa assumed to be caught industrially by foreign fleets were excluded, as such catches were considered by Coulter *et al.* (2020).

### **Transition from 2014 to 2018**

The catch reconstructed to 2014 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

The UK has agreed to protect the biodiversity of the Pitcairn Islands, a British Overseas Territory, through the international agreements of the Convention on Biological Diversity (Aichi), the United Nations Convention on the Law of the Sea, the Ramsar Convention on Wetlands of International Importance, the International Coral Reef Initiative and the World Heritage Convention. Pitcairn Islands is a signatory to regional treaties and agreements such as the Regional Seas Convention and Natura 2000. These commitments extend to NGOs and/or public bodies like the Atlantic Arc Network of MPAs (MAIA), the Caribbean MPA Network (CaMPAM) and the OSPAR Convention (Marine Conservation Institute 2020).

The Pitcairn Islands have one of the largest and most continuous MPAs. The MPA surrounds the waters of the archipelago and covers all of the EEZ of 1,596,464 km<sup>2</sup> (Chaitanya *et al.* 2016). In 1989, Henderson Island was declared a UNESCO World Heritage Site. Until 2012, the Pitcairn Island Council and the island's community did not unanimously support the creation of a marine reserve around the Pitcairn Islands. In January 2015, a proposal for the MPA creation was submitted to the UK government and after monitoring trials the Pitcairn Islands Marine Reserve (PEW 2016), it was legally designated in September 2016 (Marine Conservation Institute 2020).

In the MPA ordinance revised in 2017, the prohibited activities are fishing, mining, the disturbance of or the removal of non-living natural material from the seabed or subsoil, the dumping of waste or other matter (including from vessels or other structures) and the causing of vibrations in a manner that is likely to have an adverse effect on marine life. “The principles of the Coastal Conservation Areas are: (a) conservation of the unique marine environments and biodiversity in the coastal areas, reefs and lagoons; (b) sustenance and sustainable development of the Pitcairn community; (c) sustainable management of marine resources” (Government of Pitcairn Island 2016).

“The structure of the food web across the island group was clearly influenced by the degree of isolation (i.e. fishing pressure), with Pitcairn and Oeno showing lower overall fish biomass and a smaller proportion of top predators. The abundance of groupers and sharks at depths between 100–300 m also indicates the intactness of these deep fish populations. The high dissimilarity between the algal floras of the four islands is almost certainly related to the different eomorphologies, habitats, and/or isolation of these islands. Most of the marine flora in the island group is typically tropical Indo-Pacific in origin with most species also present in French Polynesia” (Friedlander *et al.* 2014).

### **Samoa**

Reconstruction of Samoa's marine fisheries catches were first completed by Lingard *et al.* (2012) for 1950–2010; see also Lingard *et al.* (2016). Since completing the initial reconstruction, updated data from the FAO

were used to update reported landings to 2016 and then carried forward to 2018. Any retroactive changes in the FAO data were reflected in the reconstruction.

### **Small-scale fisheries**

In the original reconstruction (Lingard *et al.* 2012), domestic small-scale landings in 2006 were estimated using the per capita consumption rate of 59.4 kg·person<sup>-1</sup>·year<sup>-1</sup> (Samuelu and Sapatu 2009) along with population data obtained from the World Bank. Since then, a new per capita consumption rate of 48.5 kg·person<sup>-1</sup>·year<sup>-1</sup> was made available by the FAO for 2013. Other estimates from Samoa's 2012 socioeconomic fisheries survey (46.2 kg·person<sup>-1</sup>·year<sup>-1</sup> of finfish and 54.7 kg·person<sup>-1</sup>·year<sup>-1</sup> of invertebrates) were assumed to overestimate per capita consumption and were not used here, because Gillett (2016) indicated that the survey focused heavily on fishing communities and was not representative of Samoa as a whole. The per capita consumption rate was linearly interpolated between the 2006 (Samuelu and Sapatu 2009) and the 2013 rates (FAO 2018) and the corresponding estimates for domestic small-scale landings were recalculated using current population data. From 2013 onwards, the 48.5 kg·person<sup>-1</sup>·year<sup>-1</sup> per capita consumption rate was carried forward unchanged and multiplied by updated population data to estimate the domestic small-scale landings up to 2016. The sectoral (artisanal and subsistence) breakdown per reported taxon was conserved from 2008 and carried forward to 2016 (Lingard *et al.* 2012). Gillett (2016) estimated total catch from artisanal and subsistence fisheries at 10,000 tonnes in 2014, which aligns well with our reconstructed total small-scale catch estimate of 10,614 tonnes in the same year.

### **Taxonomic composition**

The taxonomic composition of small-scale catches derived for 2010 (Lingard *et al.* 2012) was retained, except for 'tuna-like fishes' and 'sharks, rays, and skates'. The latter two taxonomic categories were taxonomically disaggregated using the 2007 taxonomic breakdowns (Lingard *et al.* 2012) because these categories were not reported by the FAO in 2008 or 2009.

### **Large-scale fisheries**

Landings of large pelagic taxa and bycatch were accepted at the amounts reported by the FAO. Associated unreported landed bycatch and discards were calculated using the 2009 ratio of unreported bycatch and unreported discards to reported landings of large pelagic taxa (Lingard *et al.* 2012).

### **Transition from 2016 to 2018**

The catch reconstructed to 2016 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

Samoa has agreed to protect its biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) and the World Heritage Convention (Marine Conservation Institute 2020).

Samoa has 79 MPAs and no marine managed areas. Its MPAs jointly cover 191 km<sup>2</sup> (UNEP-WCMC and IUCN 2020) and correspond to 0.15% of the EEZ of 131,535 km<sup>2</sup> (Lingard *et al.* 2016).

In the Aleipaita MPA management plan, the people of Samoa recognized "that the fisheries problems are largely caused by destructive and/or unsustainable fishing practices; like dynamiting, coral pounding (faamoa or tuiga), poisonous chemicals (chlorox, gramoxine, barringtonia seeds, ava niukini), small mesh fishing nets, commercial SCUBA fishing and fish traps. Commercial sand mining has caused beach erosion" (Government of Samoa n.d.).

Therefore, in this management plan, these fishing activities, among others, are banned. The management plan details which species are legal to fish, provides a minimum size catch, and describes a clear prohibition on the introduction of non-local species, such as tilapia (Government of Samoa n.d.).

“Under a community-based fisheries extension programme in Samoa, 44 coastal villages have developed their own Village Fisheries Management Plans. Each plan sets out the resource management and conservation undertakings of the community, and the servicing and technical support required from the government Fisheries Division. Community undertakings range from enforcing laws banning destructive fishing methods to protecting critical habitats such as mangrove areas. An unexpectedly large number of villages (38) chose to establish small Village Fish Reserves in part of their traditional fishing areas. Although by social necessity many of the community-owned reserves are small, their large number, often with small separating distances, forms a network of fish refuges” (King and Faasili 1998).

“[It] should be noted that the small, community-owned, Village Fish Reserves in Samoa are not easy to classify under existing IUCN categories for MPAs. Category IV (Habitat/Species Management Area) appears to provide the best fit, although the category guidelines refer to national rather than community ownership. Given the increasing trend towards community-based management, the popularity of reserves as a fisheries conservation tool and the necessarily small size of village MPAs, there may be a need for another IUCN category for ‘networks of small, highly protected, community-owned MPAs’” (King and Faasili 1998).

## Tonga

The Kingdom of Tonga has 172 islands in three major island groups, of which 36 are inhabited. The total marine fisheries catches for Tonga were reconstructed from 1950 to 2007 by Sun *et al.* (2011), and updated to 2010 by Sun *et al.* (2016). Since completing the initial reconstructions, data from the FAO became available to 2018. To update the reconstruction, estimates by Gillett (2016) of 3900 tonnes of commercial small-scale (i.e., artisanal) and 3000 tonnes of subsistence catches for 2014 were used. Using the last available anchor point in 1997 Sun *et al.* (2011, 2016), the catch tonnages between 1997 and 2014 were linearly interpolated to 2016. Catches were assigned to the main and outer islands using the 2016 census data of the Tonga Statistics Department (TSD 2017). The reported component, consisting mainly of artisanal catch, was obtained from the FAO data, whereas the unreported component was taken to be the difference between the total reconstructed catch and the FAO values for their respective year. The taxonomic composition of the FAO data has expanded to include a mako shark category. These catches were classified as artisanal because there was evidence of an artisanal mako shark fishery in Tongan waters (Juncker *et al.* 2006). Tonga's catch was reported in the FAO data as pertaining only to the Eastern-Central Pacific FAO area, despite there being inhabited islands in the Western-Central Pacific FAO area. Therefore, reconstructed catch data were assigned to the two FAO areas based on the population density and catch totals of each island.

### Transition from 2016 to 2018

The catch reconstructed to 2016 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### Marine biodiversity protection

Tonga has agreed to protect its biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) and the World Heritage Convention (Marine Conservation Institute 2020). “Biodiversity conservation is one of the most difficult environmental issues facing Tonga. Often it poses choices between environmental protection and economic development and conflict between landowner rights

and the government's growing role in its stewardship responsibilities. However, the Government of Tonga is committed to the implementation of the CBD, including PoWPA [(Programme of Work on Protected Areas)], and has statutory laws that have provisions for biodiversity conservation" (Marine Conservation Institute 2020).

Tonga has 43 MPAs and one marine managed area, which jointly cover 390 km<sup>2</sup> (UNEP-WCMC and IUCN 2020), corresponding to 0.06% of the EEZ of 664,751 km<sup>2</sup> (Sun *et al.* 2016). "A number of endangered marine species are present in Tongan waters, including the Humpback whale (recovering) and the vulnerable manta ray both of which have high tourism value. A number of marine parks and reserves have been established under the Park and Reserve Act and their conservation success is reported to be quite variable and the enforcement of the legislation remains weak" (The Kingdom of Tonga n.d.).

In the Tonga Fisheries Sector Plan (2016-2024), some of the expected results after implementation are as follows: "(i) an increase in benefits from fisheries; (ii) sharing of those benefits and (iii) sustainability of fisheries dependent communities and their marine environment. The conditions required to generate many of those benefits extend beyond the remit of the fisheries administration, particularly with respect to the sharing of benefits and the impacts of climate change on the marine environment" (The Kingdom of Tonga n.d.).

"It is in the mission of Tonga's Ministry of Fisheries to develop its living aquatic resources to its highest level of use and remain harmonious with the ecological sustainability with structures of technology, participation and ownership to maximize the benefits for its people (Ministry of Fisheries 2017). However, at the same time, the tasks are not easy to execute as on paper. Given the lack of resources, the Ministry cannot effectively execute its duties and obligations both locally and also at the national level (Government of Tonga 2016)" (Bloomfield 2017).

## **Tokelau**

Marine fisheries catches for Tokelau were first reconstructed for 1950 to 2009 by Zylich *et al.* (2011), updated to 2010 by Zylich *et al.* (2016) and then to 2016 by White *et al.* (2018), and forward carried to 2018. Small-scale catches were estimated based on fresh seafood demand (171.8 kg·person<sup>-1</sup>·year<sup>-1</sup>) with an estimated 10% of small-scale fishers' catch sold for profit (artisanal) in 2014, with the remainder assigned as subsistence (Gillett 2016). Fish caught for the purpose of bait were also estimated using the annual small-scale tuna/pelagic target catch to bait fish catch ration of 64:1 (White *et al.* 2018).

### **Transition from 2016 to 2018**

Catches were carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

Tokelau has agreed to protect its biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) and the World Heritage Convention (Marine Conservation Institute 2020).

There are certain discrepancies about the extent and number of marine protected areas in these waters. MPAtlas states a lack of MPAs in Tokelau, while protectedplanet.net states that the area's extent as 10 km<sup>2</sup> (UNEP-WCMC and IUCN 2020), i.e., 0.003% of the EEZ of 319,049 km<sup>2</sup> (Zylich *et al.* 2016). However, in the same database, only two MPAs appear: Atafu Marine Conservation Area designated in 1995 with 0.2 km<sup>2</sup> and the Nukunonu Marine Conservation Area designated in 1998 with 0.25 km<sup>2</sup>. Nevertheless, other sources affirm that in 2011 a shark sanctuary that bans commercial fishing of sharks was created in these waters

(Techera and Klein 2014). The sanctuary reportedly covers the entire EEZ (Marine Conservation Institute 2020).

“The Tokelau atolls support ecosystems and species of high conservation value in their own right. They also provide an important link with other archipelagos including the Phoenix Islands to the north, the Cooks and Line Islands to the east and Samoan region to the south. The islands provide stepping stones for migratory marine and terrestrial species between the Samoan region and the Phoenix Islands and beyond. A number of threatened or significant species (e.g., Tiafee and Kaleva) depend on the presence of viable ecosystems in the Tokelau. Somewhat surprisingly, at least six species of seabird have recovered at the Tokelau over the past few decades, consistent with lower hunting pressure and some localized predator management” (Pierce *et al.* 2012).

## Tuvalu

The catch reconstruction for Tuvalu’s marine fisheries was completed from 1950 to 2009 by Crawford *et al.* (2011) and updated to 2010 by Crawford *et al.* (2016). It has been updated to 2017 and carried forward to 2018 as presented here. Retroactive changes were made in the FAO data set, and the reconstructed data were corrected accordingly.

### Small-scale fisheries

Gillett (2016) reported estimates of artisanal and subsistence catch; 226 tonnes in 2007 and 300 tonnes in 2014 for artisanal catch, and 989 tonnes in 2007 and 1135 tonnes in 2014 for subsistence catch. Since these catches were assumed to support local consumption, they were applied to population data to estimate per capita catch rates of 118.6 kg·person<sup>-1</sup>·year<sup>-1</sup> for 2007 and 133.8 kg·person<sup>-1</sup>·year<sup>-1</sup> for 2014. TFD (2018) provided a 2017 consumption rate estimate of 100 kg·person<sup>-1</sup>·year<sup>-1</sup>. The Gillett (2016) estimates were used to apply a sector breakdown to the local consumption-based catch; these rates were interpolated between 2007 and 2014, and the 2014 breakdown was maintained to 2017. The per capita catch rate for each sector was linearly interpolated between 2007 and 2014, and from 2014 to 2017. Population data obtained from the World Bank were multiplied by the catch rates to estimate sector-specific catches from 2007 to 2017. The catches deemed unreported with regards to the data reported to the FAO were derived as the difference between total catches as reconstructed here and data reported by the FAO on behalf of Tuvalu. The taxonomic breakdowns were maintained from Crawford *et al.* (2011). The exception to this was the bêche-de-mer (sea cucumber) export fishery, which ceased activity in 2010 Gillett (2016). The taxonomic composition of Crawford *et al.* (2011) was therefore adjusted for the post-2010 period.

### Large pelagic fisheries

Industrial catch of large pelagic species for vessels flagged to Tuvalu were not addressed here, because the industrial catch of large pelagic species is addressed in Coulter *et al.* (2020). Landings of large pelagic taxa have increased dramatically in recent years; therefore, small-scale catch of these species were retroactively changed from 2006. To adjust the estimated small-scale landings, the ratio of tuna to total reconstructed landings for 2005 was applied from 2006 onward. The reported industrial catch of large pelagic species to WCPFC (2018) was subtracted from the reported catch of these species to the FAO in order to estimate the reported artisanal catch of these species.

### Transition from 2017 to 2018

The catch reconstructed to 2017 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

Tuvalu has agreed to protect its biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) and the World Heritage Convention (Marine Conservation Institute 2020).

Tuvalu has no marine managed areas, but it has 18 MPAs which jointly cover 61 km<sup>2</sup> (UNEP-WCMC and IUCN 2020), corresponding to 0.008% of the EEZ of 751,672 km<sup>2</sup> (Crawford *et al.* 2016).

The biggest MPA is the Funafuti Conservation Area (CA), which is a no-take area designated in 1996 with 40 km<sup>2</sup> (Marine Conservation Institute 2020). “The boundaries of the CA encompass about 20 percent of the total coral reef area of the lagoon. At least 400 species of fish (Kaly November 1997), and at least 36 species of corals (Sauni n.d.) are known from Funafuti Lagoon, with a large number of these reported within the CA” (Funafuti Kaupule 2011).

### **Wallis and Futuna**

The Wallis and Futuna Islands are comprised of three main islands (Wallis, Futuna and Alofi), and became a French overseas territory in 1961 and a French overseas collectivity in 2003. The reconstruction of Wallis and Futuna’s marine fisheries catches was completed for 1950-2007 by Harper *et al.* (2009), and has since been updated to 2010 by Harper *et al.* (2016), and more recently to 2014, after which it was carried forward to 2018 here. Since the original reconstruction, new data from the FAO have become available. Total artisanal catches were estimated by Dalzell *et al.* (1996) at 296 tonnes in 1994, 300 tonnes in 1999 (Angleviel 1999), 121 tonnes in 2007 (Gillett 2009), and 150 tonnes in 2014 (Gillett 2016). Total subsistence catches were estimated as 621 tonnes in 1994 (Dalzell *et al.* 1996), 840 tonnes in 2007 (Gillett 2009), and 675 tonnes in 2014 (Gillett 2016). Total artisanal and subsistence catches were re-estimated from 1994 using these anchor points and linearly interpolating between years without data. FAO reported landings of the ‘tuna-like fishes’ category were assumed to be caught by artisanal fisheries, and all artisanal catch was considered to be reported, except for a portion of reconstructed catch for 1994-1998 which exceeded the total reported by FAO. The remaining reported catch after all artisanal landings were accounted for was assigned to the subsistence fishery. The difference between total derived subsistence catch and reported subsistence catch was assigned as unreported subsistence catch.

The population of Wallis and Futuna has decreased by 14.9% between 2007 and 2014 (Gillett 2016), and the number of fishing boats in Wallis and Futuna was estimated to have declined by as much as 42% from 2001 to 2014 (Sourd and Mailagi 2015). Following the destruction of crops by Cyclone Evan in late 2012, fishing pressure temporarily increased to provide food as few boats were damaged (Gillett 2016).

### **Transition from 2014 to 2018**

The catch reconstruction to 2014 was carried forward to 2018 using the semi-automated procedure outlined in Noël (2020), based on FAO landings data to 2018. Semi-automated reconstructed catch data will later be replaced by a more detailed, research-intensive update.

### **Marine biodiversity protection**

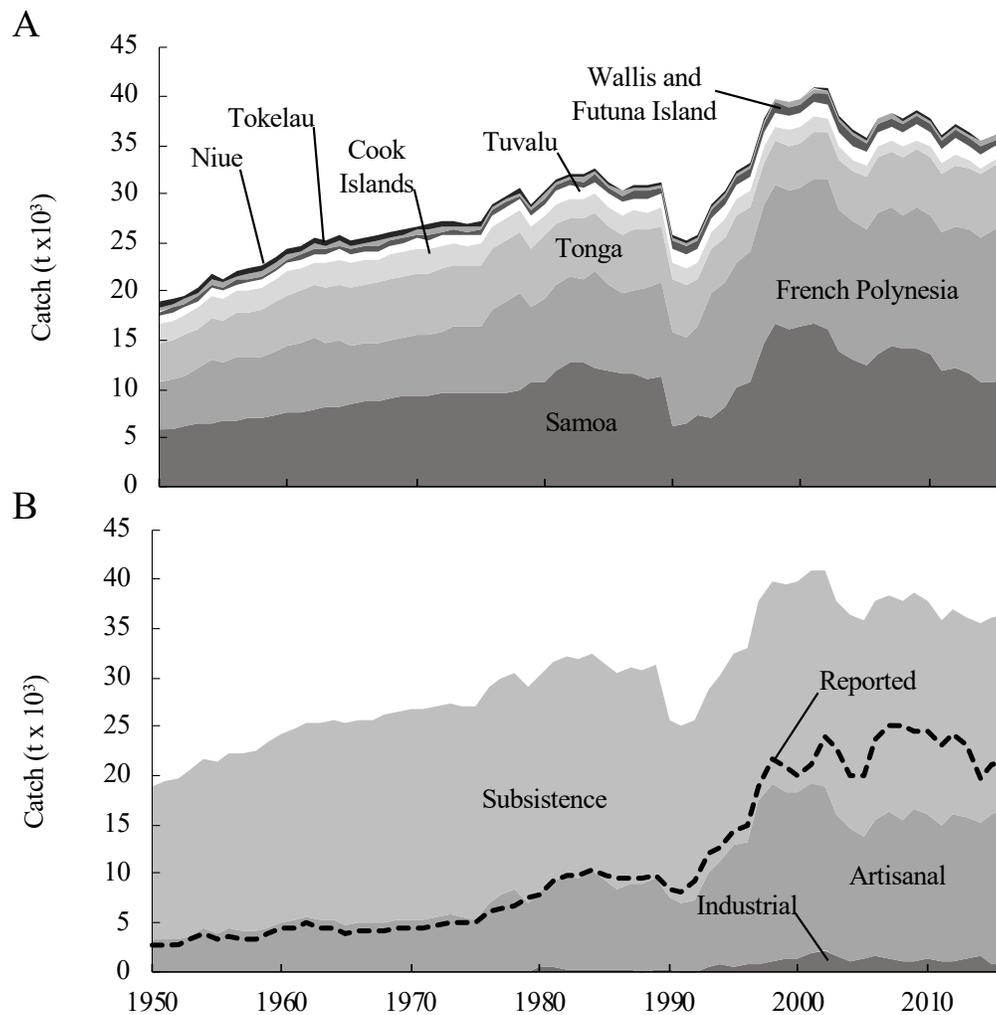
Wallis and Futuna have agreed to protect biodiversity through the international agreements of the Convention on Biological Diversity (Aichi) (Marine Conservation Institute 2020).

Wallis and Futuna have no MPAs and no marine managed areas (Marine Conservation Institute 2020; UNEP-WCMC and IUCN 2020) in their EEZ of 258,270 km<sup>2</sup> (Harper *et al.* 2016)

“Knowledge is lacking to clarify the conservation status of species and the level of degradation of their habitat. [...] Wallis and Futuna’s total number of endemic species supposedly amounts to: 7 plants and 11 molluscs. The first signs of coastal erosion were observed in Wallis with the disappearance of some beaches and coconut grubbing. A significant rise in sea level could affect the traditional cultures of taro which occupies an important place in the economy of Wallis and Futuna. Finally, salt water infiltration into the water table is likely to put greater pressure on Wallis and Futuna’s already limited freshwater supplies, and to affect the local population” (BEST n.d.).

## Results and Discussion

The EEZ specific data of the reconstructions presented above for Polynesian island areas are available on the EEZ-specific webpages of the *Sea Around Us* ([www.searoundus.org](http://www.searoundus.org)). The domestic catches of the 9 Polynesian island countries and territories covered here (Figure 1A - due to the relatively small catches, the catches of Pitcairn Islands were excluded from the figure), are primarily small-scale subsistence and artisanal in nature (Figure 1B).



**Figure 1.** Domestic catches for Polynesia Islands (Cook Islands, French Polynesia, Niue, Samoa, Tonga, Tokelau, Tuvalu, and Wallis and Futuna) from 1950-2018 by A) EEZ, excluding Pitcairn Islands as catches were too small to be legible, and by B) fishing sector with the black dashed line indicating reported catch. All catches presented here exclude the large-scale pelagic catches covered in Coulter *et al.* (2020).

However, extensive industrial fisheries targeting large pelagic species by vessels flagged to (but not majority owned by) the Polynesian islands exist (Coulter *et al.* 2020), and local food security is largely provided through domestic small-scale fisheries. Overall per capita fresh seafood consumption is decreasing as alternative proteins become increasingly accessible – a change largely driven by imports (Charlton *et al.* 2016). Commercial small-scale (i.e., artisanal) catches have generally increased over the time period (Figure 1B). True domestic industrial fisheries are rare and small (Figure 1B), with the exception of French Polynesia, compared to the distant water fleet dominated industrial fisheries for large pelagic species addressed in Coulter *et al.* (2020) and that dominate total Pacific catches. Because most Polynesian island areas are resource poor, volcanic or low-lying coral atolls, they have a high dependence on marine resources and are particularly vulnerable to the changing climate (Cheung *et al.* 2013; Charlton *et al.* 2016; Barnett 2017; Cheng *et al.* 2017).

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