The untold fishing history of Timor-Leste

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Abstract

Timor-Leste is a small food insecure Asian country with 1.4 million inhabitants. Due to historical conflicts, Timor-Leste does not have resources to invest in fisheries and depends on constant international support until recent days. The country only has small-scale fisheries, which are characterised by small boats in coastal waters and fish, an important source of nutrients, can potentially be used to improve food security in the country. Timor-Leste only started reporting its catch to the Food and Agriculture Organization (FAO) after its independence in 1999; however, the reported catch represents mainly the artisanal catch (commercial), while the subsistence catch (non-commercial) is mostly unreported. Hence, Timor-Leste would largely benefit with more accurate time-series of the total catches by sector for effective fisheries management. In this study, a catch reconstruction was undertaken from 1950 to 2019 for Timor-Leste using reported catch data and secondary literature such as colonial reports, recent publications and direct expert input. The total estimated catch was based on the number of fishers and fisher catch rate throughout the time period. The results showed that approximately 235,000 tonnes of fish was caught in the 70-year period covered in this study, 60% of which were not reported to the FAO. Most of the underreported catches occurred before 1999. This catch reconstruction is a conservative estimate of the total catch in the Timorese waters, as it is based on conservative estimates of number of fishers and does not include foreign illegal fishing activities. Nevertheless, it represents a considerable improvement for the national catch statistics as it accounts for previously unreported components. Timor-Leste aims to improve its fisheries as it is fully supporting an international partner (WorldFish) to establish the first fishing monitoring program in the country. Despite this, the subsistence sector is under-represented in Timor-Leste and investments in this sector may potentially increase food security in the country.

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1. **Introduction**

Seafood is among the oldest food sources used by humankind (Marean et al., 2007). For a long time, it was believed to be an inexhaustible resource, leading to uncontrolled exploitation and overfishing (Coll et al., 2008). Currently, seafood is the most highly traded food commodity worldwide (FAO, 2018), and plays a vital role in human nutrition (Smith et al., 2010; Golden et al., 2016; Vianna et al., 2020b). This is particularly important for coastal regions, and island countries (Zeller et al., 2015; Hicks et al., 2019; Vianna et al., 2020a).

Timor-Leste is a small developing Asian country that has a serious problem with food security and malnutrition. Approximately 25% of the Timorese population is undernourished, and 50% of the children under five years old experience stunted growth as a result of nutrient deficiencies (von Grebmer et al., 2018). The country suffered substantial political and economic impacts due to historical conflicts, which has also impacted its domestic fishing sector (Alonso et al., 2012). As a result, the fishing sector in Timor-Leste is under-developed (FAO, 2009), and stronger support for this sector may represent a possible solution to increase domestic food security.

1.1. *Historical context*

Timor-Leste, also known as East-Timor, has been heavily affected by historical conflicts over the past decades. The country was under Portuguese colonial rule from 1769 until 1975 (Anonymous, 2020b). During this period, Portugal focused almost exclusively on the production and exportation of coffee and sandalwood (Anonymous, 2020b). Conflicts were present throughout the entire Portuguese colonial period, eventually leading to the first Timorese independence movement in 1975 (Anonymous, 2020b). Within days of independence from the Portuguese colonial rule, Timor-Leste was invaded and occupied by Indonesia, remaining under violent Indonesian rule until 1999, when the United Nations (UN) intervened (Anonymous, 2020b). In 2002, Timor-Leste was officially recognised as the Democratic Republic of Timor-Leste by the UN (Anonymous, 2020b).

None of the foreign colonial and subsequent rule transitions in Timor-Leste were peaceful, especially during the Indonesian occupation (1975 - 1999), which resulted in political and economic instability (Anonymous, 2020b). The first five years of Indonesian occupation led to a drastic decrease in the country's population, with estimated 100,000 to 250,000 deaths, or approximately a third of the national population (Anonymous, 2020b). The conflict with Indonesia for its independence in 1999 resulted in considerable destruction of the country's infrastructure and thousands of Timorese refugees fleeing to neighbouring countries (Beasley et al., 2005; Anonymous, 2020b). To date, Timor-Leste is still one of the poorest countries in Asia (Anonymous, 2020a), and requires ongoing international assistance (ADB, 2004; Beasley et al., 2005).

The historical conflicts had a substantial political and economic impact in Timor-Leste, also resulting in major impacts on their marine fisheries. In contrast to the Portuguese colonial power, Indonesia invested in Timor-Leste by building and expanding ports, importing motorised vessels and installing the country's first ice machine in the main port; however, these improvements benefited only Indonesia and Indonesian fishers (Alonso et al., 2012). During the transition to independence starting in 1999, Indonesia destroyed the machinery and around 80% of the fishing fleet, leaving Timor-Leste with approximately 400 small seaworthy vessels (Alonso et al., 2012).

1.2. *Seafood consumption*

Historically, the Timorese people are more reliant on agriculture than fisheries (FAO/WFP, 2003). Between November and March of each year, there is a gap between maize and rice harvest seasons, leading to a period of increased food insecurity across the country (FAO/WFP, 2003). Although the use of fish to improve food security in Timor-Leste has been suggested since the Portuguese colonial period (BGU, 1968), little investment was made at that time.

Due to the perishable nature of fish, fish consumption in Timor-Leste is limited by the inadequate distribution infrastructure and a lack of access to refrigeration, resulting in limited market availability (Steenbergen et al., 2019). In 2011, the average Timorese fish consumption rate of 6.1 kg/person/year consisted of 5.8 kg from marine fisheries and 0.3 kg from aquaculture production (AMSAT International, 2011). This consumption rate of marine fish is five times lower than of its neighbouring country Indonesia (FAO, 2014), and approximately three times lower than the global average of 20 kg/person/year (FAO, 2018). The consumption rates also vary within the country. The coastal communities benefit from easier access to fish compared to inland communities, resulting in average consumption rates of approximately 17 and 4 kg/person by coastal and inland communities, respectively (AMSAT International, 2011).

1.3. *Fisheries statistics*

Effective fisheries management requires accurate data and information about the fisheries of the country (Jacquet et al., 2010). Currently, all the country members of the UN annually report their fish catch data to the Food and Agriculture Organization (FAO); however, the reported catch is sometimes incomplete as some fishing sectors may be missing from the reported catch (Zeller et al., 2016). Therefore, catch reconstructions can complement the officially reported statistics with the best estimates of unreported catches, providing a more accurate reflection of each country's catch (Zeller et al., 2016). Globally, most of the underreported catch generally comes from the small-scale fisheries (Pauly, 2006; Zeller et al., 2006). The small-scale fisheries can be divided into artisanal (commercial), subsistence (non-commercial, for household consumption) and recreational (non-commercial, for pleasure) sectors. The catch from the artisanal sector is largely sold in the markets, although any catch not sold is often taken home for family consumption. Thus, artisanal and subsistence sectors are connected and often overlap (Zeller et al., 2015). The subsistence sector is commonly neglected and underreported (Pauly and Zeller, 2016) as it is mostly comprised of small non-motorised vessels or shore-based fishers dispersed along the coastline, which makes catch estimation difficult.

Timor-Leste started officially reporting marine fish catches to the FAO in 1999 after it became independent; however, for unknown reasons Timor-Leste stopped reporting to the FAO in 2009 (James Geehan, FAO Fisheries Statistician, pers. comm.). In accordance with the official FAO procedures (Garibaldi, 2012), the last reported catch from 1999, has been kept constant throughout the following years while awaiting update.

Due to a lack of resources, Timor-Leste does not have an official fisheries department for coordinating fisheries data collection. Thus, fishing information from the country is the result of international cooperation within the country. Timor-Leste is currently cooperating with WorldFish, which is an international research organisation that harnesses fisheries information to support the development of small-scale fishers to reduce hunger and enhance food security around the world (WorldFish, 2020b). In 2016, WorldFish developed a program called Automated Analytics System (PeskAAS) to monitor small-scale fisheries in Timor-Leste (Tilley and Wilkinson, 2020). The PeskAAS program has been gradually introduced and expanded countrywide over the last four years, and it is designed to collect fisheries data by interviewing fishers at the main landing sites of each district. The collected information is processed, quality checked and input into an online database system which is used to estimate the total catch countrywide (Tilley and Wilkinson, 2020; WorldFish, 2020a).

In order to ensure sustainable fisheries policy and maximise the economic and social benefits received from marine fisheries, historical and contemporary trends in fish catches can provide valuable insight to further inform policy management (Pauly et al., 2005). As the newest country of the 21st century, Timor-Leste does not have a historical baseline of its fisheries. This study aims to provide a comprehensive historical catch reconstruction for the domestic fisheries of Timor-Leste from 1950 to 2019. The resulting data can provide an important historical baseline and insights into trends in total catches, taxonomy, and fishing sectors over the last 70 years in Timorese waters. The results of this study can be used to inform policy decisions in support of sustainable management and encourage the development of the country's fisheries to enhance domestic food security.

2. **Material and Methods**

Timor-Leste is located on the eastern side of Timor Island, including the smaller islands of Atauro and Jaco as well as the Oecussi-Ambeno exclave on the western side of the Timor Island (Figure 1). Timor-Leste's Exclusive Economic Zone (EEZ) is approximately 77,000 km^2 (http://www.seaaroundus.org/data/#/eez/626) and is surrounded by the Indonesian EEZ, except to the South where it borders Australian waters.

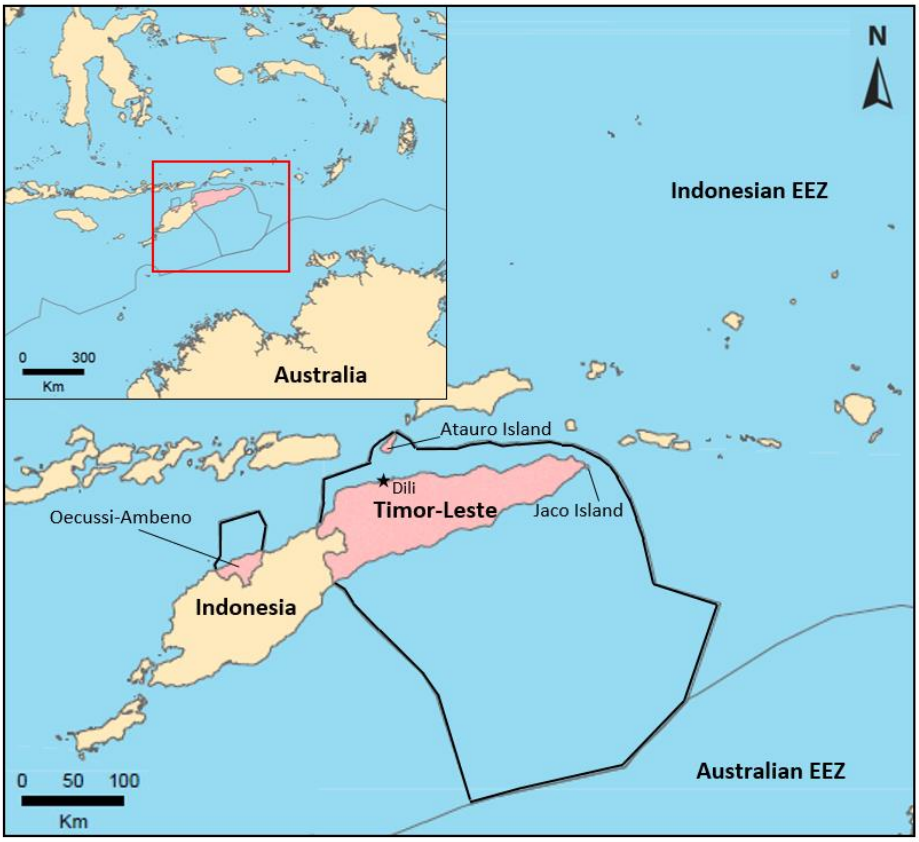

Figure 1. Timor-Leste (East-Timor) including the islands of Atauro and Jaco, and the exclave, Oecussi-Ambeno. Solid black lines defines the EEZ boundaries of Timor-Leste. Solid grey line defines the EEZ boundaries of Indonesia and Australia.

This methodology was adapted from Zeller et al. (2016). To undertake this reconstruction, primary and secondary data sources were used to determine the accuracy and to fill in data gaps in the catch data reported by the FAO on behalf of Timor-Leste (Appendix Table 1). The official catch statistics provided by the FAO on behalf of Timor-Leste was used as the reported baseline component for the catch reconstruction. Local Timorese and international reports, as well as fisheries experts, were used as secondary data sources. Portuguese colonial reports alongside grey literature sources were used to reconstruct catches during the period of Portuguese occupation (1950 - 1975). Indonesian fisheries experts were able to provide Indonesian catch data from Timor-Leste waters during the period of occupation (1975 - 1999). These secondary data and information sources were then used to differentiate between reported and unreported catches in the waters of the now declared Timor-Leste EEZ. Since most data sources provided data for a specific year and location, these data points were used as anchor-points for years with available information and raised countrywide. To generate the time-series estimates from the available data, linear interpolation was used between anchor-points to estimate catches for the years in which no information was found.

PeskAAS is also an important source of recent information, which was essential for this reconstruction. Since PeskAAS is a relatively new program, its methodology is still being refined and improved (Alexander Tilley, WorldFish, pers. comm.), resulting in large data divergence throughout the first years. Although there were data available from September/2016 until August/2020, only the data from 2019 were used for this study as it was the last full year of information and provided the most accurate report of country wide catches.

2.1. *Reported baseline*

Data reported by the FAO was used as the reported baseline used for this study, but the organisation only has Timorese fishery information from after the independence in 1999. Portugal did not hold much interest in the catch of the Timorese fishery as it was destined on supplying local market and household consumption and did not contribute to the Portuguese economy; therefore, Portugal did not make proper fishery assessments in Timor-Leste. Consequentially, Portugal never reported catch data from Timorese waters to the FAO during the period of occupation as catches were not considered substantial enough to be reported by Portuguese authorities (BGU, 1968).

The fisheries specialist Abdul Halim (pers. comm.) provided catch data in the Timorese waters from the Indonesian Fisheries Statistics, Ministry of Marine Affairs and Fisheries, between 1978 and 1997. It was assumed that Indonesia incorporated their catches from Timorese waters into the data they reported to the FAO during the occupational period. There was missing data from the Indonesian occupation period catch provided by A. Halim (pers. comm.) for the years 1976, 1977 and 1998. It was assumed that the catch data during these years was reported to the FAO like the previous information provided by A. Halim (pers. comm.); therefore, linear interpolations were made between these years. It was not possible to separate these catches from those reported by Indonesia to the FAO due to limited information. This catch data from the Indonesian occupation period was incorporated in the reported baseline as reported catch in this study.

2.2. *Anchor-points and estimate of the total catch*

A thorough analysis of all available data determined that the number of fishers was the best alternative data source to derive estimates of total catch independent from the official reported catches (Appendix Table 1). Anchor-points were set for the number of fishers and for fisher catch rate of each year with available information. Linear interpolations were used between anchor-points to estimate the number of fishers and fisher catch rate for the years with no available data. The total catch was estimated by multiplying the number of fishers by the fisher catch rate ($t \cdot fisher^{-1} \cdot year^{-1}$) throughout all the periods. The complete catch time-series estimate was classified by reporting status, i.e. reported and unreported, by fishing sector, i.e. artisanal and subsistence, and taxon. The unreported catch was estimated as the difference between the total estimated catch and the reported catch.

2.3. *Number of fishers*

2.3.1. Portuguese colonial rule (1950 - 1975)

The only data sources found for this period were from the official Portuguese colonial reports found in the Statistical Yearbook (Anuário Estatístico/ AE) and the Ultramar General Bulletin (Boletim Geral do Ultramar/ BGU). These reports provided data points predominantly in the last decade of Portuguese rule (Table 1). The Portuguese reports recorded the number of fishers in 1961 and between 1964 and 1973 (Appendix Table 1). In the last five years of data (1969 - 1973), there was a steep decline in the number of fishers reported in the Statistical Yearbook of Portugal that could not be explained as they did not occur alongside any notable events in the country. These five years of data were not used and the number of fishers from the remaining years (1961 - 1968) was averaged to obtain a single anchor-point for 1965. To estimate the number of fishers throughout the Portuguese colonial period, the proportion of fishers of the total population in 1965 was kept constant and extrapolated throughout the period from 1950 to 1975 based on population estimates. The calculated number of fishers was multiplied by three as the Portuguese colonial reports state that the number of fishers was underestimated and the real value was at least three times higher (BGU, 1968).

Table 1. Anchor-points of number of fishers, adjusted number of fishers and data source for the Portuguese colonial period (1950 - 1975). In bold, the anchor-points that were averaged and in italic, the anchor-points that were not used due to inconsistency.

Year	Source	Number of fishers	Adjusted number of fishers
1950	-	-	1161
1951	-	-	1174
1952	-	-	1188
1953	-	-	1203
1954	-	-	1220
1955	-	-	1238
1956	-	-	1256
1957	-	-	1276
1958	-	-	1297
1959	-	-	1318
1960	-	-	1341
1961	AE (1961)	**472**	1365
1962	-	**-**	1390
1963	-	**-**	1416
1964	AE (1965)	**333**	1443
1965	AE (1965)	**385**	1470
1966	AE (1966)	**240**	1497
1967	AE (1968)	**729**	1523
1968	AE (1968)	**780**	1550
1969	AE (1970)	*98*	1582
1970	AE (1970)	*116*	1620
1971	AE (1972)	*136*	1666
1972	AE (1972)	*138*	1720
1973	AE (1973)	*141*	1769
1974	-	-	1799
1975	-	-	1802

2.3.2. Indonesian occupation (1975 - 1999)

There was only one data source for this period. Pedersen and Arneberg (1999) provided the number of fishers for most of the years during the occupation period (1987 - 1997; Appendix Table 1). A linear interpolation was performed between the last year of the number of fishers estimated from the Portuguese colonial period (1975) and the first year from the Indonesian data (1987). The next linear interpolation was performed from the last year of Indonesian data (1997) to the next anchor point in 2001, which was after independence.

2.3.3. Post-independence (1999 - 2019)

After independence, there were more data sources reporting the number of fishers in the country, as Timor-Leste received international development support (ADB, 2004; Beasley et al., 2005), which conducted surveys recording the number of fishers in the country (Appendix Table 1). Minor gaps were present in these data. For some years with no available information, linear interpolation was used to estimate the number of fishers for years.

2.4. *Catch rate*

The Ultramar General Bulletin (BGU, 1968) recorded the catch rate per fisher as 0.5 t•fisher^{-1}•year^{-1} in 1968, which was used as the first anchor-point of fisher catch rate (Table 2). Since there was no fisher catch rate information available before 1968, this catch rate was held constant back to 1950. The fisher catch rate was linearly interpolated to the next catch rate anchor-point in 2004. Fisher catch rate was calculated as 1.05 t•fisher^{-1}•year^{-1} for 2003 based on the reported total catch and the number of fishers for the previous year (ADB, 2004). The PeskAAS program estimated the fisher catch rate for 2019 to be 0.77 t•fisher^{-1}•year^{-1} (A. Tilley, WorldFish, pers. comm.). The fisher catch rate was linearly interpolated between the catch rate anchor-points for the years of 1968, 2003 and 2019.

Table 2. Fishers catch rate ($t \cdot fisher^{-1} \cdot year^{-1}$) anchor-points, estimation methodology and data sources between the years 1950 and 2019.

Year	Catch rate ($t \cdot fisher^{-1} \cdot year^{-1}$)	Method	Source
1950 - 1968	-	1968 value held constant	-
1968	0.50	Anchor-point	BGU (1968)
1969 - 2002	-	Linear interpolation	-
2003	1.05	Anchor-point	ADB (2004)
2004 - 2018	-	Linear interpolation	-
2019	0.77	Anchor-point	A. Tilley (WorldFish, pers. comm.)

2.5. *Fishing sector disaggregation*

This study could not detect any evidence of recreational fishing in Timor-Leste, despite its growing importance globally (Freire et al., 2020). Most bycatch is taken home by the fishers for household consumption; therefore, there is no evidence of discarded catches in the country (A. Tilley, WorldFish, pers. comm.). There was no information regarding the proportion of artisanal and subsistence sectoral contribution towards the total catch data prior to Timor-Leste's independence. Only two sources had records of catches by fishing sector after Timorese independence, and these data were used for establishing two anchor-points for artisanal and subsistence catch proportions. The Asian Development Bank (ADB, 2004) recorded fishery catch data from motorised (reported as artisanal) and non-motorised vessels (reported as subsistence), and PeskAAS recorded the catch data collected from interviews with fishers at the main docking locations. Results from the interviews made by PeskAAS included the information about the end-use of catches, which were destined for sale (artisanal), personal consumption (subsistence) or a mixture of both (A. Tilley, WorldFish, pers. comm.). The catch not sold in the market is taken home for household consumption due to the limited market access (A. Tilley, WorldFish, pers. comm.). Since the proportion of fish sold was not available for the mixed category, it was treated as subsistence catch. The proportion of artisanal and subsistence catch was set as anchor-points for 2003 and 2019 (Table 3).

Due to the very limited information available during the Portuguese colonial period, it was assumed that catches during this time were not economically important to Portugal and thus, were likely contributed from the local subsistence fishing sector. The artisanal and subsistence proportions of total catch available during 2003 (the first available breakdown) were used to separate the sectors during the Portuguese colonial period as the infrastructure from the colonial period was similar to the end of the Indonesian occupation (Alonso et al., 2012). During the Indonesian occupation period in Timor-Leste, Indonesia had stronger fishing fleet in Timorese waters (Alonso et al., 2012), suggesting the that the majority of the catch was from the artisanal sector. For this period, the fishing sector breakdown was considered the same as the anchor-point in 2019 since the artisanal sector was dominant during the Indonesian occupation and recent years. Lastly, the proportion of artisanal and subsistence catch was linearly interpolated between 2003 and 2019.

Table 3. Artisanal and subsistence catch proportion anchor-points, methodology and source between the years of 1950 and 2019.

Year	Artisanal/Subsistence catches proportion (%)	Method	Source
1950 - 1975	39 / 61	Same proportion as 2003	-
1976 - 1999	65 / 35	Same proportion as 2019	-
2000 - 2002	39 / 61	Same proportion as 2003	-
2003	39 / 61	Anchor-point	ADB (2004)
2004	41 / 59	Linear interpolation	-
2005	42 / 58	Linear interpolation	-
2006	44 / 56	Linear interpolation	-
2007	46 / 54	Linear interpolation	-
2008	47 / 53	Linear interpolation	-
2009	49 / 51	Linear interpolation	-
2010	50 / 50	Linear interpolation	-
2011	52 / 48	Linear interpolation	-
2012	54 / 46	Linear interpolation	-
2013	55 / 45	Linear interpolation	-
2014	57 / 43	Linear interpolation	-
2015	58 / 42	Linear interpolation	-
2016	60 / 40	Linear interpolation	-
2017	62 / 38	Linear interpolation	-
2018	63 / 37	Linear interpolation	-
2019	65 / 35	Anchor-point	A. Tilley (WorldFish, pers. comm.)

2.6. *Taxonomic composition*

There were only two available data sources reporting the taxonomic information of the fish caught (Table 4). Due to major independence conflicts and the resulting socioeconomic and political changes, linear interpolations were not performed between the two datasets as different fishing fleets were fishing in the Timorese EEZ. As a result, linear interpolations would not accurately reflect the taxonomic composition from those years. Taxonomic information for the Indonesian occupation from 1978 to 1997 (A. Halim, pers. comm.) was not consistent throughout the whole period. As a result, the taxonomic composition data were adjusted to get the best conservative estimates. The data from 1978 to 1983 were not used due to poor taxonomic resolution in comparison to the remaining years. To establish taxonomic composition proportions for 1950 - 1983, the taxonomic composition proportions between the years of 1984 - 1991 were averaged; as the data after 1992 included a considerable increase in the landings of Scombridae. This family is commonly associated with industrialised fishing fleets from the Indonesian fishers in Timorese waters, which were not present in previous years. The taxonomic composition proportions from 1984 to 1997 were kept as anchor-points, and the taxonomic proportion from 1997 was kept constant until 1999 when Timor-Leste gained its independence. The 2019 taxonomic composition reported by PeskAAS was used for the years between 2000 and 2019.

Table 4. Taxonomic composition anchor-points, methodology and sources between the years of 1950 to 2019.

Year	Method	Source
1950 - 1983	Proportion of the averaged taxonomic composition between 1984 - 1991 carried backwards	-
1984 - 1997	Anchor-points	A. Halim (pers. comm.)
1998 - 1999	1997 trend carried forward	-
2000 - 2018	2019 trend carried backwards	-
2019	Anchor-point	A. Tilley (WorldFish, pers. comm.)

2.7. *Data reliability estimate*

The various datasets and assumptions used in this study had variable degrees of reliability, resulting in a range of “uncertainty” estimates around the reconstructed catch. This reliability was estimated based on the scoring method of Zeller et al. (2016), adapted from the IPCC methodology for estimating the reliability of estimates based on multiple or single sources (Mastrandrea et al., 2010; Appendix Table 2). The reliability scores given were between 1 and 4, with a score of 1 being considered the least reliable and 4 the most reliable. For each time period (1950 - 1975, 1976 - 1999, 2000 - 2019) and sector (artisanal and subsistence), a single score was derived by qualitatively evaluating the reliability and accuracy of the underlying data sources and assumptions (Appendix Table 3). The reliability scores and the associated "uncertainty" boundaries for each time-period and sector were applied to total reconstructed catches based on the catch-weighted averages of each sector and time period combined.

3. **Results**

3.1. *Reconstructed total catch*

The total reconstructed catch of Timor-Leste between 1950 and 2019 was slightly over 235,000 t (Figure 2). The total estimated catch was approximately 19,000 t for the Portuguese colonial period (1950 - 1975), 118,000 t for the Indonesian occupation period (1976 - 1998) and 98,000 t for the Timorese period (1999 - 2019). During the Indonesian occupation period, there was a rapid increase in catch to almost 8,700 t in 1997. Soon after, the total catch started to decrease to approximately 5,200 t in 2003. The total catch slowly increased for a few years to approximately 5,600 t in 2007 and declined until approximately 4,600 in 2010, remaining relatively stable in the following years.

The total catch reported by the FAO on behalf of Timor-Leste was 70,433 t between 1999 and 2019. In contrast, the total reconstructed catch for the same period was approximately 50% higher than the officially reported catch. The total reported catch before Timorese independence (1950 - 1998), in which catch was only reported during the Indonesian occupation period, was approximately 22,000 t. Most of the catch was unreported during the years before Timorese independence. Portugal did not report any catches made in Timorese waters to the FAO and all the catch during this period were classified as unreported. During the Indonesian occupation period, approximately 82% of the total estimated catch was unreported, while after independence, 32% of the total catch was classified as unreported (Appendix Table 4).

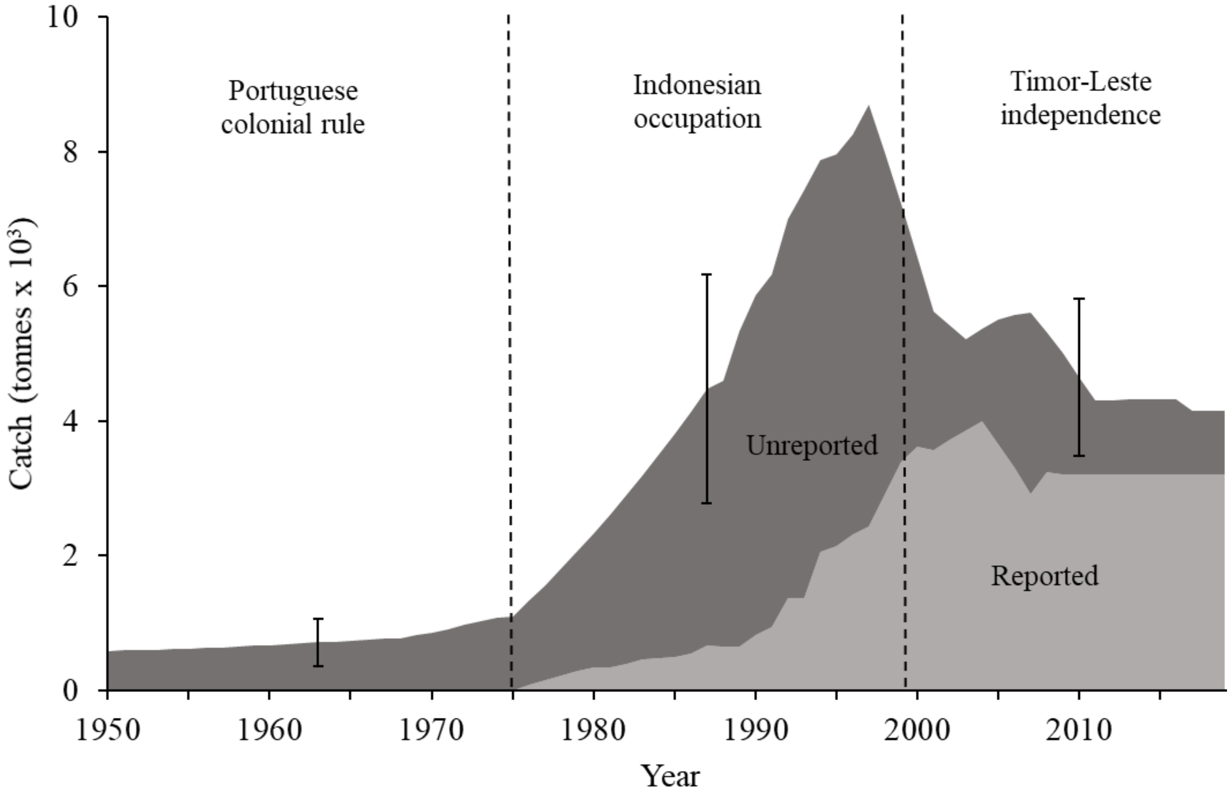

Figure 2. Reconstructed total catch (in tonnes x 10^3) in the Timorese EEZ from 1950 to 2019 by reporting status. Dashed vertical lines indicate each period. "Error bars" indicate the estimated ranges of "uncertainty" based on the data reliability scores.

Data from the Portuguese and Indonesian periods were deemed less reliable than data from recent years (Appendix Table 3). For the periods from 1950 to 1975 and 1976 to 1999, the derived uncertainties based on the reliability scores were ±50% and ±38%, respectively. For the most recent period from 2000 to 2019, the derived data reliability was of ±25%.

3.2. *Fishing sectors*

During each period, there were different trends for both fishing sectors (Figure 3). Overall, artisanal catches accounted for approximately 56% of the total estimated catch during the 70-year period. Subsistence catches represented 61% of the total estimated catch for the Portuguese period (1950 - 1975), while the artisanal (commercial) catch was dominant during the Indonesian occupational period (1975 - 1999), representing 65% of the total estimated catch. There was a decline in the commercial catch when the Indonesian occupation ended. The fishing sector proportions of the total catch gradually shifted between 2003 and 2019; where artisanal catch increased from 39% to 65%, while subsistence catch decreased from 61% to 35% (Appendix Table 4).

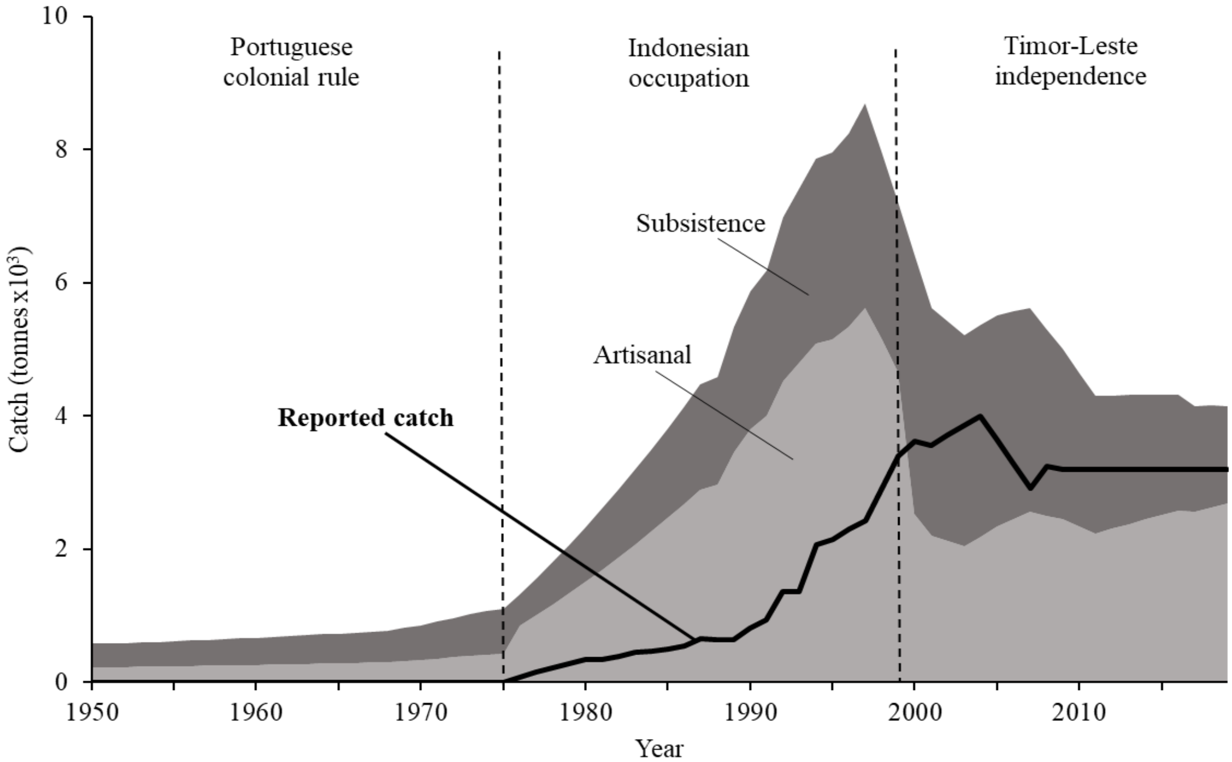

Figure 3. Reconstructed total catches (in tonnes x 10^3) in the Timorese EEZ by fishing sector from 1950 to 2019. Dashed vertical lines indicate each period while the overlaid continuous line indicates the reported catch (in tonnes x 10^3).

3.3. *Taxonomic disaggregation*

The catch composition displayed different trends before and after independence (Figure 4). Before independence, the most targeted fish families were Clupeidae (sardines), Carangidae (mackerels) and Scombridae (tunas). During the Indonesian occupation period, the family of Clupeidae, Carangidae and Scombridae represented an average of approximately 10%, 15% and 20%, of the total estimated catch respectively, while after independence, the catch of these fish families represented an average of approximately 17%, 9% and 12% of the total estimated catch, respectively. There was an increase in the catch of the families of Caesionidae (snappers) and Elopidae (herrings); which increased from 1% and 0% of the total catch, to 6% and 21%, respectively, after the independence.

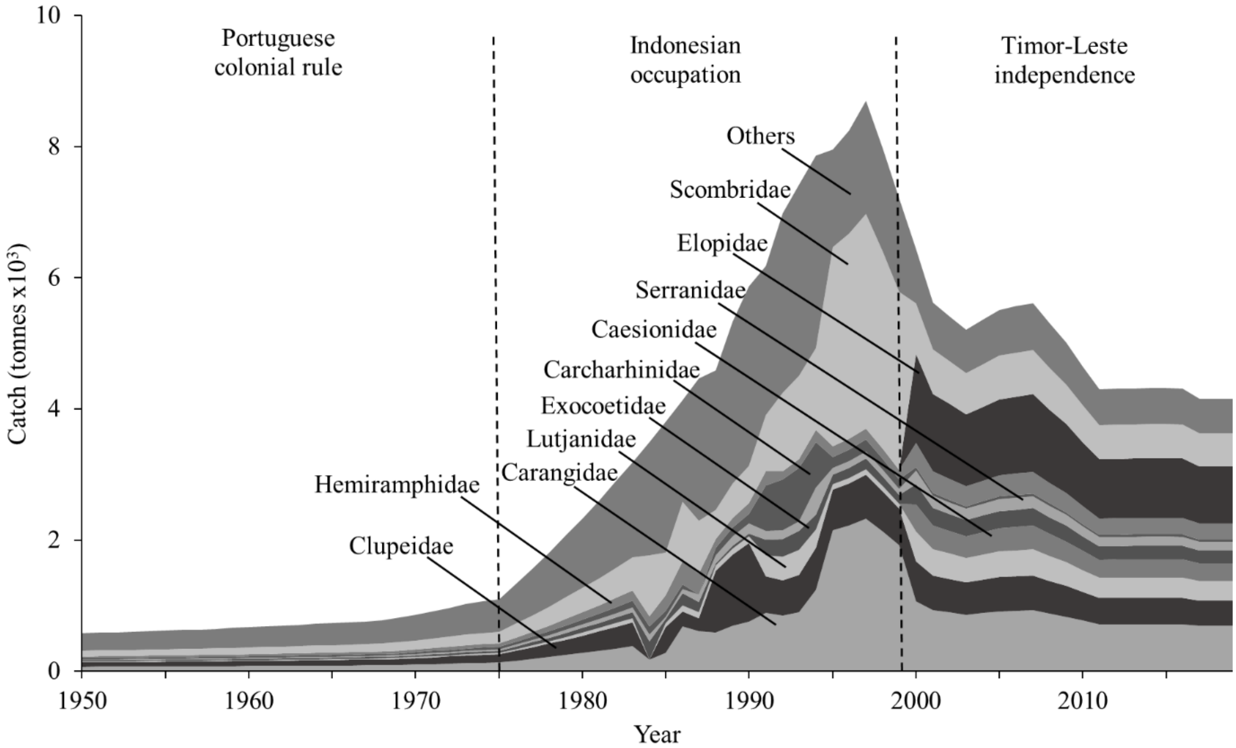

Figure 4. Taxonomic composition by family of the total reconstructed catch in the Timorese EEZ. Dashed vertical lines indicate periods.

4. Discussion

Historical conflicts greatly affected Timorese fisheries. The rapid increase in catches during the Indonesian occupation was mainly due to the Indonesian fishers operating in Timorese waters with more developed vessels; however, the fish caught was most likely sold in Indonesia, mainly benefitting Indonesia (Alonso et al., 2012). During the independence conflicts starting in 1997, Indonesian fishers left Timor-Leste, and 90% of the Timorese fishing fleet was destroyed (Alonso et al., 2012). Soon after, Timor-Leste received international assistance, including new vessels and fishing gear (ADB, 2004); which led to a smaller peak in catches (compared to the Indonesian period) over the next few years until 2007. There was a lack of maintenance capabilities in the country for the new vessels which could not be maintained (Bateman and Bergin, 2011), resulting in a decrease in fishing capacity and declining catch between 2006 and 2010. After this period, the estimated catches have remained relatively stable. A recent decline in the catch rate (A. Tilley, WorldFish, pers. comm.), might suggest that the fish stocks in the Timorese waters are being overfished. This could be due to foreign fishing, discussed later.

Timor-Leste only started reporting catch data to the FAO after its independence in 1999; however, the country has not reported their catch in recent years. During the period in which

Timor-Leste did not report to the FAO (2010 - 2019), the last reported value (3,199 t) was maintained constant by the FAO while the estimated catch for the same period was 36% higher. The Timorese fishing fleet consists mostly of non-motorised canoes, which limits the country's ability to fully use its marine resources (FAO, 2009). The lack of accurate data can potentially mislead management decisions (Jacquet et al., 2010), therefore, any growth in fisheries needs to be accompanied by management strategies to ensure it is sustainable as there are no current assessments regarding the health of the current fish stocks in the Timorese EEZ.

The estimated unreported catch represents 54% of the total catch from the Timor-Leste EEZ from 1950 to 2019. All the catch from the Portuguese period was unreported as it was not considered substantial for reporting (BGU, 1968). During the Indonesian occupation period, the unreported catch was almost four times the catch reported in Timorese waters by Indonesian fishers. This disparity between reported and unreported catches during these periods reflects the relative importance the Timorese fishery had to those countries. Since independence, reconstructed catches were approximately 50% higher than the tonnages reported by the FAO on behalf of Timor-Leste. The Timorese catch has been assessed more accurately in recent years due to the PeskAAS monitoring program; however, PeskAAS might still be missing some catches as subsistence catches are commonly distributed along the coastline and not at the main ports of the country, and thus fall outside the scope of PeskAAS assessments. While only PeskAAS data were used here to remain conservative, it is necessary to acknowledge that there are likely additional unreported fisheries information in the country. Further surveys should assess the Timorese coastline, and the relative importance of subsistence fishing to enable expanding the catch information countrywide to get more accurate estimates of the total national catch.

The contribution from different fishing sectors varied between each period depending on the priorities of different country's governance. During the Portuguese colonial period, subsistence catches represented 61% of the total catch. There was little investment in the Timorese fishery as most of the catch was destined for personal and household consumption of Timorese families and was not economically important to Portugal. In contrast, Indonesia actively invested in Timor-Leste fisheries, resulting in an increase in small-scale commercial catches. This increase in artisanal catches was mostly due to Indonesians fishers fishing in the Timorese waters. After the Indonesian fishers left Timor-Leste, the subsistence sector decreased to 35% of the total catch by 2019 as a result of a structural shift towards commercial operations due to increasing market access. This shift from subsistence-based fishing is similar to other islands countries in recent years in which small-scale catches are more commercialised throughout the years due to increased technological capabilities and market access (Vianna et al., 2020a). Although the general pattern is similar, the proportion of artisanal and subsistence catches differs when compared to small islands in the Pacific. Subsistence catch of Timor-Leste represents 50% of the total catch in 2010, which is less than the Pacific Island average of 69% in the same year (Zeller et al., 2015). As such, it is possible that subsistence catches are underrepresented in this reconstruction. Further management decisions should focus on improving the representation of subsistence fishing in Timor-Leste to increase domestic food security.

The taxonomic composition of catches was different across each period due to the interest of each ruling countries governance over the Timorese fisheries. A considerable difference in the taxonomic composition is evident between the Indonesian occupation period and Timorese independence. The methodology used to obtain the dataset provided by A. Halim (pers. comm.) was not available, while A. Tilley (WorldFish, pers. comm.) provided the methodology used for the most recent dataset from the program PeskAAS. Interviewers were at the main ports of each district collecting the catch information from the fishers at the moment of arrival. Due to limited information for earlier periods, the information from PeskAAS was assumed to be more accurate and reliable than the previous dataset. Thus, any differences in catches resulting from different methodologies could not be verified. The different data collection methodology may explain this difference between sources and the difference in reported targeted species caught for each period.

The proportion of the targeted fish species in the Timorese EEZ were also different during each period. The results show that Indonesian fishers were targeting more profitable fish families such as Carangidae, Scombridae and Clupeidae. Those fish families are commonly found in deeper waters (FishBase, 2020), suggesting that the Indonesian fishers had more developed fishing technology and capabilities, allowing them to fish in waters further from the Timorese shore; however, it is unlikely that the catch was destined to the Timorese population. The increase in catch of these species is consistent with taxonomic patterns in the same years in Indonesia’s domestic fisheries (Budimartono et al., 2015), providing evidence that this trend in catch was caused by the Indonesian fishers in Timorese waters. The results for the period before and after the Indonesian occupation (1975 - 1999) shows that the catch in the Timorese waters were mainly of Elopidae and Caesionidae and so likely came from coastal waters (FishBase, 2020). This suggests that the non-motorised Timorese fishing fleet is less developed than the Indonesian fleet. The Elopidae and Caesionidae catches, featured prominently in catch data after independence, might be included in the Indonesian catch composition dataset within the “others” category since they were likely usual Timorese catches and seemingly not economically important to Indonesia.

Timor-Leste suffers from illegal fishing in their waters as it has inadequate surveillance infrastructure to monitor and patrol within its EEZ (Pramod, 2017). There are reports of foreign vessels in the country’s waters during the Portuguese colonial period (BGU, 1968) and, in recent years, foreign vessels accessing the Timorese EEZ are mainly from Australia and Indonesia (Global Fishing Watch, 2018). Is likely that the presence of Indonesian vessels in Timor-Leste dates back to the occupation period and did not change after the Timorese independence. It is estimated that foreign vessels illegally catch up to 150,000 t of fish in the Timorese waters annually (Gusmão, 2020). Although the total estimated catch from Timor-Leste’s domestic fishery was approximately 4,200 t in the last year, the estimated sustainable catch of the Timorese EEZ is approximately 116,000 t annually (FAO, 2009). This suggests that when including foreign fishing, current catch volumes may be negatively impacting and even overfishing Timorese fish stocks, threatening long-term sustainability and economic and social benefits received from Timor-Leste’s marine fisheries. The foreign illegal fishing also influences the country economically; it is estimated at least US$36 million of potential profit are lost annually to illegal fishing (Bateman and Bergin, 2011). The lack of surveillance and enforcement infrastructure for policing the Timorese EEZ also encourages illegal fishing in Australian and Indonesian EEZ as it provides a “safe place” for the illegal vessels activity especially in the southern waters of the Timorese EEZ (Bateman and Bergin, 2011). Future management should consider investing in adequate surveillance and enforcement of the Timorese waters in order to tackle illegal fishing and guarantee the health of their fish stocks, so food and economic benefits remain in the country. Additionally, stock recovery plans should be prepared and put in practice in case stock assessments indicate overfishing in the Timorese waters.

4.1. *Data limitations*

There was no reported data from the FAO on behalf of Timor-Leste before the country’s independence (FAO, 2009), although there was fishing activity in the country long before. This sudden increase in the catch without retroactive correction is called the “presentist bias” (Zeller and Pauly, 2018). The present study addresses this issue in regard to Timor-Leste, filling the 50-year data gap and removing this bias, resulting in a more accurate time-series which can be further used for more precise policy managements directed towards food security and sustainability.

Insufficient resources is a limiting factor for fisheries data collection for developing countries (Pauly and Zeller, 2016), with Timor-Leste being no exception. Most of the data found in this study came from various international sources instead of domestic surveys. Each source used a different methodology for the conducted surveys, and not all of the methods could be verified. The most reliable information that could be used to estimate catch was the number of fishers, which formed a primary component for this reconstruction; however, a different method using alternative information resulted in a different estimate of the total catch. AMSAT International (2011) documented an annual marine fish consumption of 5.8 kg/person in Timor-Leste in 2011, which also included the consumption of canned fish, but it was not considered substantial. When applying this consumption rate to the total population for the same year, the estimated fish to feed the Timorese population would have been of approximately 6,300 t. This value is almost 50% higher than the reconstructed catch for the same year (4,295 t) inferring that there might be even more fish being caught in the Timorese EEZ and the reconstructed catch presented here might still be underestimating the total catch of Timor-Leste.

The difference between the estimated catch by the number of fishers and consumption rate might be related to the perceived definition of “fisher” by the Timorese population. Fisheries governance in Timor-Leste is mostly integrated with the agriculture sector. Many farmers are also part-time fishers as they fish for household consumption, but since it does not generate direct income, they do not identify themselves as fishers. Gleaning is characterised as the manual collection of fish and invertebrates in shallow intertidal areas exposed during low tides, mostly without the use of fishing vessels and gear (Chapman, 1987). Globally, gleaners are also usually not recognised as fishers as the activities are not considered economically important (Furkon and Ambo-Rappe, 2019). Gleaning occurs in all coastal districts of Timor-Leste and is mostly performed by women and children (Tilley et al., 2020). The catch can be sold in the markets but is usually destined for household consumption (Tilley et al., 2020). Is likely that the catch from part-time fishers and gleaners are not included in any dataset, although these fishing activities are well known to occur along the coastline of Timor-Leste (Tilley et al., 2020). The catch from part-time fishers and gleaners should be better evaluated as they contribute to the subsistence sector and provides an important contribution to food security, especially in isolated communities (Quinn and Davis, 1997; Beitl, 2011).

5. **Conclusion**

Timorese fish catches were severely overlooked and underreported before its independence in 1999, particularly during the Portuguese colonial period. Overall, the most underreported fishing sector is the subsistence sector although this is the sector that contributes the most for food security, especially in isolated communities. Timor-Leste has acknowledged the lack of infrastructure and resources, as it allows and fully supports the PeskAAS fishing monitoring program and expects to use this information to report to the FAO in the near future (A. Tilley, WorldFish, pers. comm.), demonstrating the reliability and importance of the data collected through this program. To address and correct the “presentist” bias, Timor-Leste should request a retroactive catch correction to the FAO for the period between 1999 and 2019; as well as requesting the addition of the catch data from 1950 to 1998 in which the country was under Portuguese and Indonesian governance, potentially using the data from this reconstruction as guidance.

Further research is needed to estimate the catch of part-time fishers and gleaners to provide a better estimate for subsistence catches. In addition, international cooperation is required to address and understand illegal fishing in Timor-Leste and the impact on Timorese fish stocks. This would enable the health of fish stocks in the Timorese EEZ to be assessed. Timor-Leste also needs to invest or be supported internationally in improving market access, especially to inland communities to expand access to fish and increase domestic fish consumption. This will incentivise development of the artisanal sector which would be essential for future policymaking to improve food security.

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Appendix

Appendix table 1. Number of fisher anchor-points used for reconstructing Timor-Leste's marine fisheries from 1950 to 2019 and its sources. Linear interpolations between anchor-points are not included. Number of fishers in italic were not used due to inconsistency and the number of fishers in bold are the anchor-points in which the numbers were averaged and set as one anchor-point for the year of 1965. Recorded catch found in literature and number of vessels and its respective sources.

Year	Number of fishers	Source	Recorded catch in literature (in tonnes)	Source	Number of vessels	Source
1950	-	-	8	AE (1950)	-	-
1951-1960	-	-	-	-	-	-
1961	**472**	AE (1961)	47	AE (1961)	133	AE (1961)
1962	**-**	-	121	BGU (1968)	-	-
1963	**-**	-	39	BGU (1968)	-	-
1964	**333**	AE (1965)	51	AE (1965)	87	AE (1965)
1965	**385**	AE (1965)	56	AE (1965)	95	AE (1965)
1966	**240**	AE (1966)	41	AE (1966)	140	AE (1966)
1967	**729**	AE (1968)	58	AE (1968)	-	-
1968	**780**	AE (1968)	70	AE (1968)	-	-
1969	*98*	AE (1970)	67	AE (1970)	102	AE (1970)
1970	*116*	AE (1970)	43	AE (1970)	-	-
1971	*136*	AE (1972)	32	AE (1972)	23	AE (1972)
1972	*138*	AE (1972)	19	AE (1972)	25	AE (1972)
1973	*141*	AE (1973)	37	AE (1973)	25	AE (1973)
1974-1977	-	-	-	-	-	-
1978	-	-	225	A. Halim (pers. comm.)	-	-
1979	-	-	-	-	-	-
1980	-	-	342	A. Halim (pers. comm.)	-	-
1981	-	-	345	A. Halim (pers. comm.)	-	-
1982	-	-	397	A. Halim (pers. comm.)	-	-
1983	-	-	453	A. Halim (pers. comm.)	-	-
1984	-	-	477	A. Halim (pers. comm.)	-	-
1985	-	-	494	A. Halim (pers. comm.)	-	-

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Year	Number of fishers	Source	Recorded catch in literature (in tonnes)	Source	Number of vessels	Source
1986	-	-	546	A. Halim (pers. comm.)	-	-
1987	5581	Pedersen and Arneberg (1999)	661	A. Halim (pers. comm.)	-	-
1988	5620	Pedersen and Arneberg (1999)	647	A. Halim (pers. comm.)	-	-
1989	6410	Pedersen and Arneberg (1999)	647	A. Halim (pers. comm.)	-	-
1990	6918	Pedersen and Arneberg (1999)	817	A. Halim (pers. comm.)	-	-
1991	7152	Pedersen and Arneberg (1999)	933	A. Halim (pers. comm.)	-	-
1992	7944	Pedersen and Arneberg (1999)	1365	A. Halim (pers. comm.)	-	-
1993	8284	Pedersen and Arneberg (1999)	1365	A. Halim (pers. comm.)	-	-
1994	8631	Pedersen and Arneberg (1999)	2062	A. Halim (pers. comm.)	-	-
1995	8580	Pedersen and Arneberg (1999)	2146	A. Halim (pers. comm.)	-	-
1996	8742	Pedersen and Arneberg (1999)	2307	A. Halim (pers. comm.)	-	-

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Year	Number of fishers	Source	Recorded catch in literature (in tonnes)	Source	Number of vessels	Source
1997	9066	Pedersen and Arneberg (1999)	2437	A. Halim (pers. comm.)	2027	Pedersen and Arneberg (1999)
1998	-	-	-	-		
1999	-	-	-	-	2187	McWilliams (2003)
2000	-	-	-	-		
2001	5500	McWilliams (2003)	-	-	400	Alonso et al. (2012)
2002	-	-	-	-		
2003	4940	ADB (2004)	2044	ADB (2004)	3061	ADB (2004)
2004	-	-	-	-	2230	FAO (2009)
2005	5415	ADB (2014b)	-	-	-	-
2006	-	-	-	-	-	-
2007	5718	ADB (2014a)	2192	ADB (2014a)	-	-
2008	-	-	3207	Sendall et al. (2016)	-	-
2009	5300	López-Angarita et al. (2019)	3066	ATSEA (2012)	2948	FAO (2009)
2010	-	-	3125	ADB (2014a)	4551	López-Angarita et al. (2019)
2011	4723	Alonso et al. (2012)	-	-	3016	Alonso et al. (2012)
2012	-	-	-	-	3113	Needham et al. (2013)
2013-2014	-	-	-	-	-	-
2015	-	-	-	-	3943	López-Angarita et al. (2019)

Appendix table 1. Number of fisher anchor-points used for reconstructing Timor-Leste's marine fisheries from 1950 to 2019 and its sources. Linear interpolations between anchor-points are not included. Number of fishers in italic were not used due to inconsistency and the number of fishers in bold are the anchor-points in which the numbers were averaged and set as one anchor-point for the year of 1965. Recorded catch found in literature and number of vessels and its respective sources.

Year	Number of fishers	Source	Recorded catch in literature (in tonnes)	Source	Number of vessels	Source
2016	5265	Sendall et al. (2016)	-	-	1300	Sendall et al. (2016)
2017	5185	López-Angarita et al. (2019)	1963	López-Angarita et al. (2019)	2237	López-Angarita et al. (2019)
2018-2019	-	-	-	-	-	-

Appendix Table 2. Data reliability scoring system for deriving approximate "uncertainty" bands for the quality and trust in the time series data of reconstructed catches (Adapted from Zeller et al., 2016).

Score	Reliability	± %	Corresponding IPCC criteria
4	Very High	10	High agreement and robust evidence between data sources
3	High	20	High agreement and medium evidence **or** medium agreement and robust evidence
2	Low	30	High agreement and limited evidence **or** medium agreement and medium evidence **or** low agreement and robust evidence
1	Very Low	50	Less than high agreement and less than robust evidence

Appendix Table 3. Reliability scores for each fishing sector and total reconstructed catches from 1950 to 2019. Reliability scores are based on catch weighted scores for sector sub-components across three time periods, following the approach of Zeller et al. (2016).

Time period	**Artisanal**		**Subsistence**		**Total reconstructed catch**	
	Score	± %	Score	± %	Catch-weighted average score	± %
1950 - 1975	1	50	1	50	1	50
1976 - 1999	2	30	1	30	1.6	38
2000 - 2019	3	20	3	20	2.5	25

Appendix Table 4. Reported, unreported, artisanal, subsistence and the total estimated catch (in tonnes) between 1950 and 2019.

Year	Reported (in tonnes)	Unreported (in tonnes)	Artisanal (in tonnes)	Subsistence (in tonnes)	Total catch (in tonnes)
1950	0	581	228	353	581
1951	0	587	231	356	587
1952	0	594	233	361	594
1953	0	602	236	365	602
1954	0	610	240	370	610
1955	0	619	243	376	619
1956	0	628	247	381	628
1957	0	638	251	387	638
1958	0	648	255	394	648
1959	0	659	259	400	659
1960	0	671	263	407	671
1961	0	683	268	414	683
1962	0	695	273	422	695
1963	0	708	278	430	708
1964	0	721	283	438	721
1965	0	735	289	446	735
1966	0	748	294	455	748
1967	0	761	299	462	761
1968	0	775	304	471	775
1969	0	816	321	496	816
1970	0	861	338	523	861

Appendix Table 4. Reported, unreported, artisanal, subsistence and the total estimated catch (in tonnes) between 1950 and 2019.

Year	Reported (in tonnes)	Unreported (in tonnes)	Artisanal (in tonnes)	Subsistence (in tonnes)	Total catch (in tonnes)
1971	0	912	358	554	912
1972	0	969	380	588	969
1973	0	1024	402	622	1024
1974	0	1070	420	650	1070
1975	0	1100	432	668	1100
1976	75	1251	859	468	1326
1977	150	1412	1011	551	1562
1978	225	1583	1170	638	1808
1979	284	1780	1336	728	2064
1980	342	1988	1508	822	2330
1981	345	2260	1686	919	2605
1982	397	2494	1871	1020	2891
1983	453	2734	2063	1124	3187
1984	477	3015	2260	1232	3492
1985	494	3314	2465	1343	3808
1986	546	3587	2675	1458	4133
1987	661	3808	2893	1576	4469
1988	647	3942	2970	1619	4589
1989	647	4689	3454	1882	5336
1990	817	5051	3798	2070	5868
1991	933	5247	4000	2180	6180
1992	1365	5625	4524	2466	6990
1993	1365	6055	4803	2617	7420
1994	2062	5806	5092	2775	7868
1995	2146	5811	5150	2807	7957
1996	2307	5939	5337	2909	8246
1997	2437	6258	5628	3067	8695
1998	2918	5051	5158	2811	7969
1999	3399	3816	4670	2545	7215
2000	3619	2814	2526	3907	6433

Appendix Table 4. Reported, unreported, artisanal, subsistence and the total estimated catch (in tonnes) between 1950 and 2019.

Year	Reported (in tonnes)	Unreported (in tonnes)	Artisanal (in tonnes)	Subsistence (in tonnes)	Total catch (in tonnes)
2001	3559	2064	2208	3415	5623
2002	3719	1700	2128	3291	5419
2003	3849	1358	2045	3162	5207
2004	3999	1365	2192	3172	5364
2005	3649	1863	2340	3172	5512
2006	3299	2266	2451	3114	5565
2007	2910	2704	2562	3052	5614
2008	3242	2067	2507	2802	5309
2009	3199	1813	2447	2565	5012
2010	3199	1450	2343	2305	4649
2011	3199	1097	2234	2062	4296
2012	3199	1108	2308	1999	4307
2013	3199	1115	2381	1934	4314
2014	3199	1119	2451	1867	4318
2015	3199	1118	2520	1798	4317
2016	3199	1114	2586	1727	4313
2017	3199	955	2556	1597	4154
2018	3199	956	2624	1532	4155
2019	3199	954	2688	1465	4153