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MATURITY MEASUREMENT ON BIGEYE SCAD (*Selar crumenophthalmus* BLOCH 1793) TO INDICATE OVERFISHING

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ABSTRACT

Bigeye scad (*Selar crumenophthalmus*) is one of the small pelagic economical species from the family of Carangidae. The annual landing of Carangids in Ambon Island sharply dropped in 2018. Meanwhile, demand for these fish has increased following the local population growth. Was the reduction of fish products showing an indication of overfishing? To answer this, we measured the maturity of bigeye scad caught in Ambon waters during east monsoon (May to July 2019 and March to June 2020), including the length-frequency distribution. We found that the minimum size was 5 cm, the maximum (L_{max}) was 23 cm, and the optimum length (L_{opt}) was 18.7 cm. The estimated length of first maturity (L_m) of bigeye scad was 18.3 cm. This study showed that the optimum length was slightly longer than maturity length. Less than 30% of the catch of bigeye scad was immature and indicated a small probability of recruitment overfishing. Arround 57% of megaspawner found during this study showed more robust broodstocks to produce survival larvae into the population. The possibility of overfishing is relatively low for the bigeye scad fishery during the east monsoon, except for the reduction in the maturity size should be concerned.

Keywords: Bigeye Scad; Maturity length; Maximum Length; Optimum size; Overfishing

INTRODUCTION

Bigeyes (*Selar crumenophthalmus* BLOCH 1793) is a small-sized species from the Carangids and the most species found among other Scads in Ambon waters. The adult fish prefers clear ocean water and is distributed from islands to neritic waters (Froese & Pauly, 2012). Meanwhile, the juvenile is frequently found in estuarine waters (Hutubessy, 2001). As pelagic species, these fish swim in groups of hundreds to thousands from coastal waters to a depth of 80 m. Generally, bigeye scad can reach a length of 30 cm, but the common size of the catch is around 20 cm total length. The main food habit of bigeye scad is plankton and benthic invertebrates (Matsunuma *et al.*, 2011). Juveniles mostly eat crustaceans (Euphausiids, Decapoda), while the adults are active predators for fish larvae and juveniles (Roos *et al.*, 2007). The fish are active during the night for food and spawning (Widodo, *et al.,* 1993).

The exploitation of scad resources (*Selar spp*) in Maluku has been performed for decades, and it tends to increase (Hiariey, 2009; Matakupan & Tuapetel, 2017) to support local consumption in the island. High demand for this fish is initiated by the relatively affordable price (Laluraa *et al.*, 2014) and its high nutrient content (Hidayat, 2005; Nurhayati *et al.*, 2007). Bigeye scad is commonly caught using purse seine, lift net, drift gillnet, and hand line (Sangaji *et al.*, 2016) that is more often complemented by fish aggregation devices (locally called as *rumpon*) and lights. As a nocturnal animal (Widodo *et al.*, 1993) and composed in huge schoolings, bigeye scad is captured in large numbers. The fishing ground is almost evenly spread around Ambon Island (Baskoro *et al.*, 2006; Hiariey, 2009; Nanlohy, 2013). Intensive fishing on bigeye scad around Ambon Island increased concern on the higher landing that would be impacted to risk of depletion. Fisheries statistics of Ambon City reported a significant drop in the landing of trevallies in 2018 following series landing volume which tend to increase gradually since 2007 (BPS Kota Ambon, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019). This reduction was continued by no recorded data of catch in 2019 and 2020 (BPS Kota Ambon, 2020, 2021). The reduction in catch with increased in effort has resulted in a decline in catch-

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per-unit effort, suggesting an occurrence of overfishing that requires a serious monitoring for future fisheries management issues.

Since maturity size is one of the critical parameters in life-history parameters, fishing mortality affects the reproduction pattern of fish. Early maturity as the impact of selective fishing has been reported elsewhere (Robertson *et al.,* 2005; Babcock *et al.*, 2013; Landi *et al.,* 2015). In this study, the size maturity of bigeye scad (*Selar crumenophthalmus*) was measured as an indicator of overfishing. Studies on this have been conducted in several waters for decades. Kawamoto (1973) reviewed the biology reproduction of bigeye scad in Hawaii and was continued (Clarke & Privitera, 1995); while Iwai *et al.*, 1996) focused on spawning. Ross *et al. (2007)* studied the growth and reproduction of bigeye scad from the Reunion Island ship, southeast of the Indian Ocean. Reproduction aspect and length-weight relation of bigeye scad (*Selar crumenophthalmus*) from Bangaa Faru, Maldives, was also evaluated (Fadzly *et al.,* 2017) following the statement of overfishing on the bigeye scad fishery (Adeeb *et al.*, 2014). In 2015, the population dynamic of bigeye scad from India was studied (Panda *et al.*, 2016). In Indonesia, the analysis of the frequency of bigeye scad was observed (Sadhotomo & Atmadja, 1985). After more than two decades of break, bigeye scad was overlooked again on the biological aspect (Sangadji *et al.,* 2014) and on fish reproductive biology (Chodrijah & Faizah, 2019; Fauzi *et al.,* 2018; Lakotany, 2019). Unfortunately, a study focusing on its maturity sizes indicating overfishing has been less accomplished.

This study aimed to evaluate the impact of bigeye scad fishery around Ambon Island through maturity measurement. The maturity stage and first maturity size will be assessed for estimating the optimum length of the catch. Indications of overfishing followed criteria suggested by Froese (2004) will be analyzed and discussed for sustainable fisheries management.

MATERIALS AND METHODS

Data collection

Fish were collected at several fish landings around Ambon Island during the east monsoon (Figure 1), May to July 2019 and March to June 2020. In Ambon, bigeye scads were most captured by purse seine (43%), also other gears such as gillnets (27%), lift nets (11%), beach seine (3%), hand lines (13%), and other gears (3%) (DKP Provinsi Maluku, 2012). The total length (cm) and weight (g) were measured by dissecting the body cavity. Gonadal maturity stages were determined following Effendie (1997) and sorted by sampling months.

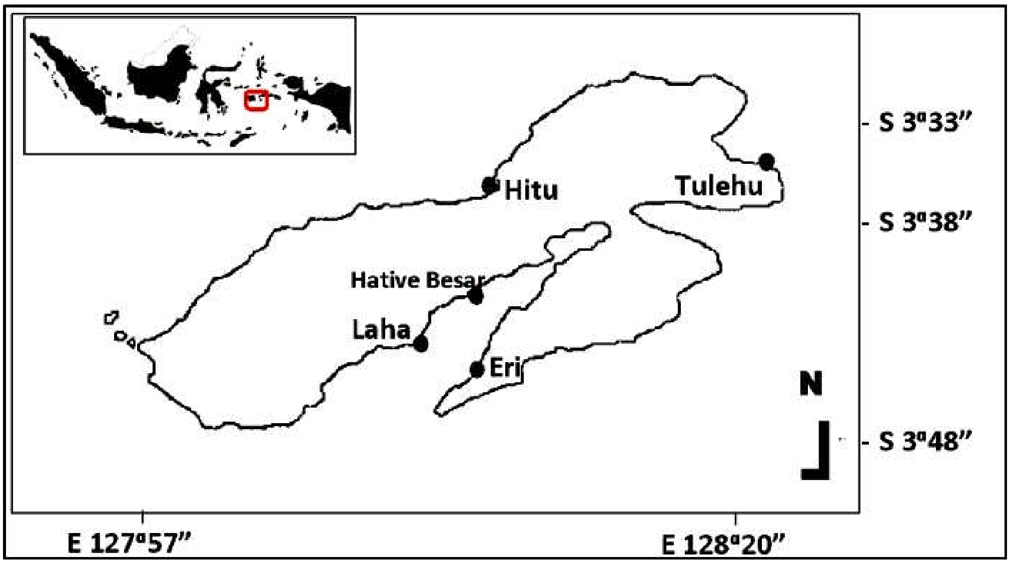

Figure 1. Ambon Island, Maluku Province, Indonesia, and the location of fish landings for bigeye scad (*Selar crumenophthalmus*).

Data Analyses

Maturity was determined based on macroscopic appearance of gonads. Fish with maturity stages I and II are categorized as immature and stages III, IV, and V as mature. Estimation maturity size is calculated based on the proportion of adult fish. The logistic curve may fit the proportion (*P*) of mature individuals by total length (*L*), as follows:

$$P = 1/\left(1 + \exp\exp\left[-r\left(L - L_m\right)\right]\right) \quad \text{(1)}$$

With parameter r is the slope of the curve and L_m is the mean maturity length, which is linearly transformed between the length and its proportion of maturity (King, 2013). After the maturity size (L_m) is obtained, the optimum length is estimated using the following equation (Froese & Binohlan, 2000):

$$Log_{10}L_{opt} = 1.053 * Log_{10}L_m - 0.0565 \quad .... (2)$$

Overfishing Indication

Two components of overfishing (Murawski, 2000): (1) recruitment overfishing: diminishing ability of fish to reproduce, and (2) growth overfishing: catching the fish before reaching the potential growth, are simple to be understood. Froese (2004) proposed three simple indicators to assess the status and trend in the most effective fisheries:

- Indicator 1: 'Let them spawn'. All targets (100%) should have spawned at least once before they were caught = P_{mat}
- Indicator 2: 'Let them grow'. The proportion (%) of targets caught at the optimum length (between $0.9*L_{opt}$ and $1.1*L_{opt}$) = P_{opt}
- Indicator 3: 'Let mega-spawner live'. More than 20% of targets is larger than the optimum size = P_{mega}

RESULTS AND DISCUSSION

Results

BPS Kota Ambon (2010-2018) showed that the catch of trevallies fisheries landed in Ambon Island in 2007-2017 increased almost two-fold from 86.2 to 152.1 tonnes (see Appendix A). The decline of the trevallies, which was 31.1 ton in 2018 and followed by no catch data recorded for 2019 and 2020, can be interpreted as depletion stock of trevallies (Heazle & Butcher, 2007). However, ntil 2014, the utilization of trevallies in Ambon was below the potential sustainability (3789 ton/year) (Matakupan & Tuapetel, 2017). Meanwhile, the actual condition of small pelagic fisheries in Maluku was reported as over-exploited (Bawole & Apituley, 2011). herefore, an evaluation should be assessed to understand the real status of trevally fishery. These two later studies were analysed based mainly on catch-per-unit-effort (CPUE) data. Since the use of CPUE data to evaluate the status of stock is considered inappropriate (Maunder *et al*., 2006), length-based method (Froese, 2004; Babcock *et al*., 2013) was chosen to assess the fisheries status.

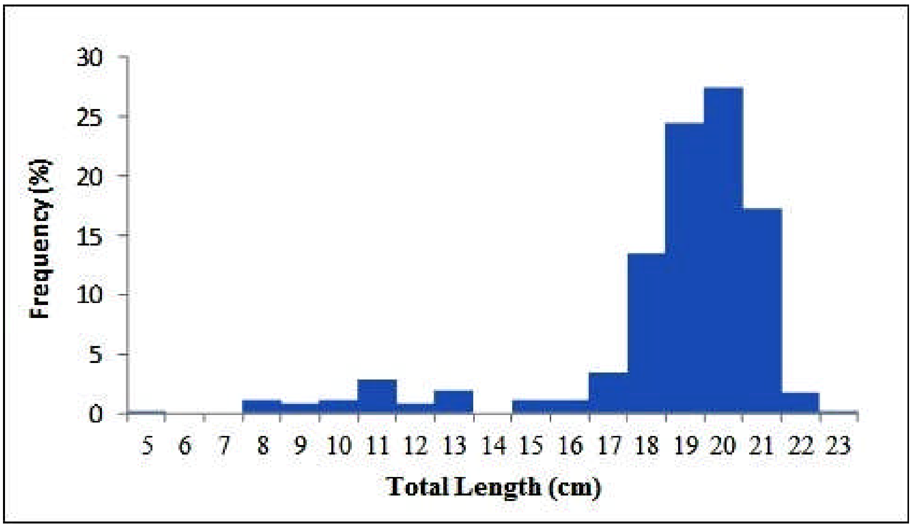

Figure 2. The length distribution of bigeye scad (*Selar crumenophthalmus*) sampled from Ambon waters.

Length data were collected in 24 days during May to July 2019 and March to June 2020 (east monsoon). A total of 594 individuals of bigeye scad (*Selar crumenophthalmus*) were identified for the sexual maturity stages. Female fish samples was 39.2% of the total samples, the male was 43.2%, and unidentified sex was 17.5%.

The length distribution of the sampled fish (Figure. 2) showed positive skewness, meaning more larger fish than small size was captured. The modus' abundant length ranged from 19 cm to 20 cm. During this study, catch assemblage by gears was not organized, and all samples were combined. Consequently, the samples consisted of fish larger than 14 cm. Fishing practices to catch bigeye scad around Ambon Island was recently dominated by purse seines compared to gillnets and lift nets. Although the mesh size of the bund part is 1 inch (Latar, 2013; Lerebulan, 2019), since fish aggregation devices (*rumpon*) and light commonly employed during the practice, purse seine is more strategic to produce larger fish. The mesh size of gillnet to catch small pelagic fish around Ambon Island is commonly 2 inches (Matrutty *et al.*, 2019), but bigeye scad is not the specific target (Setiawati *et al.*, 2015) due to its infrequent occurrence. Among other small pelagic fishes, such as Indian mackerel (*Rastrelliger spp*), anchovies (*Stolephorus spp*), mackerel Scad (*Decapterus spp*), and mackerel tuna (*Euthynnus affinis*), the proportion of *Selar spp* ranged from 4 to 15% depending on the seasons of each species (BPS Kota Ambon, 2004-2011).

In this study, only mature female fish data were measured in the analysis. Male fish data were exclusive because the male reproductive activity is adapted by social status (Danylchuk & Tonn, 2001). Female fish of 233 individuals were analyzed, with 103 individuals from 2019 and 130 individuals from 2020. The monthly distribution of maturity stages of female bigeye scad (Fig. 3) signified that monthly spawning is the reproduction strategy of bigeye scad to maintain the population. The 2019 samples showed that mature females were found in May, while only immature females existed in June and July. Compared to the 2020 data, adult females were sampled in March, June, and July but not in April due to the missed sampling on mature females. Based on those limited series data, it is estimated that bigeye scad (*Selar crumenophthalmus*) spawns every month during the east monsoon. During the rainy season, June to August, nutrient abundantly flows to the ocean due to upwelling process in the Banda Sea (Ikhsani *et al.*, 2016), provided nourishment for the young generation.

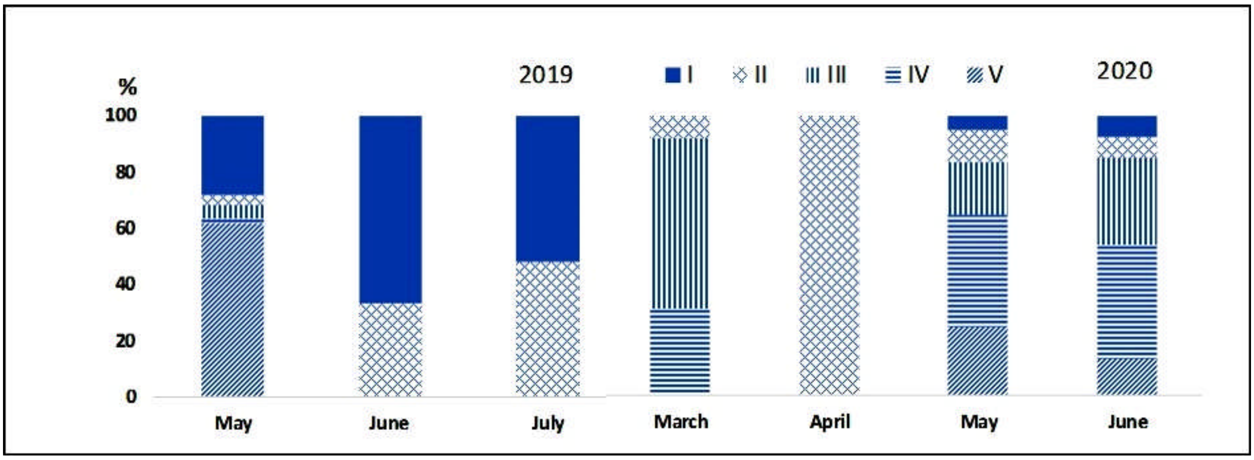

Figure 3. Monthly distribution of maturity stages of bigeye scad (*Selar crumenophthalmus*) females.

Discussion

Maturity size is one of the life history parameters that is extremely important in the fisheries management of exploited stocks (Sharpe & Hendry, 2009). Reduction in maturity size indicates intense selection pressure on fish, such as selective fishing pressure, that has been detected (Jennings & Kaiser, 1998; Enberg *et al.*, 2012; Pukk *et al.*, 2013). The size at sexual maturity of bigeye scad decreased from 20.1 cmTL in 2019 to 18.3 cmTLin 2020. The logistic curves describing the relationship between years and the proportion of 50% maturity (Fig. 4) indicated the decreasing maturity sizes. Increased selective fishing pressure generally tends to affect the size distribution of the adult stock recruited to a fishery by reducing the proportion of large individuals. Since each fishing gear contributes a particular level of selectivity that changes the life history of fish (Liang *et al.*, 2014), multigear strategy used to balance the exploitation has been proposed to be applied (Law *et al.*, 2012; Hutubessy & Mosse, 2015; Law *et al.*, 2016).

Based on the last maturity size (18.3 cmTL), the determined optimum length is 18.7 cm. To assess the sustainability of a fishery, Froese (2004) suggested three length-based indicators: (1) P_{mat}, the fraction of the catch that is above the length at maturity (L_{mat}), (2) P_{opt}, the fraction of the catch that is within ±10% of the optimal length of harvest (L_{opt}), and (3) P_{mega}, the fraction of fish that are more than 10% larger than L_{opt} ("mega-spawners"). The bigeye scad fishery in Ambon performed: (1) P_{mat} is 70.5%, (2) P_{opt} is 78.6%, and (3) P_{mega} is 56.9% (Fig. 5). To avoid recruitment overfishing, Froese (2004) suggested that the fraction of mature fish in the catch should be high, preferably 100%, so that each fish has a chance to spawn at least once before being harvested. This means that the bigeye scad fishery produced a 29.5% probability of recruitment overfishing. To prevent growth overfishing, all or most of the fish caught should be within 10% of the optimal length of harvest (*Lopt*), which is the length at which the biomass of fish in a year-class is maximized. Again, the bigeye scad fishery contributed 21.4% to growth overfishing. Where possible, maximum size limits to avoid capturing any of the mega-spawners would be appropriate because large fish is a critical source of fecundity (Berkeley *et al*., 2004). In the absence of a maximum size limit, the fraction of mega-spawners in the catch should be more significant than 20% (Froese, 2004). For the last fraction, the catch of bigeye scad kept almost 57% of robust broodstock.

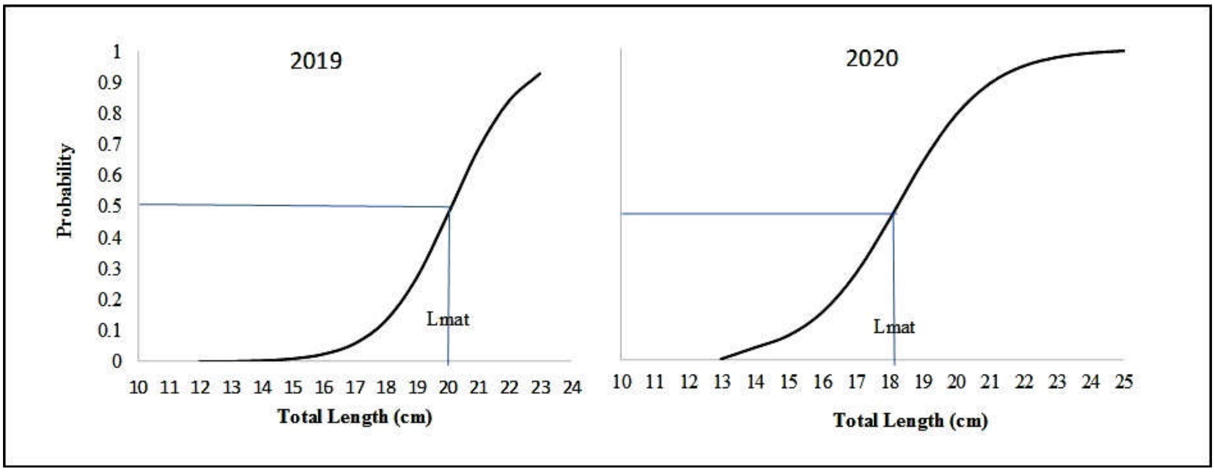

Figure 4. Logistic curves for estimation of size at the first sexual maturity of *Selar crumenophthalmus* around Ambon Island.

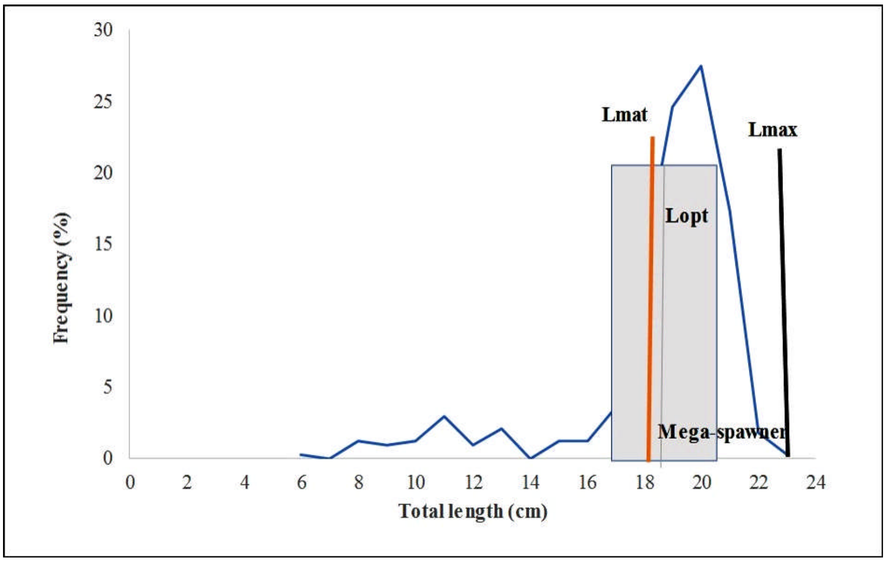

Figure 5. The length–frequency data of bigeye scad collected during east monsoon from 2019 to 2020 in Ambon Island, where L_{mat} indicates the length at first maturity, L_{opt} indicates the length range where maximum yield could be obtained. L_{max} is the maximum size reached during that time.

The stock of bigeye scad was considered as overexploited by Adeeb *et al.* (2014) and Panda *et al.*, (2016). Even though it was reported as under-exploited stock by Matakupan and Tuapetel (2017), significantly declined catch in 2018 should be concerned. This study showed occurrence of overfishing in bigeye scad stock, categorised as recruitment overfishing and growth overfishing. The stock of bigeye scad can be regenerated by setting the first maturity size as minimum catch size captured and the optimum size plus 10% as maximum catch size. This means that a specific gear that captures those intervals of lengths (from minimum to maximum catch size) can be ideally used to sustain the fishery, because protecting the juveniles and mega-spawners will provide successful spawning and, therefore, recruitment stock and spawning biomass may sustain.

CONCLUSIONS

It is concluded that the indication of overfishing for the fishery of bigeye scad is low. The possibility of recruitment overfishing is less than 30%, and growth overfishing is less than 22%. *Selar crumenophthalmus* is a short life span or fast-growing species and has a continued spawning strategy, and the vulnerability index to capture activity ranges from low to moderate.

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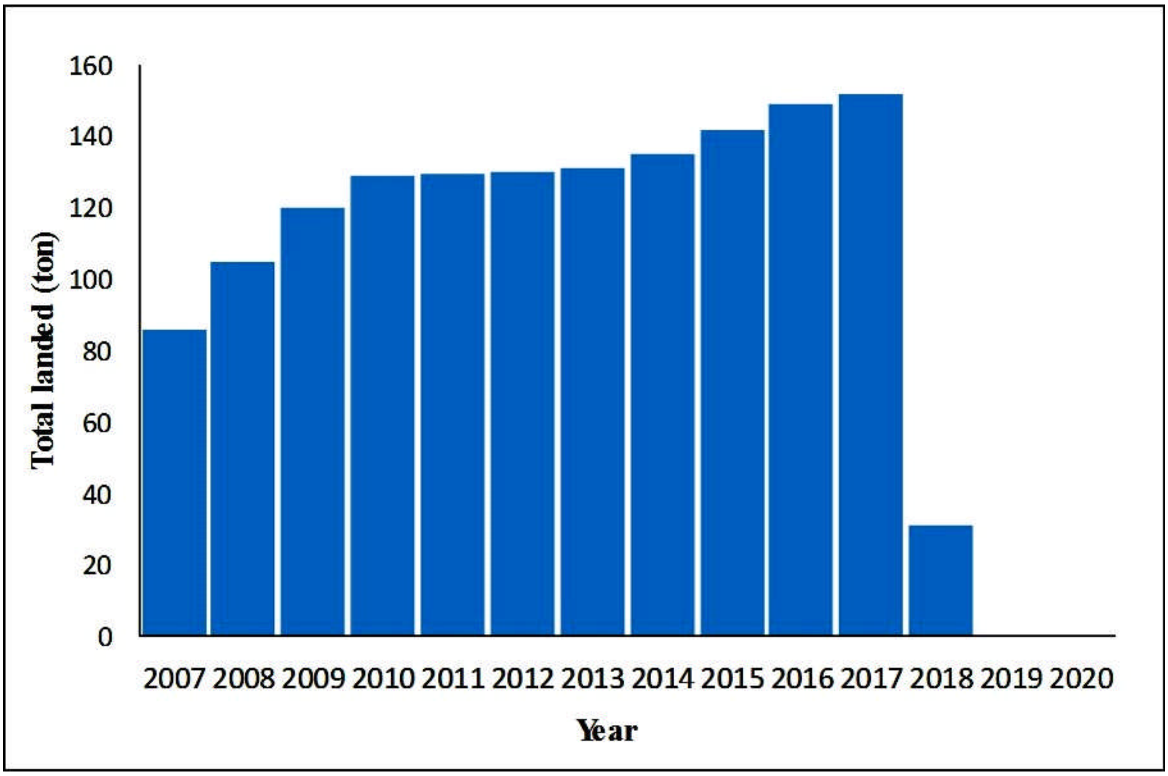

Annual landing of trevallies (*Selar spp) from* 2007 – 2020 (Source: BPS Kota Ambon 2008-2018)