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Status of yellowfin tuna (*Thunnus albacares*) handlines fisheries based on length of maturity

Status of yellowfin tuna (*Thunnus albacares*) handlines fisheries based on length of maturity

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Abstract. Yellowfin tuna (*Thunnus albacares*) is one of large pelagic potential and economical species from the family of Scombridae. Production of yellowfin tuna from several potential fisheries areas (WPP) in Maluku was reported in the condition of overfishing. Meanwhile, tuna fisheries have been the potential resource for export demand. It is therefore, the status of yellowfin tuna fisheries should be monitored regularly following the regulation of PERMEN KP no 4 year 2017. The aims of this study were to measure the size of maturity of yellowfin tuna during October to December 2018 and utilize the empirical relationship to estimate optimum length and maximum length reached during this period. Observation on yellowfin tuna was conducted by joining local fishers from Kawa village, West Seram Regency. Handlines were occupied to catch yellowfin tuna around Banda Sea. From the catch sizes ranged from was 34cm to 168cm, the length maturity (L_m) of yellowfin tuna is 107.2cm of total length for female and 112.9cm for male. From the empirical relationship, the optimum length (L_{opt}) of yellowfin tuna during October-December 2018 was 120.5cm and maximum length (L_{max}) was 181.4cm. This study showed that 90% of yellowfin catch was immature which indicated a recruitment overfishing. Only 2.4% of mega-spawners were caught during this study and indicated growth overfishing. Indication of an overfishing of the yellowfin tuna fishery contradicted to larger size of first maturity found. This contrary is discussed and balance fishing strategy is proposed as the idea to maintain the population of yellowfin tuna.

1. Introduction
Yellowfin tuna (*Thunnus albacares*), member of Scombridae family, is known as high commodity of fish in the global fisheries since the nineteenth century [1]. Highly migratory species, worldwide distribution in tropical and subtropical seas, but not in the Mediterranean sea [2]. Since 1972, Yellowfin tuna catch has continued to increase in Atlantic Ocean [3]. The catch of yellowfin tuna in the Indian Ocean increased rapidly in the 1990s and Indonesia contributed about 40,000 tonnes in the 2000s [4]. Since the 1950s, yellowfin tuna was the second biggest catch after skipjack (*Katsuwonus pelamis*) in the Pacific ocean and Indonesia contributed almost 300,000 tons of skipjack and yellowfin tuna in the 1990s [5]. Yellowfin tuna are considered a single population in the western and central Pacific Ocean for stock assessment purposes, but there is also the potential for some mixing between eastern and western stocks to occur [5, 6], and therefore, Indonesian waters play important role in stock assessment purposes for yellowfin tuna from Pacific and Indian oceans.

Banda sea is known as a potential fishing ground for yellowfin tuna [7, 8]. Geography, topography and oceanography of Banda Sea support the characteristic needed for the existence of yellowfin tuna schools [9]. Exploitation of yellowfin tuna at Banda sea have been published [10, 11] and over 2,000 vessels represented 12,326 units of purse seines, handlines, trolled lines, longlines and pole and lines have operated and yielded 130,538.4 ton of yellowfin tuna in Maluku (Central Maluku DKP, 2015). In 2011, Indonesian government has claimed that exploitation of yellowfin tuna in Banda Sea was in the level of fully exploited [12].

To consider the level of exploitation of yellowfin tuna in Banda Sea, fishing closure regulation was issued under the Marine Affair and Fisheries Ministerial Regulation No 4 year 2015: Banda Sea (126-132°E, 4-6°S) or equal to 130,000 km2 area was closed during the period of October – December each year. This closure was considered as the timing of spawning aggregation (SPAG) of yellowfin tuna [13]. This regulation was criticized due to lack of scientific basis of this closure. There is no further reproductive study on yellowfin tuna in Banda Sea since then.

Concerning the importance of sustainability of yellowfin tuna fisheries, we evaluate status of the fishery based on length frequency of yellowfin tuna captured in Banda Sea. This study aims to observe length at maturity of yellowfin tuna caught at Banda sea and assess the status of yellowfin tuna handline fishery using empirical relationship.

2. Methods

Sampling was conducted from October to December 2018. Handlines were occupied to catch tuna and conducted by fishers from Kawa Village, West Seram. Tuna fishing was started early in the morning until late afternoon, takes about 13 hours fishing per-trip. Fishing activities was begun with bait searching. Then they moved to tuna fishing grounds at Banda Sea *(*Figure 1) which were indicated by the occurrence of dolphins and towards fish aggregation devices (FADs) called *rumpon*.

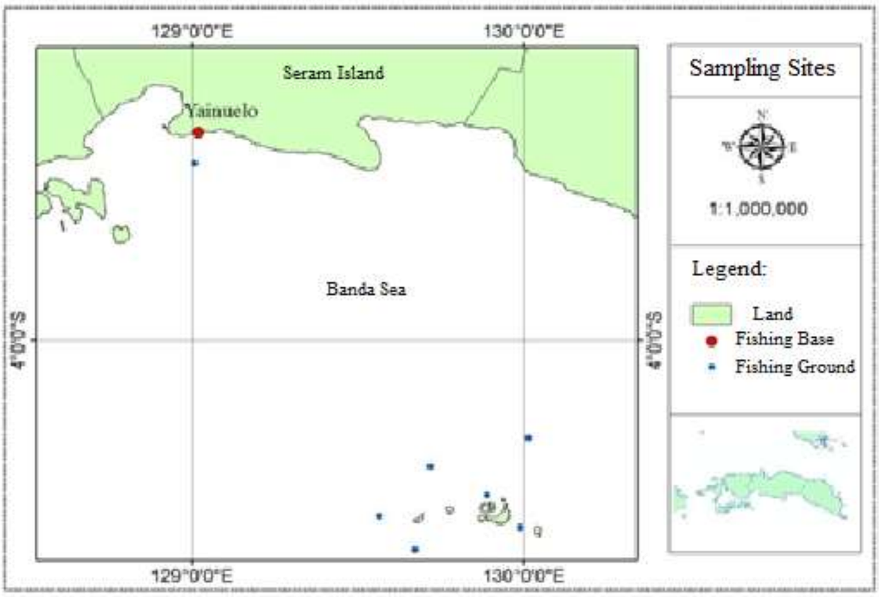

Figure 1. Map of yellowfin tuna fishing ground at Banda Sea

Sampled fish was randomly collected at the fish landing of the Kawa village. Due to large tuna was sold as *tuna loin* or fillet of tuna flesh, large-size samples taken have to wait for fishers' permission, while the small size tuna (called baby tuna) can be measured immediately. Catch of yellowfin tuna was measured to the total length (cm) and weighted to the nearest kg. Body cavity of fish was opened to identify the sex and gonad maturity was identified following [14].

Size distribution with 10cm interval for each month sampling was non-parametrically analysed using Wilcoxon test (SPSS 25). Maturity size (L_m) of yellowfin tuna was identified using logistic pattern [15]. We applied empirical relationship [16] to obtain optimum length (L_{opt}), infinitive length (L_∞) and maximum length (L_{max}) which are:

$$Log_{10}\,L_{opt} = 1.053 * \;Log_{10}(L_m) - 0.0565$$

$$\boldsymbol{Log_{10}\,L_{opt} = 1.0421 * \;Log_{10}(L_\infty) - 0.2742}$$

$$Log_{10}\,L_\infty = 0.044 + 0.9841 * \;Log_{10}(L_{max})$$

We applied three simple fisheries indicators which are exhibited as (i) proportion of mature fish captured with targeting to 100%; (ii) proportion of catch reached the optimum size, with 100% as target; and (iii) proportion of mega-spawners' in catch, with targeting to 0%. Due to there is no upper size limit for yellowfin tuna, mega-spawners' proportion is targeted to 30-40%. These simple indicators is easily understood to allow an effective assessment of status in fisheries [17].

3. Results and Discussion

Total of sampled fish collected from October to December 2018 was 381 individual of yellowfin tuna with total weight of 4,732.8 kg. Small size of fish which called as baby tuna was collected around *rumpon* (fish aggregation devices). Targeting on baby tuna was categorised as alternative fishing when no fish caught at the open ocean. Fishers sized on baby tuna for fish ranged from 30 cm to 60 cm. Size distribution of fish caught (Figure 2) was dominated by size ranged from 86 – 105 cm (325 individual). The monthly distribution of fish length was not significant different (Sig. 0.614). This means that all data can be combined for further analysis.

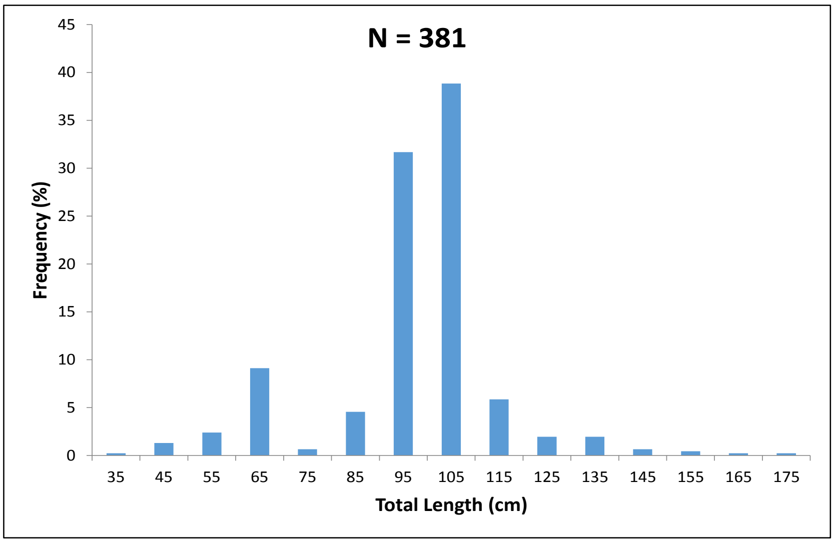

Figure 2. Length distribution of yellowfin tuna (*Thunnus albacares*) caught in from October to December 2018

Size maturity (L_{mat}) of yellowfin tuna was 107.17cm in total length for female and 112.93cm for male (Figure 3). Through the empirical relationship [16, 18], the optimum size (L_{opt}) of yellowfin tuna was 120.55cm, the infinitive length was 184.77cm and maximum length (Lmax) was 181.36cm. By plotting those important sizes upon the length distribution of fish caught, the proportion for juvenile fish captured was 90%, and about 10% mature fish (Figure 4). The proportion of fish growth to the optimum size was 7.3% and mega-spawner was 2.4%. To avoid recruitment overfishing, [17] suggested that the proportion of mature fish in the catch should be high or 100%, meanwhile in this study is only 10%. Indication of recruitment overfishing for yellowfin tuna handline fishery is clear that recruitment overfishing has been occurred, 90% of fish have been captured before they spawning [19]. Due to only 7.3% of the catch have reached optimum size, yellowfin tuna handline fishery is in the condition of growth overfishing. In the population that is overfished, fewer large fish in the population to be caught by the fishery, and our result clearly showed that mega-spawners proportion in the catch is 2.4%.

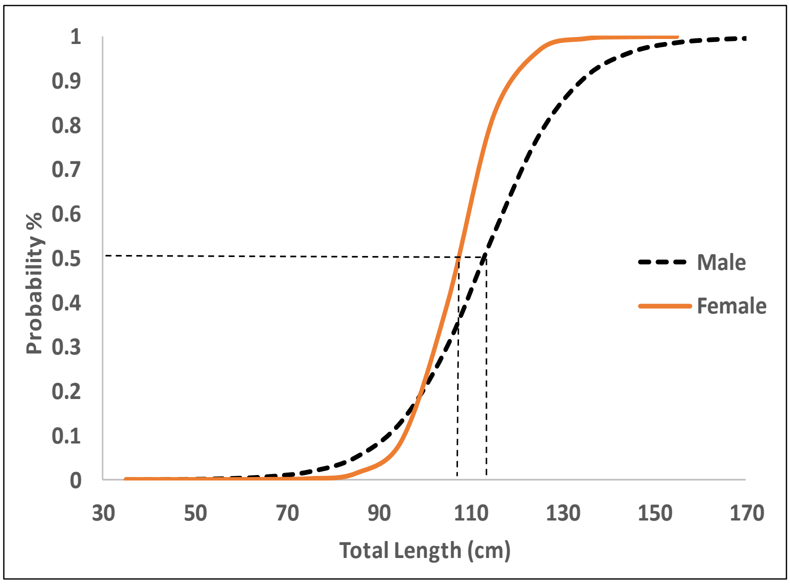

Figure 3. Maturity sizes (P50%) of male dan female yellowfin tuna (*Thunnus albacores*) sampled during October-December 2018 at Banda Sea

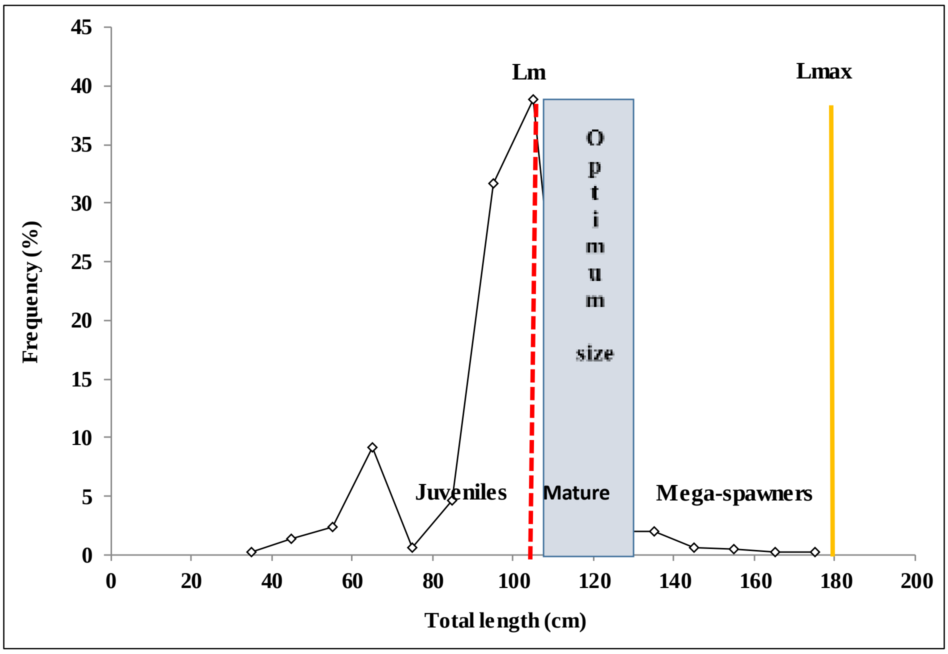

Figure 4. Dashed line indicates length at first maturity, L_m. Optimum size, L_{opt} ±10%, indicates the length range where maximum yield could be obtained (shaded bar). Straight line indicates the maximum size reached during sampling time (L_{max})

Yellowfin tuna (*Thunnus albacares*) is known as fish with characteristic of rapid growth, an early at maturity, continues spawning, a limited maximum size, a short life spent and a distribution restricted to warm waters [20]. From the size maturity point of view, length at first maturity of yellowfin tuna from Banda Sea is among the larger compared than from other regions (Table 1). Although, maturity size was declined from 150 cm to 90 cm based on 21 years observation (1989-2010) [21], large maturity size were caught during this study. First maturity size on large fish is considered to maintain long-term sustainable population through its high fecundity with large and strong eggs [22].

Table 1. Maturity sizes of yellowfin tuna (*Thunnus albacares*)

No	L_m (cm)	Type of Length	Location	Year	Sources
1	77.8		Western Indian Ocean	2010	[23]
2	100		Indian Ocean	2008	[24][25]
3	104		Hawaiian waters, equatorial west Pacific	2000	[26]
4	108		Coral Sea, Western Pacific Ocean	1991	[27]
5	92		Eastern Pacific Ocean	1998	[28]
6	98.95		West Sulawesi	2010	[29]
7	107	FL	South Taiwan – North Philippines	2001-2002	[30]
8	90-95	FL	East Coast India	2004-2006	[31]
9	99.2	FL	Eastern Atlantic Ocean	2014-2015	[32]
10	94	FL	Tomini bay	2007	[33]
11	75-102	FL	Western Indian Ocean	2009-2010	[34]
12	120 104.6		Australia Philippines and Indonesia	1994-1996	[35]
13	113.77 120.20	Female Male	West Pacific	2001	[36]
14	118.61 119.27	Female FL Male FL	Makassar Strait	2011	[37]
15	105.4-114.8	FL	Makassar Strait	2013-2014	[38]
16	107.2 112.9	Female TL Male TL	Banda sea, Southern Seram Island	2018	Present study

This study exhibits a contrary: large spawners living in an overfishing population. This contradiction might be caused by the high catch of juvenile tuna. According to [39], the catch of juvenile tuna in Indonesia might be not as harmful as has been thought as a form of depleting the stocks. Populations which were experimentally harvested on small sizes produced yields twice higher than the population which only harvested on large individual after four generations [40]. Selective on larger size harvest also had genetic effects: the population that were harvested on small fish remained having faster growth rates even when the exploitation terminated [41]. Increased fishing mortality on adult stages because of gear selectivity for large sizes reduced the maturity sizes of the fish [42]. Fisheries status based on length frequency may indicate an overfishing level, however, the large size of first maturity may indicate faster growth rates and late maturity in the population. Faster growth rates occur on fish if food resources is available sufficiently. Late maturity on fish is supported by lack of pressure towards the population. Therefore, we agree to [39]: the less we select on sizes, the original composition and size structure of the population will remain the same, including the large size of maturity can be maintained [43, 44, 45, 46]. This fishery management view can be applied in fisheries like yellowfin tuna and skipjack.

There is broad public interest in the health of our fish population by increasing concern about whether our fisheries can be sustainable without overfishing fish stocks. Several papers have explained the status of fisheries based on the catch per unit effort (e.g. [47, 48, 49, 50]). CPUE reduction suggested overfishing levels: fully exploited or over exploited, and fisheries management attributes have been hypothesized: selective fishing on large targeted species. In recent years, there is new approach to estimate the status of fish stock based on length frequency catch data (e.g. [51, 52, 53]) which was applicable for data-poor application [54]. Fisheries management suggested: selective harvesting ranged from maturity size until maximum limited size. However, debates on this method was also subsisted [55]. Our study applies this new method to evaluate the fisheries status but the maturity size assessment is used to understand the biological attributes in the population, so decision on fisheries management is not detriment stakeholders such as fishing closure for certain period and location.

4. Conclusion

The length at maturity of yellowfin tuna caught at Banda sea was 107.2cm TL for female and 112.9cm TL for male, larger than yellowfin tuna from other regions. The indication of 90% recruitment overfishing and 92.7% of growth overfishing revealed the status of overfishing for yellowfin tuna handline fishery. Decision to close specific area for yellowfin tuna fishing in Banda sea which in purpose to maintain the population is not necessary to be implemented. The existing of large spawners produced healthier young generation into the population which also supported by high nutrients available in Banda sea.

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