Trends of Indonesia’s bigeye tuna longline fisheries in the Eastern Indian Ocean: catch per unit effort and length distribution

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Abstract. Bigeye tuna, Thunnus obesus (Lowe, 1839), is one of the primary target species for Indonesian tuna longliners operated in the eastern part of the Indian Ocean. However, the fishing trend and biological information are still scarce despite their importance in developing harvest strategy in the region. The study provides nominal catch per unit effort (CPUE) and length compositions of bigeye tuna caught by the Indonesian tuna longliners from the area. Data were obtained from records made by the onboard scientific observers assigned by the Research Institute for Tuna Fisheries (RITF) from 2006 to 2021. The data covers records from 3180 longline settings in 118 fishing trips in which more than 4 million hooks deployed. The fishing efforts were distributed between 0-35°S and 75-130°E, with 10 to 15 hooks between floats. The highest CPUE was 0.29±0.05 fish per 100 hooks in 2014, and the lowest was 0.09±0.05 fish per 100 hooks in 2021. From 8150 fish measurements in 2006 to 2021, the average size was 117.66±24.13 cm FL, and the dominant size class was 120–130 cmFL. While the average size of BET shows an increasing trend the CPUEs were declining.

1 Introduction

Up to 7.5 million tons of tuna and tuna-like products were produced globally in 2016, and the Indian Ocean accounted for about 23% (1.7 million tons) of that total. In 2010, Indonesia contributed more than 207,010 tons, an increase of 1.84% from the previous year. Over 60% of Indonesia’s tuna production comes from Port of Benoa [1]. Among tuna and tuna-like species, bigeye tuna (Thunnus obesus) is one of the most commercially important species in the Indian Ocean [2-5]. Apart from the Mediterranean Sea, they are extensively distributed throughout three major oceans, from tropical to subtropical waters, between 45°N and 40°S [6]. Large longliners from Japan, China, and Taiwan and smaller longliners in the Indian Ocean Island countries, particularly Indonesia, target it as their primary species [7].

Indonesia’s commercial tuna longline fishery began in the 1960s [8]. Bigeye tuna became one of the main targets since the introduction of deep tuna longlines in the mid-1980s [9]. Bigeye tuna longline catches in the Indian Ocean have increased from roughly 40,000 tons in the late 1980s to 170,000 tons in the middle of the 2000s before dropping to less than half in the previous five years (~90,000 tons) [10]. Indonesia is the largest contributor with an

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average catch of around 26,000 tons (27%) during 2013-2017, followed by Taiwan, Seychelles, EU (Spain), and Japan with each proportion 18%, 12%, 12%, and 5%, respectively [10]. The nominal CPUE of bigeye tuna in Indonesian longline fishery from 2005-2017 showed a declining trend over the years, and the distribution of high CPUE occurred between 5-20°S and 30-35°S [11]. The proportion of zero-catches of BET in the scientific observer operational catch and effort data sets from 2005-2018 was considered low (~30%) [12]. The low of zero-catches of BET indicates targeting from the longline fishing gear.

Fisheries indicators, such as catch per unit of effort and size distribution, are two main components of constructing a robust stock assessment. Relative abundance index estimates can facilitate the development of more intricate models, which can deliver crucial data regarding the status of the bigeye tuna stock [13-14]. On the other hand, length frequency distribution can be utilized for conducting data-limited stock assessment [15-19].

Therefore, this paper provides updated information on bigeye tuna nominal CPUE and the size distribution in the eastern Indian Ocean based on the Indonesian scientific observer program. In terms of closing a knowledge gap and providing further data to evaluate the situation of BET in the Indian Ocean, we consider the results valuable.

2 Materials and methods

Indonesian scientific observer data from commercial tuna longline vessels based in Benoa Fishing Port, Bali, was used in this study. This program started in 2005 through an Australia-Indonesia collaboration (Project FIS/2002/074), and from 2010 until 2021, it has been conducted by the Research Institute for Tuna Fisheries (RITF), Ministry of Marine Affairs and Fisheries. The data were gathered between October 2005 and December 2021. As the trial scientific observer program started in 2005, data obtained during that year were removed from the analysis because of the possibility of species misidentification. The dataset contains details about the number of fish caught by species, the number of hooks used, the number of hooks between floats (HBF), and the locations (latitude and longitude) where the longliners were operated. The catch is recorded in the number of fish, and the fishing effort is recorded in the total number of hooks per set. A total of 8150 fish were measured and recorded as fork length (FL). These catch and fish size data were plotted on maps according to the recorded positions. The length frequency data were aggregated and the average length was calculated. Hook rates (CPUE), which were determined as the number of fish captured per 100 hooks, were used to calculate the nominal fishing effort of the tuna longline fishery, which was defined as the number of hooks used on a certain fishing area. Following that, these data were plotted on a map using a 5x5-degree square basis.

3 Results and discussion

The dataset contained records from 118 fishing trips, 3180 sets of longline deployment, and more than 4 million hooks deployed, respectively (Table 1). The number of hooks between floats ranged between 10 – 15 hooks. The records show distributions of fishing effort within 0-35°S and 75-130°E. The CPUE of bigeye tuna during 2006-2013 was relatively stable (0.21±0.02 on average) and rose substantially to 0.29±0.05, then dropped to 0.09±0.05 in 2021 (Figure 1).
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Fig. 1. The annual trend of tuna longliner CPUE (N/100 hooks) for bigeye tuna in the eastern Indian
Ocean from 2006 to 2021.

The mean abundance of bigeye tuna kept increasing until it peaked in 2009, after which
the series started to decline until it reached its lowest point in 2021 (Figure 1). The high
CPUE in 2014 and 2020 was likely caused by low effort combined with a particularly high
catch. Since the number of samples was relatively low, a high catch on one or two vessels
could significantly impact the overall value. Low coverage in higher latitudes (Figure 2) also
affected the overall trends, as vessels operating below 25°S were targeting southern bluefin
tuna and albacore, substantially reducing the number of bigeye catches. In addition to a
decreasing trend of the BET CPUE, it might also affected by several factors, such as the
primary production, fishing technique, and fishing ground. According to [20], the Indian
Ocean's north-eastern region may have low primary productivity, which may be aggravated
by global warming [21]. Besides that, Indonesian fishermen's capacity to operate in the region below 20°S, known to have a greater abundance [22], was further obstructed by conventional fishing techniques and laminated wooden-based vessels [23].

![Fig. 2. The spatial CPUEs of bigeye tuna from 2006 to 2021 are provided in a 5x5 grid map.](image)

A fish's size must be bigger than its length when its gonads reach their first stage of development (length at first maturity = Lm) to be considered catchable. The size distribution shows that BET caught by the longliners was dominated by mature individuals (Figure 3). More than 75% of fish caught was bigger than its first length of maturity (Lm = 100 cm FL) [24-25]. The fish was dominated by the length class of 120-130 cm FL. Longline catches of BET tend to be large and mature, whereas surface fisheries mostly catch BET that is small and immature [7; 21]. The average length of BET from 2006 to 2021 was 117.66±24.13 cm FL (Figure 3; Table 2). The average size of bigeye tuna relatively increased from 2006 to 2021 (Figure 4). An increase in the average size of fish caught might be a positive indication for fisheries stocks. On the other hand, the low abundance indices (e.g., catch per unit effort, CPUE) found in this study also convey important details regarding the condition of the fish stocks [26]. These finding needs to be further investigated.
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Fig. 3. Size distribution of bigeye tuna caught in the Eastern Indian Ocean between 2006-2021. The dashed lines refer to [-----] Lm (100 cm FL) and mean length [----] mean length (117.66±24.13).

Table 2. The number of individuals, size range, and mean length with the standard deviation (s.d) of bigeye tuna collected from 2006-2021

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of samples</th>
<th>Size range (cm FL)</th>
<th>Mean length ± s.d (cm FL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1192</td>
<td>50-193</td>
<td>114.56±26.66</td>
</tr>
<tr>
<td>2007</td>
<td>746</td>
<td>52-184</td>
<td>117.25±23.18</td>
</tr>
<tr>
<td>2008</td>
<td>1083</td>
<td>50-180</td>
<td>116.63±21.45</td>
</tr>
<tr>
<td>2009</td>
<td>772</td>
<td>50-183</td>
<td>120.36±26.00</td>
</tr>
<tr>
<td>2010</td>
<td>489</td>
<td>50-183</td>
<td>112.31±23.01</td>
</tr>
<tr>
<td>2011</td>
<td>259</td>
<td>50-190</td>
<td>116.86±28.80</td>
</tr>
<tr>
<td>2012</td>
<td>752</td>
<td>52-181</td>
<td>116.16±22.79</td>
</tr>
<tr>
<td>2013</td>
<td>415</td>
<td>52-173</td>
<td>116.23±22.39</td>
</tr>
<tr>
<td>2014</td>
<td>675</td>
<td>60-173</td>
<td>116.31±20.64</td>
</tr>
<tr>
<td>2015</td>
<td>286</td>
<td>52-174</td>
<td>118.67±21.65</td>
</tr>
<tr>
<td>2016</td>
<td>266</td>
<td>52-198</td>
<td>123.06±24.66</td>
</tr>
<tr>
<td>2017</td>
<td>302</td>
<td>52-176</td>
<td>131.79±26.24</td>
</tr>
<tr>
<td>2018</td>
<td>280</td>
<td>52-175</td>
<td>119.69±27.63</td>
</tr>
<tr>
<td>2019</td>
<td>262</td>
<td>60-173</td>
<td>116.34±21.71</td>
</tr>
<tr>
<td>2020</td>
<td>211</td>
<td>77-178</td>
<td>125.36±16.64</td>
</tr>
<tr>
<td>2021</td>
<td>160</td>
<td>51-169</td>
<td>121.86±25.46</td>
</tr>
<tr>
<td>Grand Total</td>
<td>8150</td>
<td>50-198</td>
<td>117.66±24.13</td>
</tr>
</tbody>
</table>
The captured BET was dominated by adult fish and higher proportions of juvenile fish were commonly found in the lower latitude (<25°S) rather than higher ones (Figure 5). This might show that the southern part of Indonesia is the nursery ground for bigeye tuna. The previous study [27] showed that bigeye tunas found in mid-latitudes are generally younger and still in the growth phase. In contrast, those that have reached maturity are more prevalent in tropical regions. The distribution of bigeye tuna is closely tied to the vertical temperature profile of each specific sea area.

![Figure 4](image-url)  
**Fig. 4.** Average length of bigeye tuna from 2006 to 2021.

![Figure 5](image-url)  
**Fig. 5.** Spatial size distribution of bigeye tuna less than and above Lm50 (100 cm FL)
4 Conclusion

Over 4 million hooks were used throughout the 118 fishing trips, resulting in 3180 longline settings. With 10 to 15 hooks between floats, the fishing efforts were spread out between 0-35°S and 75-130°E. Between 8150 fish measurements in 2006 and 2021, the average size was 117.66±24.13 cm FL, with the 120–130 cm FL size class predominating. Generally, the average size of BET is increasing while CPUEs are decreasing.

Acknowledgment

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